What Discoveries in Neuroscience Teach Us About Language Learning

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Summary

Discoveries in the booming field of brain science are being reported weekly. Our advances in understanding the brain are occurring so rapidly that the field is compared to the development of personal computers in the eighties. Since many of the discoveries shed new light on learning and language, it is almost certain that they will expand or reshape existing theories of L1 and L2 language acquisition. The purpose of this paper is to review the most relevant discoveries in neuroscience in order to identify potential topics of research in language teaching and learning.

Introduction

Teaching English, has always been a mixture of science and art. The science is what we do in the classroom; the art is how we do it. The science is in what we decide to teach; the art is in how we decide to relate; how we help the learners grow. Science is the syllabus. Art is the heart.

We have always needed both, but there are problems with both too. The art is pretty much uninformed. You can’t learn it from a textbook. You can only learn it from years of experience. The science has a problem too. Traditionally, it has pretty much just drawn on the science of Linguistics, with a touch of Psychology and Education. The problem is that while we know much about the English language, this knowledge just forms one side of the language learning formula. We need to know about the learning side too. Theories of language acquisition have helped in this regard, but the major ones, due to the limits of technologies when they were proposed, have pretty much been speculative, purely theoretical, and difficult to translate into practice.

A panel discussion on new advances in English teaching was held at a recent TESOL conference. The panel contained seven of the foremost leaders in our field: Jack Richards,
Diane Larsen-Freeman, Mike McCarthy and others. Each panelist reported on some advance in English teaching, but the advances they discussed – corpus studies, grammar theory, etc – were all advances in linguistics, ways of organizing the language. Only one of the presenters, Marc Helgesen, even mentioned learners and learning. In no way is this a criticism, for their insights on the structure of language have led to major improvements in our field, but it is typical of how our profession been shining this huge light on the language, and leaving the learning in the dark. The imbalance is a result of our long-standing inability to study learning directly, the physical processes of the brain. As a result, for decades, we have referred to the brain as a “black box” (Chomsky, 1986). We can see what goes in and what comes out, but we cannot even postulate what happens inside.

Until now, that is. Advances in technology have, for the first time ever, allowed us to look inside the brain and see how learning occurs. We can even see neurons reaching out and connecting to each other. Our understanding of how the brain works is growing by leaps and bounds and the current advance of neuroscience is often compared to the way personal computers or the Internet advanced in the eighties. Unfortunately, while we are discovering fantastic things about learning, our teaching methods are not following suit. As Knowles pointed out (1990), our standard educational pedagogy hasn’t changed much since the 11th century when it was developed to train monastic scribes. Teachers still lecture and students still memorize. Some educators are demanding we change the way we teach, in a movement known as “brain-compatible teaching” (Jennings, 2000). Let us examine at a few of the things brain studies have told us about learning and postulate their possible connection to language learning and future research.

What learning is

Learning, in terms of the brain, can defined very simply. It is memory. Memory represents the neural pathways that are forming in our brains all the time, even now as you read this. Dendrites reach out to the axons of other neurons to form synapses, thereby creating the circuitry of a new memory (Kandel, 2007). In this way, our brain is like a computer – an analogy most of us grew up with, but one, as will be pointed out later, is not very good for showing how the brain works.

When information comes in, certain neurons are stimulated in a process of recognition. They trigger higher sequences of neurons that identify patterns, which if stimulated, again access even higher sequences (Hawkins & Blakeslee, 2005). In reading a word on this page,
for example, certain neurons that identify lines, circles and other shapes are stimulated, which pass on the information to higher sequences, that recognize letters or words. These groups of neurons then access other sequences of neurons that process patterns of meaning. The neural sequences do not need a whole picture to identify something. Our brains are pattern recognition machines that predict and then confirm. Our brains are highly interactive with the environment and work best when discovering, recognizing and interpreting. Whereas we input data into computers, that is not the most brain-compatible means of teaching for human beings.

So memory means neurons connecting to each other through synapses, but not just a single line of synapses; there are usually tens of thousands of neurons involved, forming channels through the brain (Kandel & Siegelbaum, 2000, pp. 220–225). Even the connection between any two neurons might be through thousands of synapses, not just one. Just reviewing something might cause 1000 synapses to increase to 2000 within 30 minutes.

We are born with almost all our neurons already formed, but with only 20% of the connections between them. Again, unlike computers, these connections are not permanent. We are far less hard-wired than we used to think. Infants, for example, connect everything, and yet up until the age of five they shed more connections than they make (Stamm, 2007). In fact, babies are born with the ability–meaning neural connections–to hear any sound in any language. The sounds that are not reinforced, such as "L-R" differences for Japanese, are lost. The neural connections are shed.

The things you are learning right now are at risk too. Almost all of this might be going into your short-term memory, but only a small part of it, or maybe none at all, will go into long-term memory. You are bound to forget most of this article even before you finish it, and you’ll forget more each hour afterwards. Some of it might be retained longer, and over the next two weeks, some of it might even be integrated into the rest of what you know, meaning you’ll probably keep it for the rest of your life. Something happens to short-term memory that makes it long term, and if you think about it, this is the holy grail of learning. If we can find out what makes long-term memory take place, then we’ll have found the secret of teaching.

The process is still not completely clear, but we have been discovering some interesting things about memory formation. For starters, for a neural connection to go from being a tenuous, easy-to-shed connection to a permanent one involves genetic change. A chemical messenger moves from the synapse to the nucleus to deactivate a gene that blocks protein synthesis. (Kandel, 2007). Who knows, we might someday be able to invent a pill that helps
us form permanent memories.

**The importance of sleep**

Another extremely important and previously unappreciated factor in forming long-term memory is sleep. After a hundred years of trying to figure out why we need sleep (it is not required for rest, recovery, or cooling), we have finally found the answer. Sleep is when long-term memories are formed. It seems that in the slow-wave stage of sleep, before the dream stage, your brain replays all of the things it experienced that day, in reverse order, and tags some for permanent storage.

In addition, there is evidence that over the following nights of sleep your brain reorganizes and integrates these new memories (Medina, 2008, pp. 160–161). We go from knowing to understanding. In fact, our brains are more active when we are asleep than awake. We also solve problems in our sleep. In one study, students were given math problems with a hidden shortcut for solving them. Three times more students figured the shortcut out after 8 hours of sleep than those in the non-sleep group.

So what happens if you stay up all night? You forget everything you learned the day before. Research shows an all-A student who gets a little less than seven hours sleep on weeknights and a little more than seven on weekends will drop from the top 10% of her class to the bottom 10% of those who do get sleep (Medina, 2008, p.162). With a few all-nighters, she’ll start showing the same symptoms as someone with Alzheimer’s. Another study shows that only six hours of sleep for five nights straight leads to 60% loss in performance. Dr. John Medina, author of Brain Rules, puts it simply: "Sleep loss means mind loss" (2008, p. 162).

And yet, our youth these days, especially in Japan, are getting less sleep than ever before, and certainly far less than they need, which is 8.5–9.25 hours a night (Medina, 2008). Now that we know how critically important sleep is, it is not presumptuous to wonder if sleep, rather than study, might be the greatest determinant of academic success. In fact, I did an informal study at two colleges to see if there is any evidence for this notion. A colleague and I surveyed 1st and 2nd year students at two colleges to see if there were any differences in sleep habits. One of these neighboring schools is one of the hardest to get into in Japan, while the other is one of the easiest. The students at the higher-ranked school averaged a whole hour of more sleep on both school nights and non-school nights than the students in the lower-ranked school. While this simple survey is not rigorous enough to
make any claims with, it still makes me wonder if passing university entrance exams is more a factor of restfulness than diligence. Other studies too, disprove our notion that students who burn the midnight oil studying are the ones who get into the top colleges. The ones who get a full night of sleep do.

**Other critical factors of learning**

Obviously, things like sleep that enhance or impede normal brain function form the baseline factors of learning. Other factors in this category include nutrition, stress, and blood flow. Stress, like lack of sleep, can also inhibit learning.

While a little stress might enhance learning, too much stress prevents it. In stressful situations, our brains release an enzyme, Protein Kinase C (PKC), that impairs the short-term memory and other functions in the prefrontal cortex, the executive-decision part of the brain (Birnbaum et al, 2004). Maybe that is why after conferences or maybe because of the lack of sleep, I always find these name cards in my pockets of people I have no recollection of having met. PKC is also active in bipolar disorder and schizophrenia. This enzyme might be related to impulsiveness, distraction and some of the other behavior problems we see in the classroom. In contrast, enjoyable experiences cause the release of neurotransmitters that enhance learning (Jensen, 2000).

Even more powerful, in making your brain healthy, smart, and ready to learn, is exercise, something we repeatedly underestimated until a few years ago. Our brains evolved on legs, and as Read Montague (2006) says, this makes all the difference. Our ancestors walked from 10–20 kilos a day, so it makes sense that our brains evolved to be in motion. In fact, moving makes us smarter. One study found that even gum chewing caused retention to increase up to 35%. Other studies found that infants who sit passively and watch TV, including the popular so-called brain trainer, Baby Einstein, learn fewer words than children who do other things, such as interact with their surroundings instead. They are also more likely to develop ADHD (Stamm, 2007).

There are sound physiological reasons for why our brains require our bodies to move. One is the high degree of constant interaction with our senses and muscles, what is called the embodiment of the brain (Blakeslee & Blakeslee, 2007). Another is that our brains are on fire. The human brain burns up blood–supplied glucose at ten times the rate as other body parts. Glucose, when burned, becomes glutamate and other deadly toxins. As long as our blood keeps pumping through, these neuron busters get carried away in the oxygen,
but if not, they accumulate (Ratey, 2008). Cognitive function suffers and we age prematurely. Think about how long meetings cause your brain to feel heavy and dull, and how your cognitive agility turns muddy. That is probably because of the build-up of glucose by-products.

Exercise does other things as well. It causes the release of mood-shaping neurotransmitters like dopamine, norepinephrine, and serotonin (Ratey, 2008). Even just a little exercise gives learners better focus, higher motivation, more confidence, and less impulsiveness, in other words, the ideal of classroom behavior. It also causes the release of neurotropins, like BDNF (Brain Derived Neurotrophic Factor), at two or three times the normal level. Harvard’s John Ratey calls BDNF “Miracle Gro” (a kind of fertilizer) for the brain (Campbell, 2008, p.9).

Unfortunately, we still cling to the notion that physical education classes are an “extra” and that what our kids really need to pass the tests is more class time. And yet, a study with 5000 children over a three-year period found that 30 minutes of exercise, twice a day, led to higher grades across the board, especially for girls, especially in math, an area of study that requires intense executive lobe processing (Medina, 2008, pp.24-25).

**What makes us tag certain memories for retention.**

There might not be much we can do in the classroom to increase the fundamental factors for optimal brain function, such as sleep and exercise, other than tell our learners to get as much of possible of both. Maybe of greater relevance to us are the factors that cause memories to be retained instead of lost. Here is a table of the key factors of learning I have identified, which is by no means complete. The first column shows the baseline factors for memory formation that we have already discussed. In addition to the above-mentioned “Physiological” factors, “Psychological” factors influence learner attentiveness. The next two columns show the factors that determine whether new learning is retained or not.

<table>
<thead>
<tr>
<th>Factors shaping learning</th>
<th>Brain compatibility</th>
<th>Deep processing</th>
<th>Meaningfulness</th>
</tr>
</thead>
<tbody>
<tr>
<td>- nutrition &amp; safety</td>
<td>- connected to schema</td>
<td>- multisensory input</td>
<td>- personally relevant</td>
</tr>
<tr>
<td>- peer relations</td>
<td>- surprising, novel</td>
<td>- problem-solving</td>
<td>- life problem-centered</td>
</tr>
<tr>
<td>- stress</td>
<td>- beginning and end</td>
<td>- repetition</td>
<td>- challenging, competitive</td>
</tr>
<tr>
<td>- sleep</td>
<td>- fits learning style</td>
<td>- meaningfulness</td>
<td></td>
</tr>
<tr>
<td>- exercise</td>
<td>- stories and songs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“Brain compatibility” refers to whether the incoming information is easy for our brains to process or not. We are more likely to retain information we can connect to something we already know, information that is surprising, or information delivered through a story or song rather than an explanation. In regard to the latter, think about how you learned the English alphabet. Most of us can’t even remember a new phone number, let alone 26 meaningless bits of data with a specific order. You learned the alphabet because the letters were attached to a song.

We have long known that “Deep processing” is related to deeper learning, but brain studies are giving us a better picture of how this happens. Dr. Francis Crick, of DNA fame, spent years studying how our brains operate like multiple parallel processors. It is estimated that there are so 50 processing centers in our brains all acting independently (Jensen, 2000). But if we can get them to work together, like the instruments in a symphony, then deep processing happens, causing broader neural channels to be formed, and a higher probability of retention.

Three things that cause deep processing are important for us as teachers. They are multisensory input, problem solving, repetition, and meaningfulness. As every elementary school English teacher knows, using pictures, drawing, or having children sing, dance, or act out English phrases, has a huge impact on retention. This is because they are using many parts of their brains, especially the sensory parts, to do the processing and memory formation. Problem-solving, discovery oriented–teaching, is also far more effective than learning by lecture. It doesn’t matter whether the learners get the right answer or not; it just matters that they ponder, connect the problem to what they already know, and experiment with different solutions, since this means their brains are fully engaged (Jensen, 2000). This is why task–based learning and other approaches that make learners active are so effective. Repetition causes the same neurons to fire repeatedly as well, which causes the release of dopamine and creation of new synapses. The type of repetition and timing seems to be factors as well, since both are related to enlarging and shrinking brain areas (Doidge, 2007).

The final factor, meaningfulness, is maybe the most important of the group; so important that I have made a separate column for it. Meaningfulness is also connected to the physiology of our brains. As I mentioned before, our brains evolved on legs. Unlike computers, we are not plugged into a source of constant nourishment, so we must constantly seek the things that keep us alive and help us succeed (Montague, 2006). That is why our brains evolved as they did: they are tools of survival. We are built to pay attention
to, and learn things that have personal relevance, or help us decode our environment. We are built to forget the rest. Every bit of information that comes in gets processed first by the limbic system, the emotion center, and if the amygdala determines it is important, such as something that is dangerous, the information gets tagged for retention (Goleman, 1995). Strength of retention is related to the emotional component of each memory. We lock in memories related to survival and need satisfaction, although strength of memory has little relation to accuracy. The familiar and personally relevant are also likely to be retained, but the irrelevant likely to be lost. The emotional center is actually a part of the memory system, and each memory has both an emotional and sensory component.

How drastically important this one factor is for language education. If you think about it, language is also a tool of survival. It evolved so that we can interact and bond with our neighbors, to learn from our elders, and thus to succeed as a social animal (Deacon, 1997). To me, it makes sense that in teaching language, we should take advantage of this primitive and most basic social function of language. We can see, right before our eyes, this burning need in our students to communicate with each other and bond, to share themselves with each other, and yet, in so many classes, we restrict the use of English to something very unnatural and brain incompatible: memorizing grammar rules and practicing for tests. Indeed, getting a high test score is also a need we must attend to, but one we only feel on the conscious level, whereas most of our brain processing is done on the subconscious level.

We must assume that there are better ways to raise English proficiency and test scores than the traditional means. Claims have been made about the effectiveness of extensive reading, the communicative approach, etc., but most of us are still not willing to give up grammar translation and intensive study techniques for these more innovative, brain-compatible ones. We fear peer and parental criticism, and rightly so. However, maybe there is a middle ground we can develop: using traditional intensive study techniques but modifying the method and content to be more brain friendly, such as using powerful, personally relevant stories for listening comprehension, problem-solving approaches for reading comprehension, and noticing-discovery methods of grammar study.

**Conclusions**

As the discussion above shows, brain research has uncovered many potential areas for further research in language learning. These include: 1) the effect of staying up late, sleep deprivation and naps on language acquisition; 2) the effect of physical activity or sitting
long hours in class on language acquisition; 3) the effect of discourse style (brain compatibility) on language retention; 4) the effect of personal relevance on the retention of language and information; 5) the effect of emotional reaction to content on retention, and 6) the effectiveness of interactive methods of language practice as compared to non–interactive methods. Other possible areas of work, as suggested above, include enhancing traditional approaches with brain-compatible and learner-friendly content and activities to see if those enhanced approaches are more effective.

Without a doubt, findings in neuroscience are leading to major changes in our theories and practices of language learning. We might even venture to declare that the age of designing curricula according to the structure of English is over. From now on, curricula should be designed according to the structure of the brain.

(References)