UNIT 1: DIFFERENT BRAINS

Section 1:
A brief historical note

Q: How does the brain work?

Standard neuropsychological practice often involves comparing atypical to typical brain function in order to gain insight into how parts of the brain normally work. That is, scientists study atypical functioning not simply for its own sake, but also for what it can reveal about the ways in which all people learn and develop. The basic logic, simplified, runs like this: A person can do some task, such as make good decisions. The person sustains damage to a specific region in the brain, perhaps a part of the prefrontal cortex, and now has a deficit in ability to do the task—he or she can no longer make good decisions. Scientists then draw inferences about the role of the damaged area of the brain in typical ("normal") brains, based on analyses of the deficits in the patient.

One of the earliest and best-known studies has been the subject of speculation and debate since September 1848, when Phineas Gage, the 25-year-old foreman of a crew of railroad workers in Vermont, accidentally sparked an explosion that drove a tamping iron up through his left cheek bone and out the top of his skull. The tamping iron was over three feet long and passed through his skull with such force and speed that it landed one hundred yards behind him. Shortly after the accident, Gage was conscious and able to walk, and was driven by cart to Dr. John Harlow. Gage survived, and Harlow wrote an account of the case which was met with great disbelief, as no one could believe that Gage could survive such an accident. Two years later, a second report was published by Henry J. Bigelow, professor of surgery at Harvard, who wrote that Gage was "quite recovered in faculties of body and mind."

Although his ability to reason seemed intact, his wife and friends noticed significant changes in his personality. The likable, capable, and proper young man became angry, rude, and irrational, shouting obscenities at anyone who seemed to stand in the way of his desires. In 1868, Harlow published his second account of the case, detailing all the symptoms and concluding that Gage's "mind was radically changed, so decidedly that his friends and acquaintances said he was 'no longer Gage.'"

The damage to his frontal cortex seemed to have erased many social inhibitions, and the case has

A Brief History of Neuroscience

Antonio Damasio, Kurt Fischer, Abigail Baird, and John Gabrieli take us on a brief historical journey from phrenology to Phineas Gage to the more complex neuron theory that has been derived from...

View video
provided rich fodder for over 150 years of speculation and debate

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about the specific disruptions to Gage's neural pathways. In 1994, Hannah Damasio and her colleagues at the University of Iowa used neuroimaging techniques to reconstruct Gage's skull in order to shed new light on the mystery. More recently, the research on the role of emotion in learning is informed by this case. Trauma to the prefrontal cortex, an area central to the integration of emotion and cognition, can impair the abilities to think logically, plan, and make good judgments. This discovery provided a basis for understanding that emotion and thinking are fully intertwined—an understanding with considerable implications for education. Emotion makes a fundamental contribution to thinking logically.

Although the case of Phineas Gage is extraordinary, it is not unique: Accidents and strokes have provided neuroscientists with patients suffering from all sorts of damage to different parts of the brain. Progress in understanding brain function would be less insightful and much slower without such patients. But studying atypical brain function may also result in some misunderstandings and myths about the brain. It is not difficult to imagine that associating loss of specific abilities with damage to particular parts of the brain might produce a theory of the brain as an organ composed of modules—the brain as a super-LEGO® structure—each brick responsible for a separate brain function. Jane can't speak, and she had a left-hemisphere stroke; therefore, the left hemisphere is responsible for speech; it's the speech module. In reality, brain function is the result of activity in networks that connect many regions—webs of electrical connections—not the result of isolated modules for speech or vision or some other specific activity.

Glossary

prefrontal cortex
An anatomical location in the brain referring to the anterior (front) area of the frontal lobe. Cognitive and psychological constructs typically associated with the prefrontal cortex include executive...
capacities, personality characteristics.

**frontal cortex**
An anatomical location in the brain referring to one of four lobes (frontal, parietal, occipital, temporal) that is located behind the forehead.

**neuroimaging techniques**
Neuroimaging techniques are neuroscience tools used to investigate brain structure or activity directly or indirectly. Common tools include magnetic resonance imaging (MRI), magnetoencephalography (MEG), and electroencephalography (EEG).
UNIT 1: DIFFERENT BRAINS

Section 2:
Left-right mythology

Q: What's wrong with the old metaphors about brain function?

In 1983, Howard Gardner, also studying patients with damage to different parts of the brain, published *Frames of Mind: The Theory of Multiple Intelligences* and changed the way many people thought about intelligence, teaching, and learning.

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(Opened ScienceTalk sidebar)

**Multiple Intelligences**

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Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/professor (Harvard University: Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.

To appreciate the multiple intelligences (MI) framework as proposed by Howard Gardner is to embrace the notion that individuals possess a constellation of strengths and weaknesses across the different "types" of smart. To date, Gardner's intelligences include: linguistic, logical-mathematical, spatial, musical, naturalist, bodily-kinesthetic, interpersonal, and intrapersonal. (These intelligences are described in the table below.) We have all felt enabled and adept at some tasks, whether they involved music, language, or math. But we have each felt the sting of being in situations where what was expected of us was challenging, difficult, and all the more frustrating when we were required to do it someone else's "way" rather than our own.

A key point here is that multiple intelligences describe different ways of perceiving and processing information; these are not characteristics that are inherent in a given task per se, but rather in the learner. Many tasks could be completed by drawing on different intelligences, just as many lessons can be communicated using multiple frameworks based on MI. How the mind interacts with the environment and the demands of the task at hand is relevant to every learning situation. So, rather than being concerned with how "smart" someone may be based on an IQ test, educators can better serve their students by working to figure out how they are smart.

Relating the theory of MI to the brain is more complicated. An exciting idea that may attract us to MI is that each intelligence maps onto a distinct part of the brain: The linguistic intelligence has a corresponding part in the brain, for example. However, neuroimaging research on higher-order
cognitive skills and abilities, including intelligence, so far has suggested a reliance on a system of brain regions, rather than a single spot. In order to address this topic specifically in regard to MI, a series of neuroimaging studies, which have yet to be conducted, is required. It should be noted that the intelligences identified have met the criteria related to the consequences of brain damage, but identifying the underlying systems supporting each requires further evidence about brain functioning when there is no damage. A promising hypothesis is that each intelligence relies on a distinct network of coordinated brain regions.

Until there is a deeper understanding of the relationship between how the brain is structured and how it functions in relation to intelligence and cognitive potential, MI remains a powerful idea for shaping educational thought, but not yet one about brain-behavior relationships. However, MI provides a framework for considering essential points about learners:

- A given task can be completed in more than one way, even if there is one right answer. This distinction is referred to as "process versus outcome."

- A consideration of the interaction between a person's profile of intelligences and the demands of the task yields the most helpful educational picture of his or her performance.

- The brain is not constructed into discrete modules; to think about MI in terms of "spots in the brain" would be oversimplifying the theory and the brain's functionality.

<table>
<thead>
<tr>
<th>Intelligence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linguistic</td>
<td>An ability to analyze information and create products involving oral and written language, such as speeches, books, and memos.</td>
</tr>
<tr>
<td>Logical-Mathematical</td>
<td>An ability to develop equations and proofs, make calculations, and solve abstract problems.</td>
</tr>
<tr>
<td>Spatial</td>
<td>An ability to recognize and manipulate large-scale and fine-grained spatial images.</td>
</tr>
<tr>
<td>Musical</td>
<td>An ability to produce, remember, and make meaning of different patterns of sound.</td>
</tr>
<tr>
<td>Naturalist</td>
<td>An ability to identify and distinguish among different types of plants, animals, and weather formations that are found in the natural world.</td>
</tr>
<tr>
<td>Bodily-Kinesthetic</td>
<td>An ability to use one's own body to create products or solve problems.</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>An ability to recognize and understand other people's moods, desires, motivations, and intentions.</td>
</tr>
<tr>
<td>Intrapersonal</td>
<td>An ability to recognize and understand one's own moods, desires, motivations, and intentions.</td>
</tr>
</tbody>
</table>

(Table from Davis, Christodoulou, Seider & Gardner, 2011)
Gardner succeeded in challenging and expanding the notion of intelligence and revealed the role of cultural and social bias in how different abilities are valued and developed in children. His ideas resonated with the experiences of parents and teachers, who witnessed daily the rich variety of "talent" or "intelligence" in budding poets, mathematicians, athletes, musicians, and painters. IQ tests seemed to view people through a peephole darkly. So when Gardner offered a larger vision of human potential that jibed with observation and experience, teachers and parents rushed to embrace it.

Despite the continuing importance and validity of his richer view of human skill and of the role that culture and social forces play in learning, many educators have reduced Gardner's insights to the modular model of brain functioning that influenced his theory but proved to be too simple to fully explain the richness of the different intelligences. Many persist in believing that our brains have a music module, a language module, and a math module. They do not. The result has been years of misleading talk about designing lessons for visual learners and kinesthetic learners, left-hemisphere learners and right-hemisphere learners. "Right-brainers will rule the future," declares Daniel Pink, former White House speechwriter and author of the popular book, _A Whole New Mind: Why Right-Brainers Will Rule the Future_.

Although such statements are likely meant as metaphors to suggest that those who can think creatively and emphatically will become increasingly important to businesses, they lock us into ways of thinking about brain function that reduce our understanding of the brain and, therefore, limit our ability to develop more effective models of education. This is the nature of powerful metaphors. At first, they capture our imagination and stimulate new ways of thinking about old problems; but eventually they capture us and inhibit newer insights. The left-brain/right-brain metaphor puts us into the very box out of which we encourage creative people to think.

More recent studies reveal that both hemispheres are involved in almost all cognitive tasks. Thanks to functional magnetic resonance imaging (fMRI) and other techniques like magnetoencephalography

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(MEG), we can now marvel at the cascade of neural activity that is associated with the reading of one simple word. Anders Dale and Eric Halgren have created a movie exploring the interplay of activity from different areas across the entire globe of the human brain during reading.

Tools of Neuroscience: MEG

Dr. John Gabrieli of the McGovern Institute for Brain Research at MIT describes the benefits of the MEG (magnetoencephalography), which gives us a precise measure of both the timing and location of...

View video

The more we recognize and understand the complexity of the brain, the greater will be our understanding of learning—and of the inevitability of differences in how people learn and how we might teach them.

Reading a Word

New imaging tools allow us to observe the rich array of connections between many parts of the brain involved in doing anything. Reading a word, for example, is the result not of activating a...

View video

Watching the Reading Brain in Action

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Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/professor (Harvard University; Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.

Imagine that you are shown one word on a computer screen, and that the activity in your brain is recorded over the course of a second. What might you expect to see in your brain? Would you expect just the reading part of the brain to show activation; if so, where would that be? Would you think that different parts of the brain coordinate to read the word? What sequence might different parts of the brain activate? These questions are intended to get you thinking not just about what parts of the brain are relied upon to read a word, but to consider the thinking processes that are integral as well.
When cognitive neuroscience researchers put these sorts of questions together, they are able to use cutting-edge neuroimaging technologies to answer them. Using a novel approach to record brain activations (Dale et al., 2000), the "Reading A Word" video was created by Anders Dale and Eric Halgren. The video relies on the combination of two neuroimaging technologies: MRI and MEG. MRI is an excellent tool for determining where in the brain activation occurs. In the same way, MEG is a tool best used to determine when in the brain activation occurs. Taken together, we are able to view the intricacies of the reading brain in action both in terms of time and place, by viewing the results of these technologies combined.

Take a look at the video a few times. Once you have taken in the majestic ebb and flow of brain activations in the video, consider how it compared to your ideas of what it takes to read one word as an adult. In a split second, swaths of brain regions are awash in a red and orange hue. (Of course, the brain doesn't actually light up colorfully, but scientists apply statistical analyses to brain data to create graphical depictions representing the areas with changes in brain activity, which you can't see otherwise.) As you can see, the sequence is not random: Activations begin in the back of the brain, where the visual system is largely situated, and move forward to the front of the brain where systems for articulation of a word and activating its meaning are based. In the video, we see a carefully crafted choreography of brain activations for reading even a single word. We are not born with the functional wiring to be readers; this process requires years of reading practice that goes along with the rewiring and recycling of the brain's systems for other purposes, such as vision, audition, translating between symbol systems (sounds and letters), attention, and memory. In the flash of activations seen in the video, we can easily see how involved such a seemingly simple task becomes when we peek behind the curtain that is masking the workings of the brain.

The "Reading A Word" video reveals the dynamic and distributed reading systems required to read a single word. Rather than a unidirectional, static, single stream of activation, the brain regions recruited for a single word tell a story of the brain's interactive approach to reading.

Glossary

**functional magnetic resonance imaging (fMRI)**
A neuroimaging technique using radio and magnetic waves to indirectly index brain activity relative to specific task comparisons.

**magnetoencephalography (MEG)**
A neuroimaging technique that detects the magnetic properties of electrical impulses resulting from neuronal communication to produce maps of brain activity relative to a task. MEG is used most typically for research purposes to investigate cognitive and psychological processes. The main strength of MEG is the high temporal resolution; the main limitation is the relatively limited spatial resolution. Based on these characteristics, MEG is most effective for investigating questions of timing in brain activity rather than where in the brain activity originates.
Q: Can you give me an example of how brain function is integrated across regions?

People generally believe that language is a left-brain function separate from music, which happens over on the right hemisphere. The persistence of this belief is not surprising. Research during the 1960s and into the 1990s found that patients with damage to certain areas of the left hemisphere suffered from "aphasia," the inability to speak; while those with damage to certain areas of the right hemisphere developed "amusia," the inability to process musical pitch. Although it might initially make sense to conclude that language must be a left-brain function, a closer look reveals that language recruits areas and abilities from both hemispheres, as does music. All major categories of human behavior, especially the skills that schools strive to develop in students, use multiple parts of the brain, not merely the left or right side.

Broca's area and Wernicke's area, two parts of the left hemisphere (in most people), had been thought to be exclusively responsible for the production and perception of language.

However, using functional magnetic resonance imaging (fMRI), scientists discovered activation in two overlapping areas when music was being processed: The inferior frontal gyrus and nearby premotor cortex (overlapping Broca's area) were recruited for sight-reading, while reading and listening to a score activated the supramarginal gyrus (overlapping Wernicke's area).

It seems that language areas are not "language," and music areas are not "music." Instead, the left and right hemispheres may have broader functions that are recruited across domains like language and music to support abilities in each. Both hemispheres contribute to the production and understanding of language and music. The left hemisphere seems to specialize in tasks involving hierarchical sequencing (like grammar, syntax, and meaning), and the right hemisphere seems to deal more with contour-based patterns (like melodic contour and large repeating patterns, especially with emotional significance). The contributions of the left hemisphere are less emotional—such as grammar and definitions of words. The contributions of the right are more emotional—such as the...
melody and contour that produce the affective music of language (intonations that express our intention, like sarcasm or sincerity). Broadly speaking, the left hemisphere works with the denotation of our language; the right plays with the connotation. In most people, both are essential for fully expressive communication and understanding.

Take a simple example: Two sentences have the same words, syntax, and grammar but communicate very different meanings, depending on how they are said:

"You love me."
"You love me?"

Beyond the rising inflection that distinguishes the question from the statement, speak these words with different melodies, stresses, and pitches, and each result will yield a different meaning. The emotional prosody of language, its rhythms and intonations, is neurologically related to music processing.

But there is another layer to prosody: Some languages, like Mandarin, rely on prosody for grammatical and lexical meanings; the syllable "ma," for example, has four different meanings depending on the melody with which it is pronounced (only one of which is "mother"). Because grammar and definitions tend to be left-hemisphere functions, it may be that the purpose to which prosody is put determines which hemisphere will be more heavily recruited. In most Mandarin speakers, the right hemisphere is recruited for tones communicating emotional meaning, and the left is recruited for tones communicating "denotative" meaning, such as the specific meaning of "ma."

**Glossary**

**aphasia**
An acquired disorder, most commonly the result of a stroke, which impairs a person's ability to use and or understand language in service of communication. Difficulties can extend into reading and writing skills in addition to oral language.

**amusia**
A general term referring to a collection of possible difficulties, acquired or congenital, related to music-related processing in relation to features such as rhythm, pitch, or tone.

**Broca's area**
The region of the brain functionally associated with spoken language production discovered by Paul Broca in the late 19th century. Disorders arising from damage to the left inferior frontal cortex, as classically defined, most typically involve difficulty in using language (i.e., expressive) with the preserved ability to understand (i.e., receptive) language.

**Wernicke's area**
A region of the brain functionally associated with spoken language comprehension discovered by Carl Wernicke in the late 19th century. Disorders arising from damage to left posterior temporal gyrus, as classically defined, most typically involve difficulty in language comprehension (i.e., receptive) and meaningful use of language with preserved ability in other language features such as
form and rate (i.e., expressive).

**inferior frontal gyrus**
An anatomical location in the brain referring to one of three main gyri in the frontal lobe (inferior, middle, superior).

**premotor cortex**
An anatomical location in the brain referring to a strip of cortex in the posterior (back) region of the frontal lobe that is critical for motor function.

**supramarginal gyrus**
An anatomical location in the brain's parietal lobe that, with the angular gyrus, makes up the inferior parietal lobule. This region has been shown to be critical for skills including reading.

**prosody**
Prosody refers to features of language including—including tone, stress, and pitch—which is used to communicate emotion, express sarcasm, denote types of utterances (question versus statement).
UNIT 1: DIFFERENT BRAINS

Section 4:
Succeeding with half a brain

Q: If the two hemispheres are heavily involved in virtually everything we do, what happens when one hemisphere is removed?

Two young men, Nico, an Argentine, and Brooke, an American, provide some insight into this question. Nico's right hemisphere was surgically removed when he was three to control severe epilepsy; he has become an engaging young man who enjoys fencing, art, and singing, and who has been academically and socially successful in school in Spain, where he moved with his family. Brooke's left hemisphere was removed when he was 11, also to control persistent seizures. He, too, is a charming young man who attended high school and college and works at a recycling center. What is striking about these young men is that both are able to do things that they "shouldn't" be able to do according to conventional views of the brain—such as use their remaining neural hardware to produce and understand language and its emotional meanings.

(Opened ScienceTalk sidebar)

Self in Relationships

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Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/Professor (Harvard University; Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.

Our lives are defined in large part by the relationships we have and our respective roles in each. The Self-in-Relationships Interview (SRI) is a tool to explore the dynamics of those relationships by ranking their level of importance and by assigning a positive or negative valence to each. Through the SRI, originally created by Susan Harter and Ann Monsour (1992) and revised by Kurt Fischer and Bruce Kennedy (1997), the organization of relationships in a person's life is evident from the resulting diagram of concentric circles, with most important relationships in the center circle and those of least importance in the outermost circle. Adjectives are linked to how a person feels in each relationship, such as serious, considerate, honest, or self-conscious. For example, people who perceive their relationship with their mother to be positive and most important would list this information in the inner circle. The dynamic with a souring romantic partner may be categorized as uncomfortable and least important. Relationships with parental figures, siblings, and those in daily living and school...
environments are also categorized. As the interviewees’ depiction of relationships become personalized, they capture the most salient and relevant characteristics of a person’s role in these social dynamics. The SRI provides a platform for mapping out the different sides of ourselves across relationships. It can reveal the truth behind the cliché about "being different things to different people."

In addition to providing a visual representation of an interviewee's web of individual relationships, the SRI also explores how an individual sees the connections among these relationships and how he or she describes them. Participants are asked to indicate which relationships and descriptors go together and to categorize them. These self-generated categories can include social life, ideals, or identity. (See the circled items in the SRI figure.) Next, participants mark with solid lines those categories that seem to go together and mark with dotted lines those categories in apparent conflict. Participants mark conflicting or contradictory self-descriptions with an "X" (for example, "I can be kind in this dynamic and..."
Along with Ekman's test of facial recognition and the Self-In-Relationships Interview (see sidebar above), Mary Helen Immordino-Yang designed two tests for her study of these young men's ability to understand and produce the prosody of language. One test determined how Nico's and Brooke's prosodic discrimination and comprehension compared to their peers, and one test compared the intonation patterns in their speech to that of their peers. Although the boys certainly revealed weaknesses, they generally compared favorably to their peers. How can these findings be interpreted in terms of the young men's emotional profiles? What can the results teach us about brain plasticity and development, especially in social contexts, and their relation to compensation and learning?

REFERENCES:


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Ekman's test of facial recognition
An assessment tool developed by Paul Ekman and Wallace Friesen in the 1970s to measure recognition of emotions based on facial expressions.

brain plasticity
The potential for, or ability of, neurons or brain systems to modify functionality based on experiences. The degree to which brain function can be modified is a question of high interest, particularly for addressing topics including recovery from brain damage, responsiveness to intervention, learning, and skill acquisition.

including prosody. When he was three years old, Nico suffered from life-threatening epileptic seizures and...

View video

of the brain is generally considered the locus of detailed, procedural tasks, such as language and reading....

View video
Q: How does our brain determine how we see and interact with the world?

In most people, the two hemispheres of the brain exhibit different strengths and weaknesses, and people tend to see the world through the lens of their strengths. They interpret and solve problems using these strengths to compensate for their weaknesses. Despite their significant differences, Nico and Brooke are no exception. Essentially, it seems that these boys rely on the strengths of their remaining hemisphere to meet the challenges the world presents them, such as the challenge of successfully interacting socially with their peers, especially by understanding and using the nuances of language.

Overall, Nico's and Brooke's ability to distinguish between sincere and sarcastic tones was good, and both could use these tones appropriately in their everyday conversations with others. However, neurologically, their approaches were quite different—from each other and from their more typical peers. You could hear the difference from their peers in the exaggerated and somewhat unregulated tones the boys produced, but insight into their methods of compensation was most evident in how they talked about emotions. Nico, lacking the emotional processors of the right hemisphere, tended to avoid talking with any depth about emotion, while Brooke, who retained the strengths of the right hemisphere and lacked the mediation of the left hemisphere, tended to talk excessively about emotions.

In one exercise, Nico quickly identified the speaker's tone but seemed unable to analyze the source of his judgment. When asked how he knew the speaker was joking, he responded, "How did I know that? Because I just heard it." End of discussion. Brooke, on the other hand, went to the opposite extreme, analyzing the situation thoroughly, speculating on the psychology of the speaker, and using his own experiences as sources for insight: "She was probably joking around. But I think she was serious at the same time. It's like two things at once...joking around is like, 'You don't have no homework.' [Said in a joking tone.] That's joking around. Serious is like, 'You have homework? That's a drag.' [Said in an exaggeratedly serious tone.] That's serious. So it's like a little mix."

This difference in discussing emotion was also evident in the Self-in-Relationships interview. Nico evinced little ability or willingness to talk about his emotions, though reports from his family indicate that he certainly shows them. In marked contrast, Brooke not only is willing to discuss his emotions, but also expends considerable energy dealing with them, particularly controlling negative emotions: "I put those questions away in the back of my head... I really don't want to [pull them out]... It's like a locked door... . All those things you are saying that I don't want to do, 'cause I try to hide those things. I don't open it up. That's my theory. That's why I'm always happy."

Given Nico's avoidance of emotion, it isn't surprising that in the facial recognition test this difference would again show up. Although both boys were moderately accurate at identifying emotional states from facial expressions, Nico's errors tended to follow more of a predictable pattern than did Brooke's. Nico generally
saw emotive faces as neutral, expressing no emotion.

The results of these tests suggest that the problems presented (identifying emotions in tone of voice and facial expressions and analyzing one’s own emotional state) are not the same for the two boys. The strength of Nico's left hemisphere is hierarchical sequencing or categorizing; it's good at things like grammar, syntax, and word definitions. In the absence of his right hemisphere, he is weak at processing emotional information. So, perhaps Nico approaches these tonal qualities that express emotion as “pseudogrammatical” memorized categories. That is, relying on the strength of his remaining left hemisphere, Nico is handling affective prosody like a Mandarin language speaker, effectively memorizing tones and their meanings. For him, emotion becomes, essentially, a nonemotional grammatical problem; he interprets emotional tones of voice as categorical information rather than emotional information. "How do I know she is joking? Because I just heard it." That sound equals joking, just as the word "dog" equals this animal I am patting. And he is able to call up and use the required tone when his social situation suggests joking is appropriate.

Brooke, on the other hand, uses the strengths of his remaining right hemisphere: recognizing patterns and processing and analyzing emotion. So, in solving problems, he becomes deeply immersed in the connections between emotion and tone of voice, even when the problem doesn't call for such analysis. For example, during the facial recognition test when all he had to do was label the emotion expressed in the face, Brooke adopted an exaggerated angry voice when naming the emotion on an angry face or a deeply depressed voice to label sadness. This same overreliance on his emotional processing strengths resulted in his making errors on tasks when emotional interpretation was not relevant. He was unable to move beyond looking at and looking for the emotional content in any situation. As we have seen, this hypersensitivity to emotion resulted in his needing to pay constant attention to dealing with and trying to control his own negative emotions.

Both boys, then, appear to be reinterpreting and solving problems by using their neuropsychological strengths, including emotional strengths, associated with their remaining hemisphere, rather than by adapting their remaining hemisphere to act as the missing hemisphere would have. That is, Nico and Brooke are recruiting basic processing mechanisms common to all of us, but they are using them in a new way, to solve problems that would normally be handled by different mechanisms that they lost when half their brain was removed. They are adapting the problems to suit their processing strengths. Rather than trying hard to learn to do what their brains have trouble doing, the boys appear instead to have changed how they think to suit the brains they have.

The boys do not consciously seem to know that they are making these adjustments to their thinking. The way in which their brains are organized and function is a result of their biology, experiences, and
emotional goals (their desire to interact with their peers and to successfully pursue their interests). These, in turn, determine their way of perceiving and making sense of the world and the problems it presents them. Nico and Brooke are simply more dramatic versions of all of us. We all bring certain strengths and weaknesses to our interactions with the world. Using our strengths in whatever way we can manage, we do what we need to do, mostly not knowing exactly how we are doing things.
UNIT 1: DIFFERENT BRAINS

Section 6: Implications for education

Q: How does this research apply to teachers in the classroom?

For educators, certain principles arise from the study of Nico and Brooke, principles that provide useful lenses through which to consider many fundamental, time-honored school assumptions, designs, and practices:

- All brains are different.
- One teaching style, one approach, one design will not succeed with all learners.
- What a teacher imagines will be easy can be very difficult.
- A child's brain is remarkably plastic (malleable) but inefficient; an adult's is less plastic and more efficient.

All brains are different. They develop, adapt to, perceive, and interpret the world differently. So, it's hardly surprising that learners learn in different ways. Although the recent interest in ideas like differentiated instruction reflects this truth, many people continue to cling to a view of the brain as modular (for example, kinesthetic, visual, spatial learners) and draw a distinction between "normal" and "learning-disabled" brains. This creates an impression that most people have the same brain, except for the group of students getting special services and untimed testing—this despite the insight from neuropsychology that everyone is learning-disabled to some degree.

Research suggests that our experiences, our emotional goals, social context, and particular profile of cognitive strengths and weaknesses shape our brain and determine how we perceive the world and how we approach problems. Viewed from this perspective, it seems inevitable that students frequently will not understand problems put to them by teachers in the same way in which the teachers understand them. As a result, teachers and students are often not looking at the same problem, though they may assume it is the same. So, their ways of working toward solutions will also be different—rather like the old idea that an engineer and a philosopher standing in the same engine room on a ship will not see it or think about it in the same way.

As Mary Helen Immordino-Yang writes, "This implies a need for careful attention to learners' perceptions of the educational problems put to them, as well as a need to design learning environments that support such differences. Students from different cultural and social backgrounds may well interpret the same classroom exercises in very different ways. For example, in a second-grade math class, a student was confused over the correct answer to a problem about whether a six-foot-wide car could park in a seven-foot-wide garage. No, it could not, she explained, because the driver would not be able to open the car door. Clearly, although this student's initial response was labeled incorrect, she had indeed solved the math problem correctly but had gone beyond to consider the personal perspective of the driver. While a
simple example and one that was quickly resolved, it nonetheless illustrates that this student was considering not simply numbers but practical, personal concerns in solving her math problems. (A Tale of Two Cases: Lessons for Education From the Study of Two Boys Living With Half Their Brains).

Students' comments and answers come from their perspectives, which need to be understood and respected. Taking the time and developing the skills to see problems from the point of view of learners may be teaching's greatest challenge.

Here are several important implications:

**One teaching style, one approach, one design will not succeed with all learners.** Given the almost unique nature of Nico's and Brooke's challenges, their teachers were forced to meet the young men where they were and to take their lead from the young men. In this extreme situation, the teachers had no way of predicting how Nico and Brooke would function. So, the teachers needed to study the young men without preconceptions and see what the young men could or could not do, and invent various ways of supporting and helping them to learn and develop. They could not meet Nico and Brooke with a predetermined curriculum based on some standard of "normal" functioning but, instead, had to give the young men the freedom to engage in their own learning. The teachers were not limited to a fixed curriculum with its expectations that everyone can proceed in lockstep toward standards that are based on age groupings and expectations that have been "normed" across populations scattered over an amazingly complex landscape. This freedom to match tools for learning to each young men's strengths may be a major factor in the success of these two boys.

Perhaps this research suggests a need for administrators to rethink our current school models that, like Procrustes' Inn, provide a one-size-better-fit-all bed and then stretch or chop the students to fit it. Graduation requirements, grade point average (GPA), grouping by age, course loads, expectations based on identical standards for all, narrow concepts of excellence and rigor, homework, assessment, learning disabilities—these all look very different in the light of the implications of new research. Teachers can, as they have done for decades, continue to meet the challenges of changing their methods and lessons, but their efforts must be supported by the structures and practices of the schools themselves.

As educators, school leaders belong to this community of professionals who share a responsibility to study the research and consider its implications.

Another implication arose from this research:

**What a teacher imagines will be easy can be very difficult.** Teachers often isolate low-level skills assuming that the skills will be more accessible and easier to learn. At some point, most teachers use drills—grammar, math, science, and music drills—that are intended to isolate skills for intensive, decontextualized practice. One of Immordino-Yang's tests involved pitch contour matching, which asked Nico and Brooke simply to listen to two short phrases with the same number of syllables but different intonation (primarily rising and falling pitches). Using nonsense syllables ("na na"), the boys were asked to match the original pattern. "How are you?" "Na na na?"

Immordino-Yang expected that Brooke, with his intact right hemisphere, would perform well and that Nico would struggle a bit. Instead, Brooke performed significantly worse than his peers, while Nico performed significantly better than his peers. Given these results on a "simple" test, it seemed unlikely that Brooke
would perform well on the subsequent, more "difficult" task of recognizing sarcasm in various real-life stories. Yet, he performed extremely well, leading the researchers to recognize the importance of context for interpretation.

In this case, the social and emotional context of the real-life events producing sarcasm (the stories in the subsequent tests) played to Brooke's strengths, while the decontextualized matching of tones using nonsense sounds offered no meaningful clues to feed his mind. On the other hand, Nico's more emotionless "grammatical" approach jibed nicely with the emotionless task of the "simple" (na na) test. So, for Nico and the "teacher," the nonsense task was simpler; for Brooke, it was more difficult. In a classroom situation, it is likely that the boys' grades would reflect the teacher's preconceptions and expectations: a good grade for Nico, a poor one for Brooke.

This example suggests that teachers need to be very careful when separating skills from the contexts in which we typically use them and equally careful to search individual performance for clues as to how the student perceives and approaches the problem. Simple may not always be simple, even if that's the intention. Some students may be more able to perform a skill in a complex context than to perform it in a stripped-down context. Brooke needed the emotional context to make sense of similarity between vocal tones.

The example also suggests one reason for teachers to consider student responses to problems as data rather than simply reflections of correct or incorrect answers. Data are sources of insight that can be inferred through careful thought and analysis. Correct and incorrect answers tend to be treated as results that can be judged and assigned a grade that accurately captures understanding or ability. Had the researchers simply "graded" Nico and Brooke's responses to the contour-matching task (above the norm and below the norm), they would not have developed their insights into how each boy's brain was processing information. Grading often misses the point about a student's strengths and weaknesses. Teachers and learners need insight, not a GPA.

Here is another implication:

**A child's brain is remarkably plastic (malleable) but inefficient; an adult's brain is less plastic and more efficient.** It was this plasticity that enabled Nico's and Brooke's brains to adapt to trauma; adults suffering dramatic brain damage are less fortunate. A child working through a math problem might run up and down a maze of neural pathways playing with solutions, deciding what information might be relevant, while an adult has developed clear avenues that zip toward a solution past old pathways that have been closed off and forgotten.

Perhaps this difference offers some insight into the difficulty many teachers have imagining what is happening inside a child's mind and into the impatience many teachers feel as they watch children struggle to find the well-worn path that seems so obvious to teachers. If so, it suggests that teachers could benefit from focusing less on answers, less on the what, and more on how and why different students grapple with problems as they do. There are many paths up the mountain. Each student has to grow a new neural network that builds on a good way for him or her to climb the mountain. The more of these possible pathways teachers know, the less likely that students will become lost.

**Glossary**

**Procrustes' Inn**
In Greek mythology, Procrustes was a son of Poseidon, who physically attacked people by tying them to an iron bed and stretching them or hacking off their legs to make them fit. When something is "Procrustean," different lengths or sizes or properties are fitted to an arbitrary standard.
UNIT 1: DIFFERENT BRAINS

Section 7: Resources


