THE MAN WITH TWO BRAINS

ALAN ALDA (Narration) We began our journey into the human brain here, on the campus of Dartmouth College in New Hampshire. I'd come to meet one of the world's leading brain scientists, Mike Gazzaniga, and a man he's worked with for over a decade: A man with two brains.

ALAN ALDA You've been working a long time with Dr. Gazzaniga?

GAZZANIGA Fourteen or fifteen years.

JOE Huh... it doesn't seem that long.

ALAN ALDA (Narration) The collaboration began when Joe had surgery.

ALAN ALDA And you had this procedure to ah... to ah... correct an epileptic problem, is that right?

JOE Yeah, to try and stop the seizure. I was having seizures like everyday or so, or sometimes two or three a day.

ALAN ALDA (Narration) To control Joe's epileptic seizures, a surgeon severed the connection between the two halves of his brain. Cutting the corpus collosum like this prevented the spread of the electrical storms that caused his seizures. But it also prevented the left and right halves of his brain from communicating with each other. In the years since the operation, Joe's epilepsy has been under control. He now earns a living at an egg farm, and in his everyday life is largely unaffected by the fact that his left and right brains work independently.

ALAN ALDA Do you feel any different when you think about something than you did... differently from the way you felt before the procedure?

JOE No... it's just kind of a back-up brain is all.

ALAN ALDA ... that's something everybody could use, right?

ALAN ALDA (Narration) I found out how true that was right away when I was asked to draw a different shape with each hand. In a brain like mine - roughly speaking normal - at least all in one piece - the left half of my brain controls the right side of my body while the right brain controls the left side.

ALAN ALDA Oh no!

ALAN ALDA (Narration) But because the two halves are connected...

ALAN ALDA Nothing wrong with that!

ALAN ALDA (Narration) ...getting each hand to work independently isn't easy.

GAZZANIGA Well, we're seeing the fact that... that Alan's hemisphere's are connected.

ALAN ALDA Yeah! Gazzaniga That the uh... motor messages from one are confusing the motor messages in the other.

ALAN ALDA I was just drawing an upside down duck.

ALAN ALDA (Narration) But when Joe is given the same task, his two hands operate as if controlled by two separate brains. What's happening is that each half of Joe's brain is given a separate instruction. He is asked to fix his eyes on the cross in the center of the screen, Anything flashed to the right of the cross goes only to his left hemisphere. Things to the left go to his right hemisphere. Because the two don't communicate, each hand does only what its half of the brain sees.

ALAN ALDA Wow, look at that. It's really like two different people doing the same... Gazzaniga That's right...

ALAN ALDA ... same task.
GAZZANIGA... that's the idea.

ALAN ALDA (Narration) In an experiment that's now a classic in brain research, Mike Gazzaniga over thirty years ago used a similar set-up to find out if the two halves of the brain are specialized to do different things.

JOE Ship.

ALAN ALDA (Narration) Joe is being flashed a word only to one half of his brain. Words flashed to the right... Joe Storm.

ALAN ALDA (Narration) ...are seen only by his left brain - and Joe can report seeing those words just fine.

JOE Piano.

RESEARCHER Good.

ALAN ALDA (Narration) But when a word is flashed to his right brain...
JOE Didn't see that.

RESEARCHER OK.

JOE I'm gonna ask you...

ALAN ALDA (Narration) But now watch what happens. Researcher ... to draw that with your left hand.

Joe You got me lost.

RESEARCHER Why don't you try drawing another picture right over here? That'll help you.

JOE Oh, phone.

ALAN ALDA It's almost as though somebody has given him a secret communication...

GAZZANIGA That's right.

ALAN ALDA ... and now he knows that it's a telephone... up until then he was blind to it.

GAZZANIGA Exactly.

ALAN ALDA (Narration) When Gazzaniga first did this experiment it instantly proved that the ability to speak resides almost exclusively in the left hemisphere. Not until he sees what his right brain is drawing is Joe able to name it.

ALAN ALDA He said church, didn't he?

GAZZANIGA After looking at the picture.

ALAN ALDA But he had to figure it out about as long as we did. That's really interesting. It's... ah....it's a... picture here of somebody communicating almost with another person.

GAZZANIGA And the communication is not occurring inside the head, it's occurring out on the piece of paper.

ALAN ALDA Yeah. Joe Blob. I don't know.

RESEARCHER You want to draw a little bit more?

ALAN ALDA (Narration) So far, Joe has been seeing only one word. Things get even stranger when he flashed two words, each to only one half of his brain.

GAZZANIGA The right hemisphere just saw toad.

ALAN ALDA Yeah.

ALAN ALDA (Narration) And so his left hand draws a toad.

GAZZANIGA So there's the toad.

ALAN ALDA Oh, it's a toad.

ALAN ALDA (Narration) And this time I was able to guess what was coming.

ALAN ALDA Will he now put a little three-legged stool in there later, or what...

ALAN ALDA (Narration) Joe's speaking left brain saw "stool". Saying the word lets his right-brain-controlled hand in on the secret.

ALAN ALDA That's great. That's really interesting. And if he had seen that with the cocus collosum intact, he would've drawn a toadstool, not the toad and the stool.

GAZZANIGA Right, exactly the point. I've been doing this for thirty-five years, and it gets me every time.

ALAN ALDA It must, it must.

RESEARCHER This time instead of naming the word I want you to point to the word.

ALAN ALDA (Narration) Again, Joe sees two words simultaneously. Bell goes to his non-speaking right brain, music to his speaking left brain. When asked to point to a picture of what he saw, he chooses bell. But when asked why...

RESEARCHER Why'd you pick that one?

JOE Music.

Researcher Music?

ALAN ALDA (Narration) And when asked to explain... Joe It was music and bell and those few minutes... the last time I heard any music it was coming from the bell out here...

RESEARCHER Uh huh...

JOE ... banging away.

RESEARCHER The bells outside here?

ALAN ALDA (Narration) What's extraordinary is that Joe's speaking left brain concocts a plausible story of why he pointed to bell - even when some of the other pictures more obviously represent music. Gazzaniga believes this determination to find cause and effect, this desire to explain, to be the left hemisphere's most marvelous property.

GAZZANIGA One of the unique things of the human brain is this need to interpret why two events occur. What was the antecedent of this, what caused this and if you can imagine that a species like us, that has this little chip in its brain that asks those questions is going to survive rather well because it is going figure out more about the nature of the world than a species that doesn't have it.

ALAN ALDA (Narration) But as I was about to discover, the right brain has a very useful survival skill all its own.

ALAN ALDA What do you think will happen here?

Researcher For you we're doing a live experiment - never done it before.

ALAN ALDA (Narration) The experiment involves the 16th century Italian painter Arcimboldo, who made faces out of fruit, flowers, meat, even books. Now, from other research there's reason to believe that the ability to recognize faces is located exclusively in the right hemisphere. So Mike wondered if Arcimboldo's paintings would look different to each of Joe's two brains.

GAZZANIGA So while will his left hemisphere say 'I saw a potato, I didn't see a face'. And will his right hemisphere say 'I saw a face' and not comment on the fact that it was made out of the potato.

RESEARCHER You're gonna see a figure followed by a choice of two words.

GAZZANIGA If this works it will be terrific, but we'll see... so, here it is, live.

ALAN ALDA (Narration) The first painting goes to the right hemisphere - and Joe points to "face". The next painting goes to his left brain - and this time he points to "fruits". Mike seemed pleased...

ALAN ALDA Are you having a moment?

GAZZANIGA This is too good.

ALAN ALDA (Narration) Again to the right brain - and Joe sees it as a face. But to the left brain...

GAZZANIGA ... a face made out of books... he pointed to books.

ALAN ALDA Are you happy with what he's doing?

GAZZANIGA It's unbelievable! He's doing it! Do you see that?

ALAN ALDA It's... he's shifting so fast, he's going from left to right so fast, I can't keep up with you - you're used to looking at this.

GAZZANIGA When you show him a face in the right side - the left hemisphere - he's focusing in on the elements that made up the face. When you show him the exact same picture in the left field going to the right hemisphere he focuses on the face and not on the elements.

ALAN ALDA And not the elements. If you came down from another planet and you saw faces and vegetables, you might not think there was much of a

difference among them, but the brain seems to be made up in certain way to say 'faces are very different from other objects'...

GAZZANIGA That's right...

ALAN ALDA ... and one side of the brain specializes in faces...

GAZZANIGA ... exactly right, exactly right. It is an adaptation that we have to detect upright faces. It's a very important... you can imagine in an evolutionary time that all of a sudden you have the ability to detect quickly an upright face, you want to read the expression on that face, you want to know if it's friend or foe, you wanna have a set of questions about that face.

ALAN ALDA (Narration) The right brain might be skilled at recognizing faces. But when it comes to what gives the human mind its power - the ability to reason, to invent, to interpret the world around it - Mike Gazzaniga's thirty years of research has taught him which hemisphere he wouldn't want to be without.

GAZZANIGA The old phrase around our lab is 'don't leave home without your left hemisphere.' That's where the action is.

REMEMBERING WHAT MATTERS

ALAN ALDA (Narration) The clarinet player is Jim McGaugh; the tune, "As Time Goes By"; his passion, the mind and how it is shaped by memory.

McGAUGH Everything that we do as humans depends upon our memory. Your notion of your own past is nothing but a memory in your brain - something changes in your brain. You and I live in a world which is about a half a second long - that's the immediate experience. And what happened two minutes ago that you think is still here is gone, except in your brain.

ALAN ALDA (Narration) This rat at the University of California, Irvine, is about to get a better memory, thanks to Jim McGaugh. There's food at the end of four of these arms. Entrances to each of the other four are blocked by a plastic window. Once the rat has eaten the available food, the windows are removed and food placed in the previously blocked channels. After several trials, the rat learns to enter only the newly opened arms, ignoring the old ones it had already cleaned out. Eighteen hours later, however, the rat has forgotten the secret and checks out the old arms as well as the new. But this rat is getting some help - a shot of adrenaline immediately after learning the task. This time, after an eighteen-hour absence, his memory of the maze was is good as new.

RESEARCHER He remembered where he had been before and only went to the arms that he hadn't been to, so he performed the task very well, perfectly, one hundred percent performance.

ALAN ALDA (Narration) Adrenaline is the hormone behind the "fight or flight" response - the surge of energy we and other animals get when we're threatened. Jim McGaugh's experience with rats suggests the adrenaline rush is doing more than allowing us to run fast.

McGAUGH It also would be a very good a idea to be able to remember where the predator was and what happened so the next time the animal would be able to avoid the situation or minimize the probability of being eaten the next time. So the same hormones which were involved in generating the fight or flight response we now have discovered work on the brain to make stronger memories.

ALAN ALDA (Narration) So what would happen in a stressful situation - which for rats means having to swim - if somehow adrenaline is removed from the picture? This rat is trying to find a transparent underwater platform. Eventually he has to be shown where it is. He's tested again three days later - and this time his memory guides him to the platform quickly. Like his colleague, this rat has also been shown the platform. But moments later, he gets an injection of a drug - a betablocker - that blocks the effect of adrenaline. When this rat's tested three days later, it's as if he's never been here before. So for rats, adrenaline seems central to making stronger memories. But what about the rest of us?

McGAUGH What we need to do is to have....

ALAN ALDA (Narration) Jim McGaugh is collaborating with Larry Cahill on an experiment that involves a single set of slides telling two very different stories.

McGAUGH A boy and a mother leaving home - they're going to visit ah... father who works in a hospital.

ALAN ALDA (Narration) A subject is told his emotional reactions to a story are to be measured. In fact, this device isn't hooked up to anything.

CAHILL (talking off-camera) OK, a mother and her son are leaving home in the morning.

ALAN ALDA (Narration) The story he hears is bland.

CAHILL She is taking him to visit his father's workplace. The father is the chief laboratory technician at a nearby hospital.

ALAN ALDA (Narration) It concludes with mother and son coming across a fake car accident being used in a training drill.

CAHILL Special make-up artists were able to create realistic looking injuries on actors for the drill. OK, that was very good, now the last thing I would like you to do today is to rate your emotional reaction to the story you just saw on a scale of zero to ten.

SUBJECT Probably about a two.

CAHILL OK.

ALAN ALDA (Narration) This subject is hearing a very different story.

CAHILL ... while crossing the road the boy is struck by a runaway car which critically injures him. Specialized surgeons were able to successfully reattach the boy's severed feet. I would like you to rate your emotional reaction - your personal emotional reaction - to the story you just saw.

ALAN ALDA (Narration) Two weeks later, the subjects are given a surprise memory test.

CAHILL You were told that the father's occupation is: a school teacher, a surgeon, a laboratory technician, a hospital custodian.

SUBJECT 2 A laboratory technician.

ALAN ALDA (Narration) Memories of the emotional story are good...

CAHILL Next question. You were told that the father's occupation is...

ALAN ALDA (Narration) memories of the boring story, poor. Subject 1 I think it was the hospital custodian.

ALAN ALDA (Narration) So far so good. But is it adrenaline that's making the difference? This subject is taking a betablocker to block adrenaline right before getting the emotional version of the slideshow.

CAHILL While crossing the road, the boy is struck by a runaway car which critically injures him. At the hospital the staff prepare the emergency room...

ALAN ALDA (Narration) He still rates the story as highly emotional. Subject 3 I'd say about a seven.

CAHILL Seven? OK, very good.

ALAN ALDA (Narration) But when he's tested two weeks later, his memory is as poor as those who heard the bland story.

CAHILL ... a surgeon, a laboratory technician, or a hospital custodian.

SUBJECT 3 Um... surgeon.

CAHILL Surgeon? OK...

CAHILL (to camera) Despite the fact that their emotional reaction to the story a week earlier had been normal, they didn't experience the enhanced memory associated with the emotional reaction that the placebo controls did. So what we seem to have done - what we think we have done - is we snapped the relationship between an emotional reaction and enhanced long-term memory.

ALAN ALDA (Narration) The Irvine team is now trying to pin down the relationship between emotion, adrenaline and memory by looking inside the brain as a memory is formed. Shannon is left alone to watch thirty minutes of unpleasant images while glucose is injected into her bloodstream. This machine, called a PET scanner, produces an image of Shannon's brain revealing where most of the glucose was being used, and so which parts of her brain was working hardest, while she was watching the films. And the region that was most active is an almond-sized structure called the amygdala. What's more, in tests like this with several subjects, the brighter the amygdala, the better their memory of the film three weeks later. It's the beginning of an explanation, Jim McGaugh believes, of why we remember emotional events. Activated by the hormones the emotions produce, the amygdala sends a message to the rest of the brain as if to say: this information is important - don't forget it.

McGAUGH Life goes by, trivial things happen to us, important things happen to us. Now, it would make a lot of sense, wouldn't it, because we have a brain that probably has some limited capacity of some kind, wouldn't it be nice to have a brain which stored to a more intense extent those things that are important and to a lesser extent those things that are trivial. We... we have a brain that does that. And it's emotions that create a relationship between the importance of an event and how well we remember that event.

TRUE OR FALSE?

ALAN ALDA (Narration) What I didn't know one pleasant morning while strolling with Dan Schacter was that - in collaboration with my scheming producers - he was setting me up for a test of my memory.

SCHACTER Now we're just going to witness a... simple picnic scene and we want you to pay attention to how often either of the folks gets up and down. So whenever someone gets up and down you just make a mental note of it.

ALAN ALDA OK.

ALAN ALDA (Narration) I knew Dan Schacter to be a noted memory researcher. But this picnic was a surprise.

ALAN ALDA Oh good, I love to watch people eat.

ALAN ALDA (Narration) Although Dan had told me to keep track of how many times the picnickers stood up, I suspected there was more to this little scene than that. But what? I wasn't to find out for another two days that the picnic was part of a carefully choreographed attempt to implant false memories into my brain - to make me "remember" as real things I'd never seen. At the time it was like trying to keep track of a very bad play while sitting uncomfortably close to the author. After ten bewildering minutes, the picnic - mercifully - came to an end.

ALAN ALDA Bravo. Very nice, very nice.

SCHACTER We could have used a little more high drama here and there.

ALAN ALDA Yeah, but it doesn't lack for slowness.

ALAN ALDA (Narration) At this point I was politely asked to leave. The scene was played over for a stills photographer. But this time it included things that never happened while I was there. Which meant I also missed Dan Schacter's basic premise: that memories are malleable.

SCHACTER One of the things that we know about memory is that it's not fixed at the original experience we have. The way we talk about the event later uh... the way we think about it uh... can effect, improve or sometimes change our memory and photographs are one everyday source of reviewing past experiences that may have a potent effect on memory and we're interested in exactly what that effect is.

ALAN ALDA (Narration) Two days later I was in Dan Schacter's office at Harvard University, looking at photographs.

SCHACTER ... is it well cut-out, is it well centered? For each photo I'm gonna ask you for a one to five rating.

ALAN ALDA Oh... heh heh, part of me is trying to figure out what this is really a test of. I'd have to say, you know, four to four point five. This is a nicely composed picture.

ALAN ALDA (Narration) I didn't believe this rating ploy for a moment, but graciously played along - even when the photos where of things I knew I hadn't seen.

ALAN ALDA I take it you don't want me to mention whether or not this is a picture of something that happened or not, because this never happened.

SCHACTER Right, we're not concerned with that right now. We're just concerned with...

ALAN ALDA ... showing how smart I am.

SCHACTER Right!

ALAN ALDA (Narration) In all I looked at about twenty photographs. Finally the moment I'd been anticipating... ... the test.

SCHACTER... the fishing pole?

ALAN ALDA No.

ALAN ALDA (Narration) The question is: did I see these things at the picnic or not?

SCHACTER Umbrella?

ALAN ALDA No umbrella, no.

SCHACTER Potato chips?

ALAN ALDA No. The potato chips were in the picture. Well, I remember them in the picture but I don't remember them on the site.

ALAN ALDA (Narration) I was doing fine until...

SCHACTER Nail file?

ALAN ALDA Yes I think I remember her filing her nails, although the picture is also vivid in my mind. But I think I remember her filing her nails, too.

SCHACTER Kite?

ALAN ALDA No kite. No, there was no kite. There was a kite in the picture but that's it.

SCHACTER OK. A man's cap.

ALAN ALDA (Narration) By now it was obvious that Dan was trying to confuse my memory of things I'd seen for real...

ALAN ALDA I think he wore a cap.

ALAN ALDA (Narration) ... with things I'd only seen in the photographs.

ALAN ALDA Well, see... I think he was wearing a cap in the photographs and I think - and I remember when I looked at the photographs - there's something wrong with this picture. I don't think he wore a cap.

SCHACTER A bottle of water?

ALAN ALDA Yes, there was a bottle of water.

ALAN ALDA (Narration) Oh, oh, this would come back to haunt me.

SCHACTER Folding chairs?

ALAN ALDA No!

SCHACTER No, no way. Pasta?

ALAN ALDA Yes! You think I could forget pasta? Come on!

SCHACTER It's over.

ALAN ALDA That's it?

SCHACTER That's it. It's out of your system.

ALAN ALDA So it had nothing to do with how many times they stood up.

SCHACTER Well, that was just to get you to pay attention to what was going on in front of you.

ALAN ALDA Yeah, that's why I paid attention to everything else. Now what I'm really interested to know is, were you able to place in my memory things that never occurred in real life?

SCHACTER Yes.

ALAN ALDA You did? You did?

SCHACTER We did. Even though um... even though we... you know, we told you, you knew what the game was. You knew that some of things that we were showing you in the photographs had never happened. Despite that...

ALAN ALDA This is horrible.

SCHACTER One was the nail file.

ALAN ALDA Yeah.

SCHACTER That was only in the photo.

ALAN ALDA You know, when I first saw the nail file there was this little uncertainty - was that real or wasn't it - and then a second later, I was... I was sure I'd seen it.

ALAN ALDA (Narration) In the final tally, of eight things that appeared in the pictures only, I wrongly remembered two as having been at the picnic - the nail file and a bottle of water. The photographs had somehow lodged in my brain right along with my memory of the picnic itself and I couldn't tell which was which. To understand how this can happen means we have to first understand where in the brain memory is located.

ALAN ALDA Is it possible to point to some place on the brain and say that's where memory is?

SCHACTER Well, there's no one place - there's no one place I can point and say 'there's your memory of high school graduation and.. and there's your memory for having eaten breakfast yesterday. Instead of being in one place, many of believe that memory is kind of scattered in different parts of the brain.

ALAN ALDA (Narration) The idea is that memory consists of all the bits and pieces of an experience - the sights, the sounds, the emotions - with each fragment stored in areas of the brain responsible for handling that particular sensation. So sounds are stored in the auditory cortex; sights in the visual cortex and so on. Keeping track of what's where is a region of the brain called the

hippocampus, which functions as a sort of index for our memories. Recalling an event means re-assembling all those bits and pieces. It's not like replaying a videotape. It's more like shaking a kaleidoscope, with every shake - every recall - the pieces fall together anew - sometimes, as in my memory of the picnic, including bits that don't quite belong. Dan Schacter recently wondered if he could tell the difference between real and false memories by peering into the brain while it was remembering. Twelve people heard word lists like these, and had to remember as many of the words as they could.

ALAN ALDA Writer... um...

ALAN ALDA (Narration) What's sneaky about the lists is that while they're each united by a theme, they don't contain more obvious word...

SCHACTER Bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy.

ALAN ALDA Sleep, doze, bed...

ALAN ALDA (Narration) There - right off the bat I said "sleep", but sleep wasn't on the list. Again, I'd been given a false memory.

ALAN ALDA ... ah, bed...

ALAN ALDA (Narration) The twelve experimental subjects all got PET scans while doing this test. What's fascinating is that recalling both true and false memories mostly involved the same bits of brain, especially the hippocampus - the index region. But while the true memory lit up the auditory cortex, the false memory didn't. So even though the subjects reported hearing the words that weren't there, their brains appear to contain no trace of the sounds of the words.

ALAN ALDA So in a way you really can look inside somebody's brain and tell whether they're having a true memory or a false memory under certain conditions.

Schacter Under certain conditions. Within this one experimental paradigm group of twelve people we were able to see, ah, some differences between true and false recognition.

ALAN ALDA (Narration) Dan Schacter emphasizes there's a long way to go before this first faint trace of a false memory could be turned into a practical test that could be used, for instance, in a courtroom. Meanwhile, discovering how easily my memory can be tricked was lesson enough.

ALAN ALDA What I think this really brings home to me is it's very important to say not 'this is what happened' but 'it seems to me that I remember this is what happened.'

SCHACTER I think that's a very important lesson.

WHAT'S IN A DREAM?

ALAN ALDA (Narration) My brain is about to enter an altered state of consciousness - at least, that's the plan.

ALAN ALDA Hello... I sit here?

ALAN ALDA (Narration) All I have to do is go to sleep. Holmes OK, he first that we're going to be doing tonight is putting electrodes on so we can measure your electrical activity and know your stages of sleep.

ALAN ALDA What's that? Holmes It's called calodian, it's very similar to airplane glue. And what this...

ALAN ALDA (Narration) Airplane glue in my hair... as it turned out only the first of several indignities that lay ahead during my night as a research subject at Harvard University's Sleep Laboratory.

ALAN ALDA I don't want to rush you, but I'm falling asleep. Holmes Are you really? Good.

ALAN ALDA (Narration) The study I'm joining is to find out what happens to our minds while we're dreaming.

HOLMES OK, and that's the last electrode.

ALAN ALDA (Narration) Like most people, I've always been fascinated by dreams - my own especially. How do our brains come up with that stuff? Even more interesting - why? My night began with a test of the state of my brain. The task is to spot if the second of two words flashed on the screen is a real one. Sometimes the second word seems to be related to the first. When it is, and my brain makes the association, then I'm usually able to decide if the second word is real or fake more quickly. So by measuring my reaction time, the test can tell how good my brain is at making associations.

ALAN ALDA Bed... bed.

ALAN ALDA (Narration) The only association I was interested in right then was between bed and sleep - not so easy when you know a stranger is eavesdropping on your brain.

HOLMES Alan, I need you to lie quietly with your eyes closed. OK, if you could blink five times, slowly...

ALAN ALDA (Narration) This is to check the electrodes near my eye. They'll be looking out for REM - R.E.M. - the rapid eye movements we all make when we dream.

HOLMES Great. OK, you're all set. You can go ahead and get comfortable and have a good night's sleep.

ALAN ALDA (Narration) So if you'll excuse me, I'll leave you in the care of Jen Holmes while I try to sleep with wires pasted on my face and glued to my scalp.

HOLMES Now he's moving, getting comfortable and you'll typically see some kind of movement when people first start to fall asleep. The top two lines represent his eye movements, and this gentle rolling is also typical of falling asleep. The next lines down are his brain waves, and we see that as he falls into real sleep they start to get spikier. He's now officially asleep. Our experiment calls for him to do the word association test several times during the night, one of them when he's asleep but not dreaming. That's what's happening now, so I'll go wake him up.

ALAN ALDA Yep... nope... oh, I'm falling asleep here. I am not checking into this hotel again.

ALAN ALDA (Narration) Well, after that my night went to pieces. Every time I drifted off and started to dream I'd think, oh good, I have to remember this - and promptly wake myself up. By six in the morning, Jen had been joined by her boss, Bob Stickgold, and it began to look like we weren't going to find out what my brain does when it's dreaming. Stickgold Since about, ah, 2:30 this morning he's been having a hard time sleeping. Uh, he'll go to sleep - he'll sleep for ten of fifteen minute series - you can hear the pens slapping around - he's rolling around in bed now. He's been doing that for hours now.

ALAN ALDA (Narration) But then, when it was almost too late, I began drifting into a dream. Stickgold If we wake him up right now we've got an eighty-five percent chance - a ninety percent chance - of getting good REM reports. So what we want to do is wait until it gets another burst - there's some more right there, look at these, these are really good eyes movements, these are fast and they're big. So, I think we should go in there now and see what we can get.

ALAN ALDA I was... uh, being propelled the solar wind but the wind wasn't behind me, I was going toward the sun. And I was flying over Berlin and I remember thinking that this was, uh... called uh... 'Nightgown Over Germany.'

STICKGOLD It's only about six-thirty, it's still early.

ALAN ALDA Oh, it's still early. Well, let's try it.

STICKGOLD Let's try it. OK. Pleasant dreams.

ALAN ALDA (Narration) With one dream in the bag, I felt better about trying for another... So that once again I could be awakened for that exciting word association test.

STICKGOLD So, how does it feel to you that you slept?

ALAN ALDA How did it feel that I slept? I had a worse night of sleep at a truck route in New Zealand.

STICKGOLD Really?

ALAN ALDA Yeah...

ALAN ALDA (Narration) By now all I wanted was a little breakfast and the airplane glue out of my hair. But I was also curious of course about the tests I'd been taking. What did they have to do with dreaming? Most dream researchers believe that during REM sleep the normal signals to the brain from our bodies are cut off. Instead of receiving inputs from our eyes and ears, the visual and auditory centers are flooded with signals surging up from the more primitive regions of the brain. These signals, the theory goes, are completely random and meaningless. But dreams, of course, seem to make sense - at least at the time.

ALAN ALDA ... the wonderful part about it was I went out through my nose, see? So then I had all these words I was hearing...

ALAN ALDA (Narration) So the key question is, where do the stories of our dreams come from? According to Bob Stickgold, we simply make them up as we go along.

ALAN ALDA I'm a little thick this morning because I... I had this funny night sleep. I still don't quite get how you arrive at the conclusion that something in the brain is supplying story and meaning and uh... uh... a coherence to...to these random images... and not that they're coming up in a more coherent way already.

STICKGOLD If you look at your dream, I mean there you have the start of - gee, it's going to be an out-of-body experience, and first of all it goes out through your nose. I... I'm sorry, it's just hard for me to believe that someone scripted that for you to do. You were just thinking 'out-of-body, how am I going to get out of body, help me somebody how can I get out-of-body' and something in your brains says 'oh your nose.'

ALAN ALDA (Narration) So during dreaming, our brains are scrambling to make sense of nonsense. Here's where the word tests are revealing - because subjects woken from REM sleep are quicker at making associations between words than when woken from non-REM sleep - or even when they are wide awake during the day. It's as if during REM sleep our brains are primed to put together stories from random images and feelings.

STICKGOLD Our guess is - and it's truly just a guess at this point - is that the brain is just trying to keep up with these random inputs and trying to use everything it knows to make some kind of sense out of it.

ALAN ALDA (Narration) That might be how we dream. But it still leaves the question of why. This experiment, being conducted in the sleep lab at Trent University near Toronto in Canada, is suggesting dreaming helps us learn.

SYLVESTER OK, you're all set. We'll see you in the morning.

ALAN ALDA (Narration) Lara Sylvester is spending four nights of her summer vacation here. At least she gets to sleep in peace. The aim of the study is to see how active her eye movements are during dreaming while she's in a relaxed, summery frame of mind. Recording and counting her eye movements is researcher Carlyle Smith. Summer's over and Lara is studying hard for her final exams. Now her brain is in high gear, right up through the finals themselves. Her mind still buzzing from all that learning, Lara again gets to sleep in the lab. And now the number of rapid eye movements during her dreams is strikingly different. Carlyle Smith For some people there's almost a doubling of the number of eye movements after they've had intense learning activity then when they've been just in uh..

ALAN ALDA (Narration) This discovery led Smith to wonder if the extra eye movements during learning are useful. Do these apparently more intense dreams actually help us learn? So he set up an experiment to see if learning a complicated logic game was affected by how much dreaming a person does. The game is baffling enough to explain let alone play, but it involves making letter combinations according to complex rules.

STICKGOLD... J... ... or E to start of with so you can then make one final, gigantic, messy whiff.

ALAN ALDA (Narration) The game is a tough test of logical thinking. The students' skills at the logic game were tested, and then they were then given a much simpler memory test. After seeing pairs of words they were shown one of them and had to remember its partner. Then some of the subjects - this isCatherine - got to have a night's sleep almost as bad as mine. Researcher What we're trying to do is deprive them of two REM periods. So, once she goes from Stage Two to REM sleep I will go in and wake her up.

CATHERINE Good morning.

ALAN ALDA (Narration) Once woken, Catherine is kept awake for five minutes by a math task, to make sure she doesn't slip back into her dream. Other students were the experiment's controls, either being awakened when they weren't dreaming...

RESEARCHER You need to get up for a few minutes.

ALAN ALDA (Narration) ...or getting to sleep through the night in peace. A week has passed, and it's time for the memory test again. Catherine, deprived of dreams, doesn't do as well as she did before - but then, nor do any of the subjects, even those whose night was undisturbed. But then came the logic task. And this time there was a significant difference between the dream-deprived and the dream-indulged.

SMITH Any task where it seems to be just straight memorization that's involved... uh, don't appear to be vulnerable to sleep loss - REM sleep loss. Tasks where some kind of more uh... understanding is involved you not only have to memorize some rules but you have to be able to apply the rules, that kind of material uh, is vulnerable to REM sleep loss.

ALAN ALDA (Narration) Carlyle Smith now took a daring leap. What if people could be somehow prompted to learn during dreaming? A new batch of student volunteers hear a loud clock while learning the logic game. When they are tucked in for the night, some of the subjects subjects now wear earphones. And whenever their eyes are darting most rapidly, they get to hear ticks reminiscent of the clock. The idea is to see if the ticks remind the dreamer of the learning task right in the middle of her dream. The results were startling. Students who heard ticks during active eye movements proved far better than controls in learning the logic task, suggesting that being reminded of a problem during dreaming helps us tackle it. All in all, finding out that not only is my mind more capable of mental leaps when I'm dreaming, but that I might actually be doing something useful with

that ability, made my night at the sleep lab seem worthwhile - at least in retrospect. It is nice to know that something we spend perhaps a tenth of our lives doing is more than simply nightly entertainment.

OLD BRAIN - NEW TRICKS

ALAN ALDA (Narration) For our final story I'm once again having my head examined, this time in the lab of Helen Neville at the University of Oregon, Eugene.

ALAN ALDA You know I think after this show a lot of people will be wearing these. Neville We've had many requests for extra hats after our subjects see how fetching they are.

ALAN ALDA Yes, so a lot of people want to wear them out in the street? Neville Oh, absolutely.

ALAN ALDA Cute little suspenders. Are we afraid my helmet will like whip off if I turn my head too fast? Neville When we turn the propeller on we want to make sure you don't go anywhere.

ALAN ALDA I'm going to ask you some dignified questions while I'm wearing this.

ALAN ALDA (Narration) Now a special gel is added to each of the thirty two electrodes in the hat.

ALAN ALDA F7... OK.

ALAN ALDA (Narration) The gel helps make electrical contact between the electrodes and my head.

ALAN ALDA ...too high.

ALAN ALDA (Narration) It has to be firmly worked into place to be effective.

ALAN ALDA Well I think you drove the gel right into my scalp... direct contact with neurons... get a very good reading. Sixty-two point nine - I guess it's time to jam another Q-Tip in my brain.

ALAN ALDA (Narration) That was the warm up, but for the actual experiment I'm going to have to plug in... get comfortable... and relax.

ALAN ALDA Want me to hold this? Researcher No, that's fine. Neville We're going to check first that we have good contact from all the electrodes and that we

can see good, clean signal out of your head. And then we'll begin with the experiment.

ALAN ALDA OK. I'll just relax.

ALAN ALDA (Narration) When they're listening in on brain waves, neuroscientists like Helen have to get their subjects to reduce muscle activity to a minimum, so the faint signals from the brain can come through. Neville OK, Alan, this looks really good. Keeping your eyes nice and still, your muscles are really relaxed - keep that up.

ALAN ALDA (Narration) Helen studies where in the brain we process language. My task is simply to follow each sentence and register whether or not it makes sense. That one seems OK. Here's the next. Sue-- shared -- her -- candy -- with -- her -- best -- boat. Well that's nonsense. But actually the task itself isn't important -- it's just to hold my attention. In fact the system is continuously checking every electrode to look for tiny changes that might coincide with each new word flashing up. Averaged over hundreds of subjects, these signals show where in the brain different words are processed. The result is fascinating. Vocabulary words, like light -- daytime -- candy -- boat -- are processed in several different places in both left and right hemispheres. But grammar words, her -- with -- the -- in, are concentrated in parts of the left hemisphere. So for language, different parts of the brain have different jobs. That's true, at least, for adults. The question Helen Neville asked was, is the same true for children? Fourteen-month-old Dassi is at the stage of life when we rapidly acquire language. To find out what's going on in her brain, she needs to put on that charming hat with the electrodes, this time in a fetching shade of green. Dassi, however, has other ideas. I can't say I blame her. Well how about a blue one? Or maybe yellow will do the trick. Fortunately Davi, her brother, couldn't see what all the fuss was about. With stuffed animals to hold his attention, he settled down to listen to a series of words, while the system measured his brain's response. [Bottle... carbon... cat... diaper]

ALAN ALDA (Narration) The result, once again averaged over many subjects, looks completely different from the adult pattern. Very young children process language all over the brain. But then pretty soon, by about age four or five, the typical adult specialized areas have developed. This kind of result has important implications for education in general.

ALAN ALDA Are there things we should be doing sooner when we educate children? Neville We don't know when the critical time windows are, when learning math, learning music. learning science - adult-kind of learning - would be optimized. I don't have any doubt that there are such critical window of

opportunity. We just need to do the research to determine when they are. What we do know is that from the point of view of language learning, early is better.

ALAN ALDA (Narration) For people who learn more than one language, the early locking in of the brain's language areas makes a big difference. Arthur Goh, for example, speaks fluent Chinese and English Researcher Where were you born? Goh Uh... Singapore. Researcher How old were you when you started learning English? Goh About three or four. Researcher So in school... Goh Uh huh, in school.

ALAN ALDA (Narration) So while English is Arthur's second language, he learnt it when still young. When he's tested, his brain's response to English is indistinguishable from that of a native English speaker, with the same specialized areas for grammar and vocabulary. Researcher Where were you born? Goh I was born in... Viet Nam.

ALAN ALDA (Narration) English is also Nick Hong's second language, but he didn't start learning it until age 10. And when responding to English, his brain looks different -- there's no single grammar area. Nick ran up against a limit that confronts all late learners of languages.

ALAN ALDA In my case I... I started studying French in my teens, I got really serious about it in my late teens... I... I... thought I could speak it pretty well. What.... what were the things limiting me? Neville The sound of the language and the grammar of the language are the parts of the language that suffer most from delayed learning of a language. So you probably speak with an accent in French - people will probably tell you that. And your grammar probably isn't perfect. On the other hand you probably have a huge vocabulary.

ALAN ALDA (Narration) Nobody who learns a language after childhood can expect to speak it perfectly. [Poem]

ALAN ALDA (Narration) So don't blame the speakers -- for grammar and pronunciation, at least, you can't teach an old brain new tricks. [Poem]

ALAN ALDA (Narration) Back in the lab I met another of Helen Neville's test subjects, Dean Gabel.

ALAN ALDA When did you learn to sign? Interpreter I learned when I was four years old.

ALAN ALDA What brought that about? How did you learn to sign? Interpreter When my parents found out that I was deaf - they found out that when I was two -

and they decided to send me to the deaf school when I was four years old and there is where I learned to sign.

ALAN ALDA (Narration) When Dean's response is tested in the same way as for a spoken language, the result looks like that of any other first language, with typical grammar and vocabulary areas. That makes sense, because he learned sign language while still young. But take a look at this. It's a peripheral vision test, in which Dean has to detect the flashing squares on the edges of the screen, while concentrating on the one in the center. When his brain response is mapped, it shows he's using both the normal vision processing area and a large section usually devoted to sound. Of course vision takes on critical importance when you're deaf. When I took the same test my peripheral vision wasn't as good as Dean's, and I didn't use that extra processing area in the brain. This is the flip side of development in the young brain-- not only is it locking in particular parts for specific functions, but it can also invent new uses for sections if necessary.

ALAN ALDA That's just amazing... that you've got this kind of uh... that the brain is kind of malleable like a piece of clay in a way - it's not so hard and fast as uh... as uh... at least I thought it was.

NEVILLE That's right. There's no doubt about the fact that there are very strong biases, or likelihoods according to which the brain will develop. That's why in ninety-nine point nine percent of the people this visual brain, this is auditory brain, this is the part that's important for touch, this is the part that's important for language - but these strong genetic biases can be changed - they can be modified within limits, within time limits. [This is a sheep's brain.]

ALAN ALDA (Narration) Our knowledge of what's going on inside all brains...

NEVILLE This is the brain of a cat.

ALAN ALDA (Narration) ...cats', sheep's or people's -- is still limited.

NEVILLE This is a human brain and we've cut it in half...

ALAN ALDA (Narration) It's easier to explain the processes taking place in the distant stars than in our own heads.

NEVILLE Right above the ears is important for hearing...

ALAN ALDA (Narration) That's one reason Helen likes to talk to school kids about what we do know. Great challenges exist in neuroscience. We don't yet understand how three pounds of tissue produce consciousness -- how our brains turn into our minds, and into our selves.. The brain may be the final frontier of

science -- waiting to be crossed by tomorrow's scientists. Kid 1 ... like making decisions.

KID 2 ... the left side is for controlling your right side.

NEVILLE There's a lot more of the brain that we didn't talk about. That's because scientists don't by any means know what all the different parts of the brain do. That's why maybe some of you guys will grow-up to be brain scientists. Because there's... the most complicated structure in the universe that's gonna take a lot of people to figure out how it works.