BRAIN SCIENCE PODCAST

With Ginger Campbell, MD

Episode #36

Interview with Dr. Arthur Glenberg on Embodied Cognition

Aired May 2, 2008

[music]

INTRODUCTION

This is the *Brain Science Podcast* – the podcast for everyone who has a brain – and I'm your host, Dr. Ginger Campbell. On the *Brain Science Podcast* we explore how recent discoveries in neuroscience are unraveling the mysteries of how our brains make us who we are. For more information including Show Notes, links to previous episodes, and information about how to subscribe please go to the website brainsciencepodcast.com. We also have a Discussion Forum at brainscienceforum.com, and you can send me email at docartemis@gmail.com.

[music]

"The basic idea is to develop hypotheses and test hypotheses that high level cognition is based on neural systems that control action, neural systems that control perception, and neural systems that control emotion. And this is in contrast to the previous 40 years or so in cognitive psychology where the presumption has been that those high level cognitions have been analyzed as a separate sort of ability: something that's unique to humans, perhaps something that required particular evolutionary changes. The notion of embodied cognition is to at least try out the hypothesis that higher order cognition—this high level cognition—arises from these other bodily and neural processes."

[music]

Welcome back to the *Brain Science Podcast*. This is Episode 36. Today's episode is an interview with Art Glenberg from Arizona State University, and as I think you might be able to tell from that excerpt we're going to be talking about embodied cognition. We're going to be talking about the relationship between language and embodiment. This episode really is a continuation of the last episode about mirror neurons. However, if you are a new listener I think that this is an episode that you will be able to enjoy without listening to any other episodes first. I do refer during our conversation to my interview of Maryanne Wolf, but you do not have to have heard that interview to listen to this episode.

This episode is a little different because Dr. Glenberg is a working researcher. I think our conversation will give you a taste of what cognitive psychology is all about and, more importantly, a taste of how science is done. I hope it will increase your appreciation of the importance of taking an interdisciplinary approach to understanding how our brains work. I'm going to get on in to the interview, but I want to remind you to stay tuned at the end of the interview for some announcements, including announcements about the next episode.

[music]

INTERVIEW

GC: I am happy to welcome Art Glenberg to the *Brain Science Podcast*. I'm glad you could be here today, Art.

AG: It's my pleasure. I'm looking forward to talking with you.

GC: Now, you're the first person I've had on, I think, that hasn't written a book, so this is going to be an experiment. But I'm sure that we're going to have a lot of interesting things to talk about. To start out can you just tell us a little bit about yourself?

AG: Sure. I was born in Cleveland, and earned my undergraduate degree at Miami University—that is, the real Miami University in Oxford, Ohio. And then I took my PhD at University of Michigan. I moved from there to University of Wisconsin where I spent about 33 years, and then just this January—January of 2008—moved down to Arizona State University. And in terms of my research, it was originally investigating aspects of human memory, and then in the mid 1980's I became more interested in language comprehension.

That interest was driven by an applied question. It was one that I was working on with a good friend and colleague, William Epstein. We were interested in the phenomenon that our students reported. They would say that they had been studying for an exam and they knew all the material, but then they didn't understand why they did poorly on an exam. And so, we were trying to figure out what exactly that was that would lead people to incorrectly assess their comprehension. And so, it was on the basis of that question that I became interested in language comprehension, and I've been studying that ever since.

GC: So, moving from Wisconsin to Arizona, I guess that's a big change in the weather.

AG: Yes.

GC: And I know you told me that you were in Arizona but somehow a part of me thought you were still at Wisconsin, because I was telling my husband that you were at Wisconsin.

AG: You may also be thinking I'm still at Wisconsin because I still have a laboratory going at Wisconsin.

GC: Yes. I was thinking about your Laboratory for Embodied Cognition. What attracted me to your work was this whole idea of embodied cognition, and I thought maybe you might tell my listeners a little bit about what that means.

AG: I would be happy to. There are, as you might suspect, multiple brands of embodied cognition, so I'll try to stay pretty general but be sure to tell you that what I'm about to say is certainly my brand of it. The basic idea is to develop hypotheses and test hypotheses that high level cognition is really based on lower level bodily and neural processes—lower level perhaps is a misnomer—that high level cognition is based on neural systems that control action, neural systems that control perception, and neural systems that control emotion.

And this is in contrast to the previous 40 years or so in cognitive psychology where the presumption has been that high level cognition—that is, our ability to speak, to image, to attend, our ability to do mathematics—the previous 40 years that those high level cognitions have been analyzed as a separate sort of ability: something that's unique to humans, perhaps something that required particular evolutionary changes. The notion of embodied cognition is to at least try out the hypothesis that higher order cognition—this high level cognition—arises from these other bodily and neural processes.

GC: And this work in embodied cognition, this was going on before the discovery of mirror neurons.

AG: Yes. That's correct. I would say that, at least for me, I date the beginning of work in embodied cognition to the mid 1980's and to some of the seminal work that George Lakoff did in cognitive linguistics, and a marvelous book he wrote in 1987 called, *Women, Fire, and Dangerous Things*. Reading that book convinced

me to give the notion of embodied cognition a fair chance. And so, that was a decade before mirror neurons.

Certainly much of the development of embodied cognition has taken place without reference to mirror neurons, because although the mirror neurons were discovered in about 1997—the first publications—they really didn't start affecting people in cognitive psychology until just a few years ago. And it was because the mirror neuron phenomenon was really discovered in a neuroscience context and most of the publications were in neuroscience outlets, and it just took a while for the data and the theorizing to trickle into cognitive psychology.

GC: I hope you don't mind giving my listeners a little bit more background about Lakoff's work. Is he one of the pioneers of this whole idea of the brain evolving for action? Where does he fit into that story?

AG: That isn't the way I would characterize Lakoff. I think the notion that the brain evolved for action, that really is very much more consistent with the mirror neuron researchers. It's consistent with the work that I've been publishing since the mid 1990's. But it's not the foundation of Lakoff's theory. So, let me first talk a little bit about Lakoff's theory. Lakoff is a linguist, and so he is trying to focus mainly on language and particularly on where language gets its meaning—rather than the structure of language, which is the driving question for many linguists. That is, many linguists are concerned with structure. One of Lakoff's main concerns is with meaning.

And on Lakoff's analysis that meaning derives from basic bodily experiences. So, for example, he says that because of the sort of bodies that we have we are able to investigate containers; for example, using our fingers to feel the inside of a container and the outside of a container. And by virtue of that common experience of containers over the course of development, we develop what Lakoff calls an image schema for a container. And that image schema is not only visual

but also has motoric components to it and, in Lakoff's thinking, has a logic, part of the logic being that something can be inside the container or outside the container, but not both at the same time.

And so, then Lakoff goes on to propose that words such as 'in' and 'out' are based on our image schemas. Then he takes the really interesting leap which is to say that many abstract concepts are also based on these image schemas that develop through bodily experience. So, for example, Lakoff suggests that our understanding of the logical premise, P or not P but not both, that that comes from our image schema where we can conceptualize something being inside a container or outside a container but not both. And so, it's a really interesting analysis of how we can get to the most abstract of human concepts from the most ordinary experiences.

GC: And you've done some experiments that seem to support that idea, don't they?

AG: Well, certainly experiments that support the idea that abstract ideas arise from simple bodily experiences. I don't want to buy completely Lakoff's notion of an image schema. At times I think he tries to push it too hard, and that's why I'm not fully subscribing to it. But shall I describe some of the experiments that I've done?

GC: Sure. I do think I want to bring in one other little term before you get into the experiments. It may not turn out to be relevant yet, but I want to sort of lay in the groundwork here for my listeners. Is there a relationship between Lakoff's ideas and Gibson's ideas of affordances? This is something that I've mentioned on a previous podcast but you should probably start from scratch with.

AG: Right; with what an affordance is and maybe who Gibson was. So, James Gibson was a psychologist mainly studying perception. He did important work in

the 40's, 50's, 60's, and 70's. And Gibson is very strongly related to the notion of cognition evolving for action—or let me say that perception evolves for action—and that the idea is that the way we perceive the world is to allow us to control our action. So, when we're looking at a chair what we see about that chair is what we can do with it. So, we might be able to sit in it. But that ability to see that we can sit in a chair depends on having the right sort of bodies—namely human-like bodies—whereas an elephant couldn't sit in an ordinary chair. And so, Gibson says that one of the affordances of a chair is that it affords sitting, and that when we're perceiving a chair we're perceiving those affordances to control our actions.

Different animals will perceive different affordances because they have different sorts of bodies that have to take different sorts of actions. It's also the case that chairs can afford multiple actions. So, not only can we sit in a chair, but we can stand on a chair to change a light bulb. If you're a child you can hide under a chair. If you're an adult you might be able to pick up a chair to hold it for defense against an attacking dog. But all of those ways of using a chair depend on the sort of bodies we have. And Gibson would say the reason why we can perceive those affordances is because of the sorts of bodies we have.

GC: OK. See, to me, not being a deeply rooted in either one of their work, I see a lot of overlap there between both of them being rooted in the whole idea of it's about what kind of body you have.

AG: That is absolutely correct. And so, there's that strong relation between Lakoff and Gibson in that regard. Where they part, or at least where they don't talk to each other quite as much – You know but I have to admit, it's been a while since I read Lakoff's book, and so I'm making some of this up and it may not be fair to him. What I was about to say is where they part is that Gibson is much more concerned with action, whereas Lakoff is much more concerned with perception.

GC: And your work is mainly really focused on both, isn't it?

AG: Well, actually it is focused on both. Right. The way I try to characterize my work is that whatever we perceive is for action, and also—and what I'm about to say next is very Gibsonian—that the actions we take control what we perceive. So, by moving around in a room—by moving our head, by moving our eyes, by walking—it changes what we perceive, and so it changes what affordances we might derive. And so, it is taking action that contributes to our perception.

A great illustration of that is in regard to the haptic system—to perceiving things with your fingers. Imagine that you reach into your pocket to discover how much change you have there, but you can't move your hand: you just reach it in, and you can't move. Well, there's no way that you would be able to perceive the coins that you have in the pocket—certainly to individuate the coins in your pocket. Even if you start to move your hand around, you might start getting a sense of how many coins but not a very fine discrimination of what those coins might be. And it's only when you then engage your thumb acting with your fingers that you're able to determine how many coins you have, what size the coins are, what those denominations might be. So, it's having a particular body—that is this opposable thumb—and using it in conjunction with the fingers—that is, taking action—that generates the perception.

GC: That makes sense. And you gave a great example, because I've talked in the past about the experiments that show that animals don't develop normal vision if they're not allowed to move around in their environment when they're developing. And it seems like it's related, and again goes back to that whole perception and action being so much intertwined.

AG: I think that's exactly correct.

GC: So, do you want to talk a little bit about your experimental work?

AG: I certainly do. But before that let me just bring up something with humans about the perception-action interchange and human cognitive development. There are a couple of just brilliant papers that illustrate that so nicely. One is using a procedure that Amy Needham invented—she calls it the sticky mittens procedure—where you put on a young infant a mitten with half of a Velcro strip on it, and then the other half of the Velcro might be attached to a toy. And then what this allows is for the child to swipe at the toy and to grab it, even though the child might not have fine motor control yet. But it allows the child to get the experiences of grabbing an object, of rotating it, of studying it much earlier than they would ordinarily be able to do that.

And you can then track that those children who have this special experience of using the sticky mittens, and therefore being able to interact with their environment better, those children then show the ability to understand other people's goals more quickly than infants who haven't interacted in this way. Let me say that again and try to make it a little bit more clear. When infants are wearing these sticky mittens which allows them to grab onto objects and to use their own actions to study the objects, those infants are then able to understand adults' goals in reaching for objects better than infants who haven't worn the sticky mittens and haven't had that opportunity.

It's a marvelous experiment. Amy Needham is one of the authors and Amanda Woodard is another one. So, that's one sort of experience with human infants that shows the importance of action development affecting perception, and thereby affecting understanding of the world.

Another beautiful example of that is work that Joseph Campos has done on self-locomotion. We've known for a long time that when infants start to crawl it apparently changes a lot in their ability to interact with the world. It seems to change a lot in their social environment and their emotional environment.

What Campos did was to again show that it was the experience that the infant has in controlling self-locomotion that's important. And the way he did it was by taking infants who could not crawl, putting them in a walker so they were suspended and by kicking their legs they could move around the floor, so they could control their locomotion. After some experience in this controlled locomotion Campos was able to show that that experience changed the way the infants perceived the world. So, again very powerful experiments.

GC: And that one has some pretty strong implications for what could be done to help handicapped children, I would think.

AG: I would think so. I don't know if anybody's followed up with those implications, but it certainly seems right to me, that you want to give children—whether handicapped or not—control over their own actions. Doing something for the child or the infant may not always be the best way to engender cognitive development.

GC: It seems like mothers that are good mothers seem to have an instinct for that.

AG: I think you're right. I think you're absolutely right.

GC: And fathers too.

AG: Right.

[music]

GC: When we come back from this break Dr. Glenberg will tell us about his own experimental work.

[music]

AG: Let me tell you a little bit about my work. There are two components to my work that I'd like to talk about. One is more basic work, and the other is more applied work—taking what we've learned from the basic research and applying it in the classroom. So, I'll start out with the basic work.

This is research that I published with Mike Kashak, who's now at Florida State University. We wanted to show—or at least to test the hypothesis—that when people are understanding language they are doing a type of simulation that involves the motor system: that the language understanding is not simply in terms of words, it's not simply a specific module that has evolved for language, but that in fact language comprehension taps into motor systems. And then later on Mike went on to show very nicely how it also taps into perceptual systems.

But let me start out with the motor system. Imagine that you hear a sentence such as, 'Close the drawer' and you have to indicate whether that's a sensible sentence or not. A nonsense sentence might be something like, 'Close the plate.' And so, it's a very simple experiment. The participants are just saying sensible/ nonsense—that is, they're indicating sensible/nonsense for a sentence like, 'Close the drawer,' and, 'Open the drawer.'

The trick of the experiment was that we had people indicate sensible by either moving their arm out from their body to a button—that is moving their arm away from their body—or moving to a button close to their body, moving their arm toward their body. And half of our sensible sentences seem to require in the real world action away from the body; like 'Close the drawer' almost always involves moving your arm away from the body, and 'Open the drawer' involves moving the arm towards your body.

And our idea was if people are engaging in a simulation of those sentences using the motor system, that we should be able to detect that simulation by its effect on their literal movement; so that if people are understanding a sentence like, 'Close

the drawer,' they should be faster to say that's sensible if they're making the response away from their body than if they're making the response toward their body. Similarly, if people are understanding a sentence such as, 'Open the drawer' they should be faster to make the response going toward their body than away from their body.

And that's exactly what we found. We found that for sentences that were imperative sentences like those. We also found it for sentences describing transfer. So, I can say something like, 'Art gives you the pen,' or, 'You give Art the pen,' invoking action away from you or toward you; and we find the same effect with the response direction. And perhaps most importantly, or of greatest excitement, was that we also found this effect when the sentences were describing the transfer of information rather than the transfer of objects such as pens.

So, for example, I could say, 'Art radioed the information to you,' or, 'You radioed the information to Art.' And in responding 'sensible' you would respond more quickly when the sentence is describing information that flows from you to somebody else—you would respond more quickly moving your arm away—and when sentences describe information that's flowing toward you, you respond more quickly moving your own arm toward yourself. So, for us that was pretty convincing evidence that in fact the motor system is being tapped during language comprehension.

GC: Do you know whether when a person hears a sentence like, 'Close the drawer,' whether that activates mirror neurons, or just motor neurons? I guess it's not possible with our current technology to really know it down that precisely.

AG: That's correct. There's certainly a lot of speculation that it is activating mirror neurons and there is data consistent with it—namely if you look at imaging experiments you see activation in the areas of the brain in which mirror neurons are found; you see activation of those areas of the brain in

understanding these sentences. But that's still not conclusive evidence that it's mirror neurons themselves that are being activated. It's a good guess, it's a good hypothesis, but the data aren't conclusive.

GC: I guess until they figure out a non-invasive way to do single neuron recordings it's going to be hard to know for sure.

AG: That is correct. Let me expand on that. Until they figure out a way to do single neuron recording in humans it's going to be difficult to know for sure. Certainly people are doing single neuron recording in animals—in monkeys in particular—that allows a more secure investigation of the mirror neuron system. There is in fact a little bit of work that's being done now with single cell recording in humans. And the way that can be done ethically is that in preparation for surgery, often when somebody has an incurable epilepsy and so that part of the brain needs to be cut out, what the neurosurgeon will do will be to implant electrodes along the path that the surgeon might take to get to the epileptic foci, and then just have the person live their daily life for awhile.

The point is to try to find the best path—the path that would be least disruptive to functioning. But once you're recording from those neurons you can be doing experiments like mirror neuron experiments and see if you can deduce evidence for mirror neurons in humans. And the strongest sort of evidence would be to find a neuron that fires equally well when the person is perceiving an action or when that person is undertaking an action. So far I only know of one piece of work that's used that methodology, and although the authors were very positive, my assessment was that they have a way to go yet before they pin down the idea of mirror neurons in humans using that methodology. I didn't think the data were as strong as they could be.

GC: The experiment you just described was a sort of basic experiment. Do you want to share one that has to do with a practical application?

AG: I would be happy to. Also I could tell you more basic experiments. I leave it up to you. Which way would you like to go: a little bit more on basic, or go over to the applied?

GC: I think we'll go to the applied because actually I just got done doing an episode that covers a lot of this, well, not exact material, but similar material. And I have some other questions I want to ask you. So, go ahead and tell us a little bit about how you apply this. I mean it's pretty exciting stuff, and I'm sure my listeners would like to know the practical implications.

AG: I would be happy to talk about that. So, if we summarize the work on language comprehension—that experiment that I just talked about, as well as a lot of other experiments that I've done and others have done—one easy summary of it is that when we understand language we do that by mapping the words and sentences to our own experiences. And to the extent that we can call upon our experiences—perceptual experiences, action experiences, and emotional experiences—to the extent that we're successful in bringing up those experiences, that's the extent that we understand the language.

So, based on that summary we asked ourselves why is it that virtually all children love language? They love to talk, they love to watch TV, they love to watch movies. But why is it that those same children don't like to read? Why is it that reading is so difficult for them? And the hypothesis that we began with was that when children are in a reading situation they haven't learned to map the written words to their experiences. So, why should that be?

Imagine an infant learning an oral language, learning the meaning of the word 'bottle'. So, we might have the infant's mom giving the infant the bottle and saying, 'Here's your bottle.' Now, note that the word 'bottle' is immediately associated with the perception of the word 'bottle,' with the actions associated with the bottle: that there's this immediate grounding of the linguistic term to

perception and action. And I think that that is almost always the case in learning an oral language—at least learning your native language.

But what happens when a child is reading? When a child is reading, particularly in English, that has such a dense orthography—that is, the mapping between the letters and the sounds is so complex—when a child is reading in English that child has to be focusing completely on the words on the page and trying to sound out those words. So, for example, the word on the page might be a sentence about a dog and the child's going, 'd,' 'd,' d,' 'dahg'. And then if there's a teacher there, the teacher may say, 'No, no; dog.' And the child goes, 'OK, dog,' and then goes to the next word. So, the child's attention is focused on getting the word out rather than mapping the way the word looks to the experiences.

And so, our hypothesis was that maybe some children really dislike reading because they haven't learned to take that step of mapping the written word to their experiences. So, to overcome that what we did was to devise a two-part procedure to try to illustrate for the children how important that mapping can be and how they can do it. So, in the first part we have children reading simple stories: for example, a story about events on a farm. And while the child is reading the story right in front of the child there are toys that can be used for that story.

So, there might be a barn, a tractor, a farmer, and animals. And as the child is reading the story a sentence might be, 'The farmer brings the hay to the horse.' The child then manipulates the toys to correspond to the sentences. And our idea is to enforce the relation between the words—'The farmer brings the hay to the horse'—and the corresponding perceptions and actions that the child creates by manipulating the toys.

What we've found is that that sort of physical manipulation while reading enormously enhances reading comprehension. This is a little bit of a statistical

terminology, but it enhances reading comprehension sometimes by one to two standard deviations, which is truly an amazing amount. It's like increasing an IQ from 100 to 130. So, that's the first step, is doing the physical manipulation.

What's perhaps even more exciting is that after a child has done this for just a few stories even, we can take the toys away and we can spend a few minutes teaching the child how to imagine the manipulation as opposed to physically doing it. And then after the child has learned to imagine the manipulation the child can read that story and show virtually the same benefits as if she had been doing the physical manipulation.

And so, it's that ability to transfer to imagined manipulation that makes this really powerful. I think it makes it educationally relevant, because certainly we can't have toys in front of the children all the time. But if we can use the toys to teach the child how to read for meaning, then it looks like we can pretty much let the child go on his or her own, and they get the meaning from the text.

GC: Do you have data about follow up. Like once they've been taught this on an indexed story can they take that skill to reading other things? Do you know?

AG: Yes and no. So, here are the data that we have. First off, the older children can do that more reliably than the younger children. And let me back up even further; let's stick with stories on the farm. Even the youngest children, once you take away the farm toys, they can read new stories about events on the farm and that's no problem. But when you then start talking about events in the factory, or events in the house, then the youngest children can't do it. But children in like the second and third grade, they can.

So, there is evidence that this is a more general skill, at least in the slightly older children. Now, what we don't know yet is whether when the child goes home and starts reading a book at home, or starts reading something for their homework,

we don't know if they'll do it. But at least within the context of our experiments we see pretty good generalization to text in different domains.

GC: Do you have some ongoing research in this area to try to come up with exactly how to make it something that could be used out in the real world?

AG: Indeed. We have one project that's just finishing up and another one that we hope to get going in the Fall. The one that's just finishing up is a project that was conducted at a charter school. It's called Young Leaders Academy in Milwaukee. They were terrific students and terrific teachers, and so I'm happy to say that the Young Leaders Academy was a great place to work.

In this experiment with about 40 children we had the teachers implementing this two-part procedure in their classrooms with all of the children. So, it was the teachers that showed the children how to do the physical manipulation. And we did that for a couple of weeks, and then after the physical manipulation for a couple of weeks the children were then taught the imagined manipulation.

And we had some teachers implementing this two-part program. In control classrooms we had teachers implementing a different reading program that focused on Wisconsin State reading standards. And we were able to show in these classrooms that again the children who engaged in manipulation did much, much better on comprehension tests than children who were reading to try to implement Wisconsin State standards, such as identify the main character.

GC: Now, these were all children that were considered of normal reading ability for their age groups.

AG: That's correct. And then we have a much larger project that we're trying to get going in Arizona in the Phoenix area in the Fall. And that much larger project we hope will have around 30 or 40 teachers, with half of them randomly assigned

to implement this two-part intervention and the other half randomly assigned to implement an intervention based on Arizona State standards.

GC: And I guess at this point it's too early to know in the long run what would be the best age to do this for children, since we're still at the sort of data gathering stage.

AG: Right. As far as we've been able to think it through this is only a part of the reading problem. It's still the case that the children have to be taught the alphabetic principle—that is, that different letters of the alphabet have different sounds. They still have to be taught how to blend those sounds. They still have to practice an awful lot on developing fluency in translating from the written letters to the sounds of the words.

So, that, as far as we can tell, all has to come first. And that's starting now in kindergarten, first grade, and partly in second grade. But we think once the kids get into advanced first grade, into second grade, into third grade, that then this program for teaching them how to systematically map the words onto meaning, we think that this program can be very beneficial.

GC: I don't know if you've had a chance to listen to any episodes of the *Brain Science Podcast*, but I had an interview with Maryanne Wolf. I don't know if you know her work. She's at Tufts. She wrote a book called *Proust and the Squid*. She is very involved with helping children learn how to read and all the problems involved in the various kinds of dyslexia.

It seems to me like your work and her work in the long run hopefully will complement each other. But what I was thinking when you were talking about your work was you were describing the motor aspect. I guess the perceptual aspect I was thinking is kind of one of those 'duh' moments. Now I think I understand why they have pictures in little kids' books.

AG: I think you're exactly right. And I think those pictures can help a lot, particularly when the children look at them. But I think often when children are reading—at least on their own—they're so focused on trying to get the words out that they can't look at the pictures; they have to be looking at those words. And then whether the child after saying the words bothers to go back to the picture, I don't know.

The other aspect of picture books that I think is not quite as useful as this technique is that the pictures are static—they can only illustrate one part of the text, one part of the sentences the child is reading—whereas with this technique the student uses her own action to create a dynamic display of the story. It's as if the student is in some sense creating a movie by interacting with the objects. Again, I think it's another illustration of the idea how action creates perception; that as the child is moving these toys, the child is creating the perceptions that are required for understanding the story.

GC: Yes. I was just thinking in terms of parents when they're helping their children when they're at that picture book stage, that what we now know I think indicates that we ought to do what parents have done, which is encourage the children to identify the objects in the pictures, and not to regard the pictures as something that's not important, or is just there to avoid reading. That maybe if they can be creative they can make that part of the learning to read process. That's what I was really thinking.

AG: Right. I think you're absolutely correct.

[music]

GC: I'm going to take a brief break and be right back with the rest of Dr. Glenberg's interview.

[music]

AG: Two aspects of what you said certainly resonate with my own thinking. One is to actively have the child do the mapping between the words and the pictures. And the second part—I like the way you said it—is that the pictures aren't there to avoid reading; to try to guess what the story is without doing the reading. The pictures that are there should be used as a way to reinforce the reading.

GC: I just think that could be very useful to parents when they're spending time reading with their children. We know that the time spent with a parent makes a difference in how children learn how to read, so I just thought that might be something that would be useful.

AG: Yes, I think you're absolutely right. So, maybe I will write a book.

GC: Maybe you should. Well, when you have a little bit more information together you'll be ready.

AG: That's right.

GC: And then you'll have to come back on my show.

I wanted to ask you if we could get into a little bit more of a theoretical frame of mind before we run out of time. I guess that you have already discussed the basic evidence that linguistic meaning is based on both our body's perception and our body's action system. And I was kind of wondering, does this have any relationship to grammar? Is there any evidence that grammar could be rooted in the motor system?

AG: Yes, that's a beautiful question. And the evidence is just starting to be collected. People are just starting to propose theories of that sort that can be tested. I'll tell you about my favorite approach to answering that question. It's my favorite approach because it's my approach to answering that question. This is discussed in a paper that Vittorio Gallese and I have just submitted for

publication, so we'll have to undergo the multiple revisions and rigors of peer review before it's finally published.

The idea is that the motor system is inherently hierarchical: that we take similar actions, for example, in grabbing a pencil, in grabbing a cup, in grabbing a calculator. We have the same arm motion, and then it differs at the end whether we wrap our fingers around a cup or we use a precision grip to pick up a pencil. So, the idea is that that precision grip for picking up a pencil is imbedded within the control procedure for generating the whole movement. So, we end up with hierarchies of action control. The hypothesis that Gallese and I offer is that the mechanisms that generate that hierarchy are also used by language as the mechanisms that generate grammatical hierarchies.

So, we have a sentence describing a transfer—'Art gives Ginger the pen,' or, 'Art gives Ginger the cup,' or, 'Art gives Ginger the story'—and all of those can be seen as invoking a similar hierarchical relation, a similar structure, a grammatical-giving structure—some people call that a dative structure—and that within that dative structure we imbed the particulars, such as the cup, or the pencil, or whatever. And so again, just to reiterate, the hypothesis is that it's the same hierarchical mechanism that's used for controlling action that's then used in generating grammatical sequences.

GC: How are you going to test that hypothesis?

AG: That's a good question. You know we take a lot of the data that we've already talked about—like that Glenberg and Kashak experiment about the motor system being invoked during understanding—we take that as at least consistent with the hypothesis. Other data that's consistent with the hypothesis has to do with imaging data and showing that when people are understanding hierarchies of many different sorts—whether they're linguistic hierarchies or action

hierarchies—that there is strong involvement of premotor areas in the brain; Broca's area in particular.

GC: So, you're kind of at the stage where you're taking the experimental data that you have and using that to form this hypothesis. And then I guess the next stage will be trying to come up with new predictions from that hypothesis that you can then test.

AG: That's absolutely correct. Right now I think we were just pretty much enthralled with noting the variety of data that we could accommodate using this hypothesis and we haven't as yet come up with something that uniquely supports it that other theoretical approaches could not explain. And so, I think you're right, that's the very next step.

GC: Yes, one of the things that I try to do on this podcast is to communicate to people how the scientific method really works, because in school they teach you the steps but they're not very good about giving practical examples. And I sort of suspect that the average non-scientist doesn't really have a real practical grasp of how it works, or they wouldn't be thinking that something like intelligent design was a scientific theory.

AG: You know I wish I could comment with a form of expertise on that.

GC: Oh, no. You're just a working scientist and it's great to talk to a working scientist about the day-to-day reality of how you do science. That's really what I was meaning.

AG: Yes. You know that creative part where you said, well how are you going to test that, and I said, I don't know. It's a mystery to me where the ideas come from. For example, before that Glenberg and Kashak experiment with moving the arm back and forth, we must have done half a dozen different experiments trying to get at the idea of language and action, but none of them were very good.

But we knew that none of them were—I shouldn't say they weren't very good—they weren't definitive. And we just kept plugging away on it, looking for new ways to test the hypothesis. And then finally—to tell you the truth, I don't remember what triggered the idea—finally we got this idea and we knew immediately that this was the right idea, this was the way to test the hypothesis. But where that came from, I don't know.

GC: But that's what makes doing science fun, right?

AG: Oh, absolutely. This is what I tell the students in my laboratory all the time, that that's what makes the laboratory experience fun also. It's getting people together and discussing these ideas. And person A says something and everybody realizes it's not very good, and person B says something that's not very good, and same with person C. But somehow by virtue of A, B, and C saying those things a good idea appears, and it's just tremendously gratifying.

GC: And you need the contributions of the bad ideas to come up with the good ones.

AG: I think that's correct. Right. At least in my laboratory we do. I think it speaks to the social nature of language.

GC: Do you have time to answer just one more question?

AG: Sure.

GC: This is about emotion. Does your work shed light on the interaction between language and emotion?

AG: I believe so. And in fact we have one publication out—a couple of publications out—and I'm just working on a lengthier paper that tries to bring several of the experiments together. So, I think the same general story can apply:

that when you are understanding language about emotional content—about somebody being scared or about somebody being happy—understanding that language often requires a simulation that taps into one's emotional experiences. And to the extent that you've had similar emotional experiences you can understand that language better.

I think the notion of simulation and tapping into the emotion system is just about the only way to explain the commonplace phenomenon that when we're reading we are experiencing those emotions. We're reading something scary and we're becoming petrified. Or, we're reading something arousing and indeed we're becoming aroused. And I think it's because of that simulation experience.

And we've been able to demonstrate that in a couple of ways. The first demonstrations we did—this was done by a student, David Havas, and Mike Rink, a collaborator in Germany, and was just published in 2007—we generated an emotion using a procedure that's actually a lot of fun. It was invented by a psychologist named Fritz Strack. You hold a pen in your mouth using only your teeth, not your lips. And what it does is it forces you to smile, and that forcing you to smile brightens your mood. Or, you hold the pen in your mouth using only your lips, and what that does is to force some people to frown; or at least prevents them from smiling.

And what we were able to show is that when people have the pen in their teeth they understand sentences describing happy situations faster than when they have the pen in their lips and they're frowning. And visa versa for sentences describing sad situations. When people have the pen in their lips so they're frowning, they understand the sentences describing sad situations faster than when they have the pen in their teeth and they're smiling.

So, that was one way of demonstrating the contribution of emotional state to language understanding. We've also gone the other direction trying to show that

the language induces an activation of the emotional system and consequent activation of action systems that are appropriate. Let me say that in ordinary words. When we're angry one of the things we do is to try to strike out, and when we're sad one of the things we do is to gather up our resources and to literally gather up other people by hugging.

So, we had people reading sentences about angry situations and sentences about sad situations, and people were reading the sentences and making the judgment about whether the sentence was sensible or not. And again, sometimes we would imbed sentences that were nonsense. And to make the judgment we had one group of people pushing the lever away from their body as if they were striking out, and another group of people were responding that the sentence was sensible by pulling the lever towards their body in an affiliative sort of motion. What we found was that when people are reading the angry sentences they are faster to push that lever away from their body than toward, and when people are reading sad sentences they're faster to pull the lever toward their body.

To make it a little bit more exciting I'll tell you about gender differences. But I need to say a caveat first, and that is that these gender differences are very small. The similarities between the men and the women in these experiments are much greater than the differences. Nonetheless there are some interesting differences. One of those differences is that the effect of the angry sentences is much greater—again, 'much' is too strong—the effect of the angry sentences is greater for men than for women. It's as if men are more able, or more quickly able to simulate anger than women. And similarly the effect of the sad sentences is greater for women than for men. It's as if the women are more able, or more quickly able to simulate sadness than men.

GC: And that seems to fit with the whole idea of tapping into something that's already in our repertoire, be it motor or emotional repertoire.

AG: That's right. And whether these gender differences are due to culture, or due to differences in bodies, or some interaction of those two, we certainly don't know yet.

GC: Well, Art, I have had a great time talking to you, and I'm sorry that we don't have more time. If my listeners want to learn more about your work do you have a website that they could find? I'm going to put links in the Show Notes, but if there's one that you want to just tell that I can play out in the podcast I will.

AG: You know that's a very good question.

GC: If you don't you can just let me know and I'll put links, like I said, into the Show Notes. And I'll get with you about which papers you have that are available on the Internet and make sure that I link to those.

AG: Right. The website for the Wisconsin lab is still active, and that's probably the best one for them to go to. So, Laboratory for Embodied Cognition. But I don't know the URL off hand.

GC: OK. Well, I'll track that down and put it in the Show Notes.

AG: OK.

GC: And what about email? Would you like to hear feedback from people?

AG: Sure. That would be fine. The email address—that I can give you—it is glenberg@ASU.

GC: Well, great. I appreciate that. And we have a Discussion Forum for the podcast, and we usually have discussions for each episode, so I'll let you know if anyone posts up anything on there. I'll send you a link to that so you can see

what kind of conversation. Who knows? Maybe somebody will come up with an idea for an experiment to test your hypothesis.

AG: That would be great. Well, it's been a great pleasure talking with you.

GC: Yes, me too. I'll let you go, and I'll let you know exactly when this is going to come out and I'll send you links.

AG: Great. Thanks very much.

GC: OK. Bye.

AG: Bye bye.

[music]

I want to thank Art Glenberg for coming on the *Brain Science Podcast*, and remind you that if you go to brainsciencepodcast.com you can find links to many of his papers, and also you can find links to the other scientists that he talked about during the podcast. And I have his email there in case you'd like to send him some feedback. I'm sure that he would enjoy hearing from you.

I want to take just a moment to remind you to listen to my other podcast *Books and Ideas*, which is available at booksandideas.com. The current episode is an interview with best-selling author Dan Ariely about his book, *Predictably Irrational*. *Predictably Irrational* is also available in audiobook form from Audible.com. If you haven't already signed up with Audible you can get a free audiobook download when you sign up. Just go to audiblepodcast.com/brainscience, or click on the ad on any of my websites. I don't get very much money from Audible.com; however, I am a big fan of Audible, since I have had a subscription to Audible.com since 2003.

I have a few pieces of news with regards to the *Brain Science Podcast*. One is that Diane Jacobs, one of our most loyal listeners, has done a complete transcript for Episode 31, which was György Buzsáki's interview on brain rhythms. There is a link to that on the website and I'll include that in the Show Notes. I especially want to thank Diane for that because I know that represents quite a few hours of work.

Another listener, John Richards, is working on a glossary of various terms that we've used on the podcast, and his glossary is going to include links to all the books that have been featured on the *Brain Science Podcast*. I'll be linking to that also on the website as soon as he gets that up online.

As always I want to remind you that you can send me email at docartemis@gmail.com. You can post comments at the website brainsciencepodcast.com. But best of all I'd love for you to participate in the Discussion Forum at brainscienceforum.com.

And I really need your help in getting more listeners. I've noticed that over the last few months the number of listeners seems to have sort of plateaued and the show's not really growing the way that I need it to. So, don't forget to tell your friends about the podcast. And if you have an opportunity to put up a review at iTunes, or to vote on Digg, or anything like that, it's very much appreciated. I want to thank everyone who's been putting up blog posts about the *Brain Science Podcast*. It's very much appreciated. And, of course, if you have the ability to help support the podcast financially there is a link for that on the website.

I've got several good interviews coming up. The next episode is going to be an interview with John Medina, author of a new book called, *Brain Rules*. And after that we are going to be talking with Michael Arbib about the mirror neuron hypothesis for language development.

Finally I want to remind you to visit sciencepodcasters.org. It's a great place to find other science podcasts. And don't forget to tell your favorite science podcaster to send me an email if they're interested in becoming part of that website.

I guess that's about all for today. Thanks again for listening. I look forward to talking to you again soon.

[music]

Transcribed by Lori Wolfson
All errors or omissions responsibility of the transcriber