

Chapter 12: Language, Attention, and Decision-Making

Summary

Talking, paying attention, and making choices feel effortless, but each depends on networks of brain areas working together. This chapter covers the classic language areas, the modern network view of language, and the kinds of aphasia that strokes cause. It then explains why language usually leans on the left hemisphere, what split-brain patients revealed, how attention works and fails (as in neglect), and how executive function and a dopamine prediction-error signal guide decisions. It ends at the bedside with two stroke patients who lost language in very different ways.

Concepts Covered

1. Language Areas
2. Broca's Area
3. Wernicke's Area
4. Aphasia
5. Hemispheric Lateralization
6. Split-Brain Studies
7. Attention
8. Executive Function
9. Decision-Making
10. Reward Prediction Error
11. Neglect Syndrome

Prerequisites

- Chapter 1: Neurons, Glia, and the Nervous System
- Chapter 2: The Action Potential
- Chapter 3: Synapses and Neurotransmitters (especially dopamine)
- Chapter 4: A Tour of the Brain: Neuroanatomy (lobes, corpus callosum, prefrontal cortex)
- Chapter 9: Learning, Memory, and Neuroplasticity (working memory and plasticity)

Welcome to the talking, thinking, choosing brain



I'm a sea slug with about 20,000 neurons, and I can't say a single word. You, on the other hand, are reading this sentence, deciding whether it's worth your attention, and choosing whether to keep going. In this chapter you'll learn which brain networks make that possible, and how doctors use a patient's speech to find exactly where a stroke happened.

12.1 Two Ways to Lose Your Words

Maya, 16, volunteers on Saturday mornings at a rehabilitation hospital, partly to see real neurology while she studies for the Brain Bee. This week she meets two patients who both had a stroke in the past month.

The first, a retired bus driver, seems to understand almost everything Maya says. He laughs at her jokes and nods when she offers water. But when he tries to tell her about his grandson, the words come out one at a time, with long, painful pauses: "Grandson... soccer... goal. Good." He knows what he wants to say. He just can't get it out.

The second, a retired librarian, is the opposite. She talks easily, in long sentences with normal rhythm. But the sentences don't make sense: "Oh, the tarvels came by this morning, and I told them the window was very orange about it." When Maya asks her to point to the door, she smiles and points at the ceiling. She doesn't seem to notice anything is wrong.

How can one person understand every word but be unable to speak, while another speaks fluently but makes no sense? By the end of this chapter, you'll answer that the way a neurologist would: by listening carefully and working out *where* in the brain each problem lives.

12.2 Intuition First: Language Is a Team Sport

Before naming any brain areas, picture a busy restaurant.

- A **server** listens to each customer's order and figures out what they actually want, even if they mumble or use odd words.
- A **kitchen line** takes the order and builds the meal step by step, in the right sequence.
- A **pass-through window** connects the two, so orders can go back and forth quickly.
- A **manager** watches the whole room, decides which tables need attention first, and keeps the plan on track when something goes wrong.

Now break one piece. Damage the kitchen line, and the server still understands orders, but meals come out slowly with pieces missing. Damage the server, and the kitchen keeps cooking at full speed, but cooks the wrong things, and nobody notices. Block the window, and both sides work, but passing an order through exactly as given becomes hard.

That's surprisingly close to how language works in the brain. Maya's two patients have damage to different parts of the "restaurant." The manager stands for attention and executive function, which come later in the chapter.

12.3 The Language Areas

Language areas are the regions of the brain, mostly in the cerebral cortex, that work together to understand and produce language, whether spoken, written, or signed. The first two were found in the 1860s and 1870s by doctors who studied patients after brain injuries.

Broca's area: building speech

In 1861, the French surgeon Paul Broca described patients who had lost the ability to speak after an injury to the lower back part of the left frontal lobe. His most famous patient, Louis Victor Leborgne, was nicknamed "Tan" because "tan" was the only syllable he could produce. Yet Leborgne seemed to understand what people said to him.

Broca's area is the region in the inferior (lower) frontal gyrus of the language-dominant hemisphere, usually the left, that helps plan and produce speech. It lies close to the motor areas that control the mouth and face, and it's usually described as two small regions called

Brodmann areas 44 and 45. In our restaurant, it's part of the kitchen line, assembling words and grammar into an ordered sequence the body can say out loud.

Wernicke's area: making sense of speech

In 1874, the German neurologist Carl Wernicke described a different kind of patient. These people spoke fluently but made little sense, and they had great trouble understanding others. Their damage was in the back part of the left temporal lobe, near the areas that process sound (you met the auditory cortex in Chapter 6).

Wernicke's area is the region in the posterior (back) part of the superior temporal gyrus of the language-dominant hemisphere, usually the left, that helps link the sounds of words to their meanings. It's the server in our restaurant. Even today, researchers don't fully agree on its exact borders. Some include nearby parts of the parietal lobe.

The bridge between them

A bundle of axons called the **arcuate fasciculus** arches from the back of the temporal lobe toward the frontal lobe. For more than a century it was taught as the "pass-through window" between Wernicke's and Broca's areas, and damage to it was blamed for trouble repeating words. Modern research has made this picture more complicated.

This table summarizes the three classic parts.

Structure	Where it is	Classic job	Restaurant role
Broca's area	Left inferior frontal gyrus (frontal lobe)	Planning and producing speech and grammar	Kitchen line
Wernicke's area	Left posterior superior temporal gyrus (temporal lobe)	Linking word sounds to meanings	Server
Arcuate fasciculus	White-matter bundle arching between them	Connecting sound to speech output	Pass-through window

Both areas get their blood from branches of the **middle cerebral artery**. A clot in one branch can damage Broca's area, while a clot in another can damage Wernicke's area. That's why strokes can take away language in such different ways.

The modern view: language is a network

The Broca-and-Wernicke story is a great starting map, but three findings changed how scientists think about language.

First, in 2007, a team led by Nina Dronkers used high-resolution MRI to re-examine the preserved brains of Broca's two original patients. Their damage reached much deeper than the surface area Broca described, so today's "Broca's area" doesn't perfectly match the damage in Broca's own patients ([Dronkers et al., 2007](#)).

Second, in 2007, researchers Gregory Hickok and David Poeppel proposed a **dual-stream model** of speech. In this model, a *ventral* (lower) stream running through the temporal lobe handles understanding what speech means. A *dorsal* (upper) stream connects sounds to the frontal areas that control speaking. The ventral stream works in both hemispheres, while the dorsal stream depends strongly on the left. A 2018 study of stroke patients found that problems with the motor side of producing speech mostly followed dorsal-stream damage, while problems understanding speech were more linked to the ventral stream. Tasks like naming objects or repeating sentences needed both. The same study found that patients with damage in different places could show similar problems, because each task relies on a wide network ([Fridriksson et al., 2018](#)).

Third, language isn't only about sound. In a 1996 study of 23 deaf sign-language users with damage to one side of the brain, left-hemisphere damage disrupted signing much more than right-hemisphere damage, the same pattern seen in speakers ([Hickok, Bellugi, and Klima, 1996](#)). The left-hemisphere network seems to handle language itself, not just hearing and moving the mouth.

Areas are hubs, not boxes



I like to think of Broca's and Wernicke's areas as busy hub stations in a subway map, not as sealed boxes. Damage to a hub disrupts a lot of traffic, but the trains also depend on the tracks (white matter) and on stations that never made it into the old textbooks.

12.4 Aphasia: When Language Breaks

Aphasia is a language disorder caused by damage to the parts of the brain that handle language. It can affect speaking, understanding, reading, and writing, and in deaf signers it can affect sign language too. It's not a hearing problem, a muscle problem, or a loss of intelligence. People with aphasia usually know what they want to say and still think clearly. Their access to language is what's damaged.

Aphasia is common. The National Institute on Deafness and Other Communication Disorders (NIDCD) reported in 2025 that about 2 million people in the United States live with aphasia, citing the National Aphasia Association. Stroke is the leading cause, and about one in three stroke survivors has aphasia. Head injuries, brain tumors, brain surgery, and brain infections can also cause it.

The vocabulary of a language exam

Before comparing the types of aphasia, you need five terms that doctors and speech-language pathologists use when they listen to a patient.

- **Fluency:** whether speech flows in normal-length phrases with normal rhythm. *Nonfluent* speech is slow, effortful, and broken into short pieces.
- **Telegraphic speech:** speech that leaves out small grammar words like "the," "is," and "of," like an old-fashioned telegram ("Walk dog. Park. Rain.").
- **Paraphasia:** a word error. A *phonemic* paraphasia swaps sounds ("wishdasher" for "dishwasher"). A *semantic* paraphasia swaps in a related word ("table" for "chair").
- **Neologism:** a made-up word that the listener can't recognize ("the tarvels came by").
- **Comprehension and repetition:** how well the person understands what others say, and how well they can repeat a sentence back word for word.

Comparing the major types

Now we can sort the major types of aphasia using three simple questions: Is speech fluent? Is comprehension good? Can the person repeat?

Type	Fluent?	Comprehension	Repetition	Typical speech	Classic damage site
Broca's (nonfluent)	No	Relatively good	Poor	Short, effortful, telegraphic; person is aware and often frustrated	Left frontal lobe, around Broca's area
Wernicke's (fluent)	Yes	Poor	Poor	Long, smooth sentences with paraphasias and neologisms; person often unaware of errors	Left posterior temporal lobe, around Wernicke's area
Conduction	Yes	Relatively good	Very poor	Fluent with sound errors; person notices and tries again and again to fix them	Classically the arcuate fasciculus region (now debated)
Global	No	Poor	Poor	Very little speech at all	Large areas of the left language network
Anomic	Yes	Good	Good	Normal sentences,	Can follow damage in

Type	Fluent?	Comprehension	Repetition	Typical speech	Classic damage site
				but frequent trouble finding the right word	many parts of the network

A few details help these types make sense:

- **Broca's aphasia** often comes with weakness on the *right* side of the body. The left frontal lobe also contains motor areas, and each hemisphere controls the opposite side of the body (Chapter 4).
- In **Wernicke's aphasia**, the person can't understand language well, including their own speech, so they often don't realize their sentences make no sense.
- **Conduction aphasia** was once explained simply as a broken pass-through window. Newer studies suggest damage to nearby cortex may matter as much as the fiber bundle itself.
- The table is a simplified map, not a complete list. It leaves out rarer types, such as the **transcortical** aphasias, in which repetition is surprisingly spared, and NIDCD also lists mixed and unspecified forms. Many real patients don't fit neatly into one box.
- **Primary progressive aphasia** isn't caused by a sudden injury. It's an early sign of a slowly worsening brain disease, such as a form of dementia, so the language problems grow over time. (Chapter 13 covers dementia and other neurodegenerative diseases.)

Three questions sort most aphasias



When you meet an aphasia case in the Brain Bee, ask the same three questions every time: Is the speech fluent? Does the person understand? Can they repeat? Those three answers narrow the list fast, and they usually point toward the front or back of the language network. Real patients can be messier than the textbook types.

Try it: sort the speech samples

Now you be the clinician. The MicroSim below shows ten short speech samples written for this book, each with a one-line clue about comprehension or repetition. Decide which category each fits.

Diagram: Aphasia Sorter

Aphasia Sorter

Read the speech sample and the clue, then choose: Broca's, Wernicke's, Conduction, or Normal.

Item 1 of 10 Score: 0 / 0

SPEECH SAMPLE
(Describing a picture of a park) "Dog... run. Ball... man... throw. Tree."

Clue: Points to the right picture when asked "Which one is the umbrella?" His right hand is weak.

Ask yourself: Is the speech fluent? Does the person understand? Can they repeat?

Broca's Wernicke's Conduction Normal

Next Restart

Aphasia Sorter: a classification game. Each round shows a short original speech sample and a clue about comprehension or repetition. The learner sorts it as Broca's aphasia, Wernicke's aphasia, conduction aphasia, or

Screenshot of the interactive simulation. Try it online: <https://aaryavvatts-lab.github.io/neuroscience-textbook/sims/ch12-aphasia-sorter/>

Open the Aphasia Sorter fullscreen

MicroSim specification: Aphasia Sorter

Type: microsim **sim-id:** ch12-aphasia-sorter

Library: p5.js

Status: implemented

Bloom Level: Analyze

Bloom Verb: classify

Learning Objective: The learner will classify short speech samples as Broca's aphasia, Wernicke's aphasia, conduction aphasia, or normal speech, using fluency, comprehension, and repetition, scoring at least 8 of 10.

Canvas: width-responsive; 560 px drawing area plus 85 px control area (iframe 647 px).

Controls: four category buttons (Broca's, Wernicke's, Conduction, Normal), Next, and Restart.

Behavior: 10 original items (3 Broca's, 3 Wernicke's, 2 conduction, 2 normal), shuffled at start and on Restart. One answer per item; feedback says "Correct" or "Not quite," names the right category, and explains the clue. A running score is shown, and a summary after item 10 reports whether the learner reached 8 of 10.

As you play, notice *which clue* settles each item. Fluent but meaningless speech with poor comprehension points to Wernicke's aphasia. Slow, telegraphic speech with good comprehension points to Broca's. Fluent speech with good comprehension, but repetition that falls apart, points to conduction aphasia.

Watch out for the "normal" samples. Healthy people say "um" and pause all the time. What matters is the overall pattern of fluency, meaning, comprehension, and repetition.

12.5 Hemispheric Lateralization: Why Language Leans Left

Your two cerebral hemispheres look almost like mirror images, but they don't do exactly the same jobs. **Hemispheric lateralization** is the tendency for some brain functions to depend more on one hemisphere than the other. Language is the classic example.

Think of handwriting: most people could write with either hand, but one hand is much better at it. Similarly, both hemispheres contribute to language, but in most people the left does the heavy lifting for producing words and grammar.

How often is the left hemisphere dominant? In a 2000 study, German researchers tested 326 healthy people with functional transcranial Doppler ultrasound, which tracks blood flow

to each side of the brain while a person silently thinks of words (Knecht et al., 2000). The results depended on handedness:

Group	Share with <i>right</i> -hemisphere language dominance
Strong right-handers	4%
Ambidextrous people	15%
Strong left-handers	27%

So left-hemisphere language is the rule for most people, but not everyone. Most left-handers are still left-dominant for language, yet a sizable minority are not. That's why a doctor can't assume which side handles language just by looking at which hand a person writes with.

Lateralization is also a matter of degree. Remember the dual-stream model: the ventral stream for understanding speech works in both hemispheres, while the dorsal stream for producing speech leans strongly left. The right hemisphere still contributes to understanding. It just isn't usually the main driver of speech output.

There are no left-brained people



Lateralization is about which hemisphere leads on a specific task, not about personality. Calling someone "left-brained" (logical) or "right-brained" (creative) is a pop-psychology myth, because almost every real task, including math and art, uses networks in both hemispheres.

12.6 Split-Brain Studies: Two Hemispheres, One Person

The two hemispheres normally share information constantly through the **corpus callosum**, the thick band of axons you met in Chapter 4. It's the main highway between the hemispheres. What happens if that highway is cut?

For a small number of people with severe epilepsy that medicines can't control, surgeons perform a **corpus callosotomy** as a last resort, cutting the corpus callosum so seizures spread less easily between hemispheres.

Split-brain studies are experiments on people whose corpus callosum has been cut, designed to test what each hemisphere can do on its own. Beginning in the early 1960s, Roger Sperry, Joseph Bogen, and Michael Gazzaniga developed clever ways to send information to just one hemisphere.

The trick uses the visual pathway from Chapter 5. If a person stares at a central dot, a picture flashed briefly to the *left* of the dot reaches only the *right* hemisphere, and one flashed to the *right* reaches only the *left* hemisphere. Here's what split-brain patients did.

What the patient experienced	Which hemisphere got the information	Could they say what it was?	Could they show what it was?
Picture flashed in the right visual field	Left	Yes, they named it	Yes
Picture flashed in the left visual field	Right	No, they often said they saw nothing	Yes, the left hand could pick out the matching object
Object felt with the left hand, out of sight	Right	No	Yes, by choosing it again by touch

In these patients, the left hemisphere controlled speech. The right hemisphere clearly *knew* what it had seen, because it guided the left hand to the right object. It just couldn't put the answer into words, and with the corpus callosum cut, it couldn't pass the answer to the left hemisphere.

Roger Sperry received half of the 1981 Nobel Prize in Physiology or Medicine "for his discoveries concerning the functional specialization of the cerebral hemispheres." David Hubel and Torsten Wiesel shared the other half for their work on the visual system, which you read about in Chapter 5.

Later studies found that some information can still pass between the hemispheres by other routes, so the "two separate minds" picture is more complicated than early textbooks suggested. Split-brain patients are also a small, special group whose brains had lived with severe epilepsy before surgery.

12.7 Attention: The Brain's Spotlight

Back at the hospital, Maya notices something about herself. When she's focused on what a patient is saying, she completely tunes out the beeping monitors and the TV in the hallway. But when someone across the room says her name, she hears it instantly.

Attention is the brain's ability to select some information for deeper processing while ignoring the rest. A useful analogy is a spotlight on a dark stage. Whatever falls inside the beam gets processed in detail. Things outside it are processed much less, or not at all.

The brain needs a spotlight because your senses send far more information than you could ever think about at once. Attention is how the brain chooses.

The spotlight's limits can be startling. In a 1999 experiment by Daniel Simons and Christopher Chabris, people counted basketball passes in a video while a person in a gorilla suit walked through the scene. About half of all the viewers never noticed the gorilla. This is called **inattention blindness**: failing to see something in plain view because attention is busy elsewhere.

Where attention lives

Attention isn't in one spot. Brain-imaging and stroke studies point to networks that link the frontal and parietal lobes:

- A **dorsal (upper) attention network** lets you aim your spotlight on purpose, like when you look for a friend in a crowd.
- A **ventral (lower) attention network**, which leans toward the right hemisphere, grabs your spotlight when something unexpected and important happens, like hearing your name.

The myth of multitasking

When people switch back and forth between tasks, researchers measure a **switch cost**: right after a switch, people respond more slowly and usually make more errors. Preparing ahead shrinks the cost but doesn't erase it. For demanding tasks, "multitasking" is really rapid switching. When Maya texts while studying for the Brain Bee, she pays that price over and over.

12.8 Neglect Syndrome: Losing Half of the World

Neglect syndrome (also called hemispatial neglect) is a condition, usually after a stroke, in which a person fails to notice or respond to things on one side of space, even though their eyes and the visual pathway still work. It's most common and most severe after damage to the *right* hemisphere, especially the lower part of the parietal lobe, and it affects the *left* side of space.

A person with left neglect might:

- eat only the food on the right half of the plate, then say they're still hungry
- shave or put makeup on only the right side of the face
- bump into door frames on the left
- ignore someone standing on their left and talking to them
- insist nothing is wrong, because they're unaware of the problem (a symptom called **anosognosia**)

Neglect is not blindness. In **hemianopia**, damage to the visual pathway cuts off vision on one side (Chapter 5). In neglect, visual information reaches the brain normally, but the attention system doesn't "light it up." A person with hemianopia usually knows they can't see one side; a person with neglect often doesn't realize half the world is missing.

Why the right hemisphere? One explanation is that the right hemisphere attends to both sides of space, while the left mostly handles the right side. Damage on the left leaves the right to cover both sides, but damage on the right leaves nothing fully covering the left. The right-leaning ventral attention network also plays a role.

Doctors check for neglect with simple pencil-and-paper tests:

Test	What the patient does	What neglect looks like
Line bisection	Marks the middle of a horizontal line	Mark lands well to the right of center
Cancellation	Crosses out every small line or letter on a page	Targets on the left side are missed
Clock drawing	Draws a clock face with all the numbers	Numbers crowded onto the right half

Therapies such as prism adaptation (wearing prism glasses that shift the visual world during practice tasks) have been studied, and some patients improve. Researchers still consider the evidence limited, and many people recover some attention to the neglected side naturally in the weeks and months after a stroke.

12.9 Executive Function: The Brain's Manager

Remember the restaurant manager from Section 12.2? The manager doesn't cook or take orders, but sets goals, decides what matters most, stops unwise moves, and changes the plan when things go wrong.

Executive function is the set of mental skills that let you control your own thinking and behavior to reach a goal. Psychologist Adele Diamond describes three core executive functions:

1. **Inhibition:** stopping an automatic or tempting response (not blurting out an answer, or not checking your phone during practice), and filtering out distractions.
2. **Working memory:** holding information in mind and working with it, like keeping a phone number in your head while you dial (see Chapter 9).
3. **Cognitive flexibility:** switching between rules or points of view, like changing your soccer strategy when the other team changes theirs.

These core skills combine into planning, problem-solving, and reasoning. They depend heavily on the **prefrontal cortex** at the front of the frontal lobe, working with the anterior cingulate cortex, which helps detect errors, and with deeper structures.

Psychologists measure executive function with tasks like these:

- **Stroop task:** name the ink color of the word "RED" printed in blue ink, which requires inhibiting the urge to read the word.
- **Wisconsin Card Sorting Test:** sort cards by a hidden rule that secretly changes. People with frontal-lobe damage often keep using the old rule, a problem called **perseveration**.
- **Tower of London:** move colored balls into a goal pattern in as few moves as possible, which requires planning.

You met Phineas Gage in Chapter 4. After an iron rod shot through his skull in 1848, damaging mainly his left frontal lobe, people who knew him reported big changes in his self-control and planning. His case was an early hint that the frontal lobes support executive function.

According to the National Institute of Mental Health, the brain finishes maturing in the mid-to-late 20s, and the prefrontal cortex is one of the last areas to mature (Chapter 8).

Executive function suffers from stress, lack of sleep, loneliness, and lack of exercise, and it can improve with practice.

12.10 Decision-Making and Reward Prediction Error

Some decisions are small, like which snack to grab. Some are big, like whether to go to a party the night before a test. **Decision-making** is the process of choosing between options by weighing their expected costs and benefits. It draws on everything in this chapter so far: attention picks which options you notice, executive function holds them in mind and keeps impulses in check, and value signals in the brain help you compare them.

The ventromedial prefrontal cortex: feeling the future

The **ventromedial prefrontal cortex** (the lower, middle part of the prefrontal cortex, just above the eyes) seems especially important for decisions about reward and risk. University of Iowa researchers tested people with damage here using a card game. Some decks paid big rewards right away but led to bigger losses over time; others paid less but came out ahead.

Healthy volunteers tended to shift away from the "big win, bigger loss" decks. People with ventromedial prefrontal damage kept choosing them, even as their losses grew. The

researchers described it as a kind of "myopia for the future": these patients were guided mainly by what happened right now, not by what would happen later.

Reward prediction error: learning from surprise

How does the brain learn which choices pay off? A big part of the answer is a signal carried by dopamine neurons in the midbrain (you met dopamine in Chapter 3).

Intuition first. Maya's coach usually brings oranges to practice. One day the coach brings pizza instead, and Maya is delighted. The next week, pizza again: she's happy, but less surprised. By the fifth week, pizza is just what happens at practice. Then one week the coach brings nothing, and she's disappointed, even though she's no worse off than a month ago.

What drives her feelings isn't the reward itself. It's the gap between what she expected and what she got. Neuroscientists call that gap a **reward prediction error**: the difference between the reward you actually receive and the reward you predicted.

$$\text{reward prediction error} = \text{reward received} - \text{reward predicted}$$

Wolfram Schultz recorded dopamine neurons in monkeys and found that they fire in a pattern matching this equation. A 1997 paper by Schultz, Peter Dayan, and Read Montague linked these recordings to mathematical theories of learning.

Situation	Prediction error	What dopamine neurons do	What the brain learns
Better than expected (surprise pizza)	Positive	Fire a burst above their normal rate	"Do that again"; raise the prediction
Exactly as expected (pizza for the fifth week)	Zero	Stay at their normal baseline rate	Nothing new to learn
Worse than expected (no snack at all)	Negative	Dip below their normal rate	"That didn't pay off"; lower the prediction

The equation is simpler than it looks



If equations make you nervous, just remember "surprise = got minus expected." Positive surprise, dopamine bursts; no surprise, nothing changes; negative surprise, dopamine dips. That's the whole idea.

Something else changes with learning. Once a cue reliably predicts the reward (say, seeing the coach's car pull up with pizza boxes), the dopamine burst moves from the reward itself to the earliest cue that predicts it. The reward has become expected, but the cue is now the surprise. This pattern was first recorded in monkeys and has since been found in rodents and humans (Schultz, 2016).

This signal works like a teacher. After each prediction error, the brain updates its expectations a little, so future predictions improve. Reward prediction errors help explain why a reward stops feeling exciting once it's routine, and why drugs of addiction are so powerful: they hijack and amplify the dopamine signal (Chapter 15).

At the Bedside: Two Strokes, Two Kinds of Silence



Meet the patients

Patient 1: Mr. Alvarez, 66, a retired bus driver, suddenly couldn't speak more than a word or two at a time during breakfast. His wife noticed his right hand was clumsy and the right side of his face drooped. She called 911 right away. In the emergency department he nods correctly to yes-or-no questions and follows commands like "close your eyes," but when he tries to answer questions he says things like "Wife... car... hospital," and he looks frustrated.

Patient 2: Mrs. Chen, 71, a retired librarian, was brought in by her son after she started "talking nonsense" during a phone call. She speaks quickly and confidently, with normal rhythm, but uses odd and made-up words. She has no weakness. When the doctor asks her to point to the window, she smiles and touches her watch. She doesn't seem worried at all.

What the doctor checks: A stroke team works fast, because the sooner blood flow returns, the more brain tissue can be saved. The neurologist checks strength, face, vision, and sensation, then does a quick bedside language exam built on the three questions from Section 12.4: listening to spontaneous speech (fluency), giving spoken commands

(comprehension), and asking the patient to repeat a sentence (repetition). An emergency CT or MRI scan shows whether a blocked artery or bleeding caused the stroke, and where. A speech-language pathologist later does a detailed evaluation.

Where is the problem? (localization): Mr. Alvarez has nonfluent, telegraphic speech, relatively good comprehension, poor repetition, awareness of his errors, and *right*-sided face and arm weakness. Nonfluent speech plus right-sided weakness points to the *left frontal lobe*, around Broca's area and the nearby motor cortex. That area is supplied by the upper branch of the left middle cerebral artery. Mrs. Chen has fluent speech full of paraphasias and neologisms, poor comprehension, poor repetition, no weakness, and little awareness of the problem. That pattern points to the *left posterior temporal lobe*, around Wernicke's area, supplied by the lower branch of the left middle cerebral artery. It's far from the motor cortex, which explains why she isn't weak.

Diagnosis: Mr. Alvarez: ischemic stroke in the left frontal lobe causing Broca's (nonfluent) aphasia with right-sided weakness. Mrs. Chen: ischemic stroke in the left posterior temporal lobe causing Wernicke's (fluent) aphasia.

Why it happens: Language depends on a left-leaning network. The frontal part, including Broca's area and the dorsal stream, turns plans into ordered speech. Damage there leaves understanding mostly intact but makes speaking slow and broken. The temporal part, including Wernicke's area and the ventral stream, links sounds to meanings. Damage there lets speech keep flowing but strips away meaning, both in what the person hears and in what they say, so they often don't notice their own errors.

Treatment today: For an ischemic stroke, emergency care aims to restore blood flow as fast as possible. For eligible patients, that can mean a clot-dissolving medicine given within a few hours of symptom onset, or a procedure called thrombectomy, in which a doctor threads a thin tube through an artery to pull out a clot in a large brain vessel. Doctors also work to prevent another stroke. For the aphasia itself, the main treatment is **speech-language therapy**. A 2016 Cochrane review of 57 randomized trials found that, in the trials comparing therapy with no therapy, therapy improved everyday communication. Many people improve a lot in the first few months, and gains can continue for years. Families learn to help by using short sentences, giving the person time to talk, and welcoming gestures, drawing, and pointing.

What's new in research: A 2017 randomized trial in *The Lancet* (FCET2EC) tested intensive therapy long after a stroke. It enrolled 158 people aged 70 or younger who had had aphasia

for at least six months, at 19 centers in Germany. Those who received at least three weeks of intensive speech-language therapy, at least 10 hours per week, improved their everyday verbal communication, while those whose therapy was delayed did not. The results suggest that language can still improve with enough practice long after the first months of recovery (Breitenstein et al., 2017).

? Your turn: diagnose a variation ✓

Mr. Okafor, 70, had a stroke yesterday. He speaks fluently, understands questions, and repeats sentences perfectly. But at lunch he eats only the food on the right side of his tray. When the nurse stands on his left and says hello, he doesn't turn. When asked to draw a clock, he crowds all twelve numbers into the right half. His left arm is weak, but he insists he's "fine" and doesn't need help. Where is the stroke, and what is this syndrome?

Answer: This is **neglect syndrome** (left hemispatial neglect), most likely from a stroke in the *right* hemisphere, especially the right parietal lobe. His language is normal because the left-hemisphere language network is undamaged. The left arm weakness also fits right-hemisphere damage, since each hemisphere controls the opposite side of the body. His belief that he's fine is anosognosia, which is common in neglect. It's not blindness: the visual information reaches his brain, but his attention system doesn't light up the left side of space.

This is a fictional teaching case. It is not medical advice. If you or someone you know has symptoms like these, talk to a doctor.

Common Misconceptions

Myth: Multitasking makes you more productive.

Reality: For demanding tasks, the brain mostly switches rapidly between them. Each switch costs time and accuracy, so finishing one task before starting another is often faster and more accurate.

Myth: Language lives only in the left hemisphere, for everyone.

Reality: Most people are left-dominant for language, but in one study about 4% of strong right-handers and 27% of strong left-handers were right-dominant. The right hemisphere also helps with understanding speech.

Myth: Some people are "left-brained" (logical) and others are "right-brained" (creative).

Reality: Lateralization describes which hemisphere leads on particular tasks, not

personality types. Real thinking, whether math, music, or art, draws on networks in both hemispheres.

Myth: People with aphasia have lost their intelligence.

Reality: Aphasia damages access to language, not intelligence. Many people with aphasia know exactly what they want to say. Treating them as less intelligent is both wrong and hurtful.

Myth: A person with neglect is just blind on one side.

Reality: In neglect, visual information still reaches the brain; the problem is attention. That's why a person with neglect often doesn't realize anything is missing.

Brain Bee Practice

? 1. A patient speaks in short, effortful phrases like 'Walk... dog... park,' understands simple questions, and has a weak right arm. What type of aphasia is this, and which lobe is most likely damaged? ✓

This is Broca's (nonfluent) aphasia, most likely from damage to the left frontal lobe around Broca's area. The right arm weakness fits, because the left frontal lobe also contains motor areas that control the right side of the body.

? 2. What is the key difference between Wernicke's aphasia and conduction aphasia? ✓

Both are fluent, but comprehension is poor in Wernicke's aphasia and relatively good in conduction aphasia. Conduction aphasia stands out for very poor repetition, with sound errors the person tries to correct.

? 3. In a split-brain patient, a picture of a key is flashed to the left visual field. What can the patient do, and why? ✓

The patient usually can't name the key, but the left hand can pick it out from a group of objects. Only the right hemisphere saw it; it can guide the left hand but can't speak, and the cut corpus callosum keeps it from telling the left hemisphere.

? 4. Damage to which hemisphere most often causes neglect syndrome, and which side of space is ignored? ✓

Damage to the right hemisphere, especially the parietal lobe, most often causes neglect. The person ignores the left side of space.

? 5. Define reward prediction error and describe what dopamine neurons do when a reward is better than expected. ✓

A reward prediction error is the difference between the reward received and the reward predicted. When a reward is better than expected (a positive prediction error), midbrain dopamine neurons fire a burst above their baseline rate.

Exercises

Remember

1. Name the two classic language areas, the lobe each is in, and the scientist each is named after.
2. List the three core executive functions described by Adele Diamond.

Answer

1. Broca's area is in the frontal lobe (inferior frontal gyrus), named after Paul Broca. Wernicke's area is in the temporal lobe (posterior superior temporal gyrus), named after Carl Wernicke.
2. Inhibition (including self-control and filtering distractions), working memory, and cognitive flexibility.

Understand

1. Explain why a person with Wernicke's aphasia is often unaware that their speech makes no sense.
2. Explain why neglect syndrome is not the same thing as being blind on one side.

Answer



1. Wernicke's area helps link word sounds to meanings, so damage there impairs understanding of all language, including the person's own speech. They can't monitor their words, so they don't notice the errors.
2. In neglect, visual information still reaches the brain; the problem is that the attention system doesn't process the left side of space. In hemianopia, the visual pathway itself is damaged, so the information never arrives.

Apply

1. A patient speaks fluently and understands conversation well, but when asked to repeat "The red car is in the garage," says "The rel... the red car is in the... the gararge." Which type of aphasia fits best? Explain using the three questions from Section 12.4.
2. Maya expects a 90 on her Brain Bee practice test and gets a 98. The next week she expects a 98 and gets a 98. Describe the reward prediction error and the expected dopamine response for each week.

Analyze

1. Compare Mr. Alvarez's and Mrs. Chen's strokes in the Bedside case. Explain how the location of each stroke accounts for both the type of aphasia and the presence or absence of weakness.
2. The Knecht study found right-hemisphere language dominance in 4% of strong right-handers and 27% of strong left-handers. What can, and can't, you conclude from these numbers about a single left-handed patient about to have brain surgery?

Evaluate

1. An app claims it can "train your right brain to unlock creativity." Evaluate this claim using what you learned about lateralization.
2. A school allows phones on desks during study hall "because students can multitask." Judge this policy using evidence about switch costs, and suggest a better rule.

Create

1. Write three original speech samples (Broca's, Wernicke's, and normal) about the same topic, each with a one-line clue, that a classmate could sort correctly.
2. Design an experiment testing whether students make more homework errors when switching between homework and texting than when finishing the homework first. Name your groups, your measurements, and how you'll keep the comparison fair.

Key Takeaways

- Language depends on a mostly left-hemisphere **network**. Broca's area (left frontal lobe) helps produce speech, Wernicke's area (left temporal lobe) helps link sounds to meanings, and white-matter pathways connect them.
- **Aphasia** is a language disorder, most often from stroke, affecting about one in three stroke survivors, without removing intelligence. Fluency, comprehension, and repetition separate the main types.
- **Hemispheric lateralization** means some functions lean on one hemisphere. Most people are left-dominant for language, but a minority, more often left-handers, are right-dominant.
- **Split-brain studies** by Sperry, Bogen, and Gazzaniga showed that each hemisphere has special abilities. Sperry shared the 1981 Nobel Prize for this work.
- **Attention** is a limited spotlight run by frontal-parietal networks; multitasking really means costly switching. Damage to right-hemisphere attention networks causes **neglect syndrome**, in which the left side of space is ignored.
- **Executive function** (inhibition, working memory, cognitive flexibility) depends on the prefrontal cortex, which keeps maturing into the mid-to-late 20s.
- **Decision-making** uses value signals in the prefrontal cortex, and learning from outcomes depends on the dopamine **reward prediction error**: reward received minus reward predicted.

You can read a stroke from a sentence!



You can now listen to a patient's speech and point to where the damage is, which is real neurologist thinking. Next, in Chapter 13, we'll follow what happens to the brain as it ages, and why some people's neurons begin to fail in diseases like Alzheimer's and ALS.