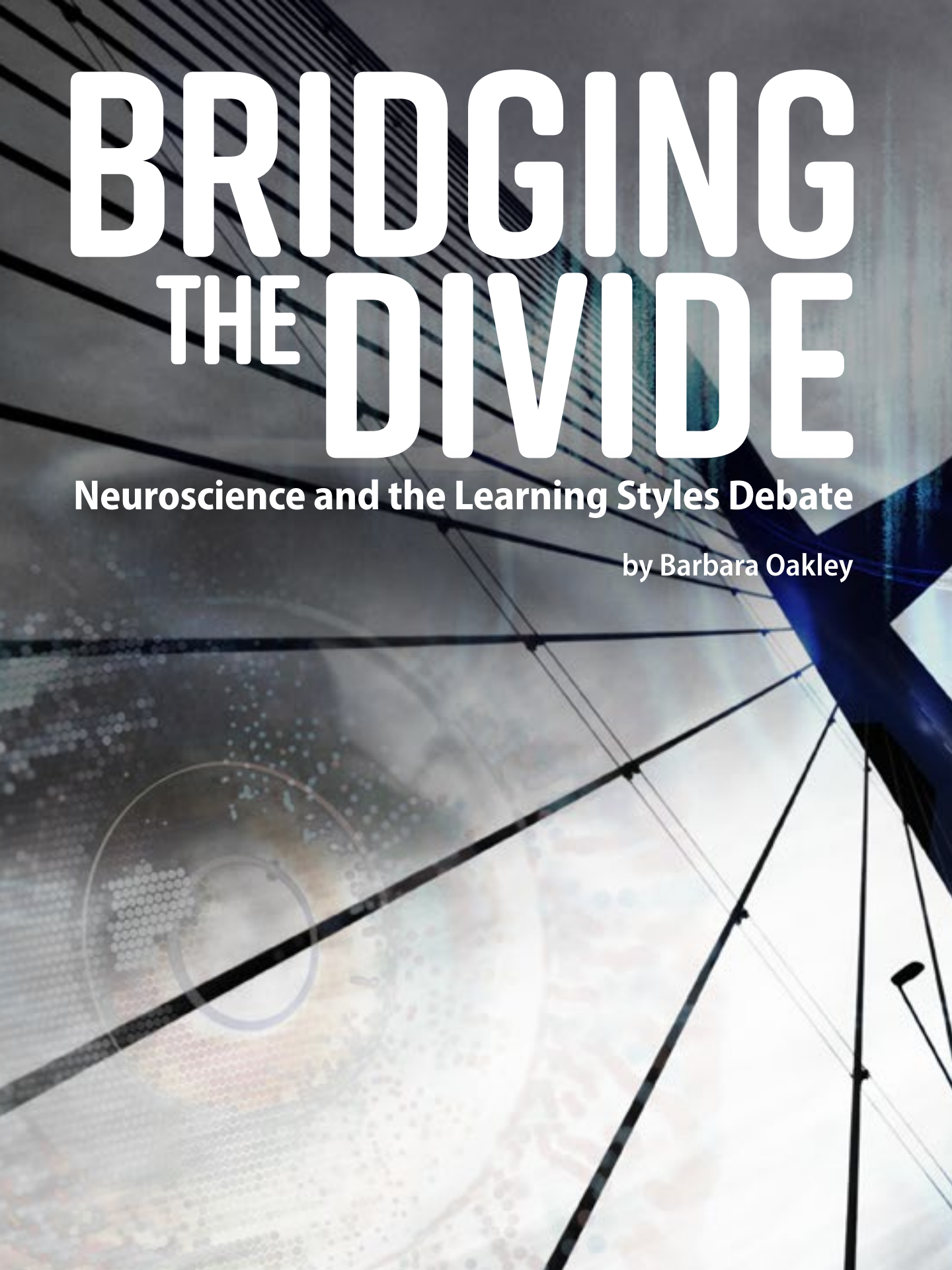


BRIDGING THE DIVIDE

Neuroscience and the Learning Styles Debate

by Barbara Oakley

One of the biggest controversies in education centers on learning styles. Those who say that learning style differences exist believe, for example, that some people learn better by hearing while others learn better by seeing. But most prominent psychologists cite research revealing that "auditory" and "visual" learners learn similarly and conclude that learning styles don't actually exist. This debate matters because how we understand learning has concrete implications for educational policy and teaching practices. All this means that it's worthwhile to bring fresh perspectives from neuroscience to this long-simmering and contentious issue.

When Definitions Collide: Style Versus Ability

One keen opponent of the idea of learning styles is Daniel Willingham—a psychologist who has done admirable work in education. Willingham observes:

> Ability is that you can do something. Style is how you do it. Thus, one would always be happy to have more ability, but different styles should be equally desirable. I find a sports analogy useful here. Two basketball players may be of equal ability, but have different styles on the court, one being a risk-taker, and the other quite conservative in his play. (Sometimes people say it's obvious that there are learning styles because blind and deaf people learn differently. This is a difference in ability, not style.)[1]

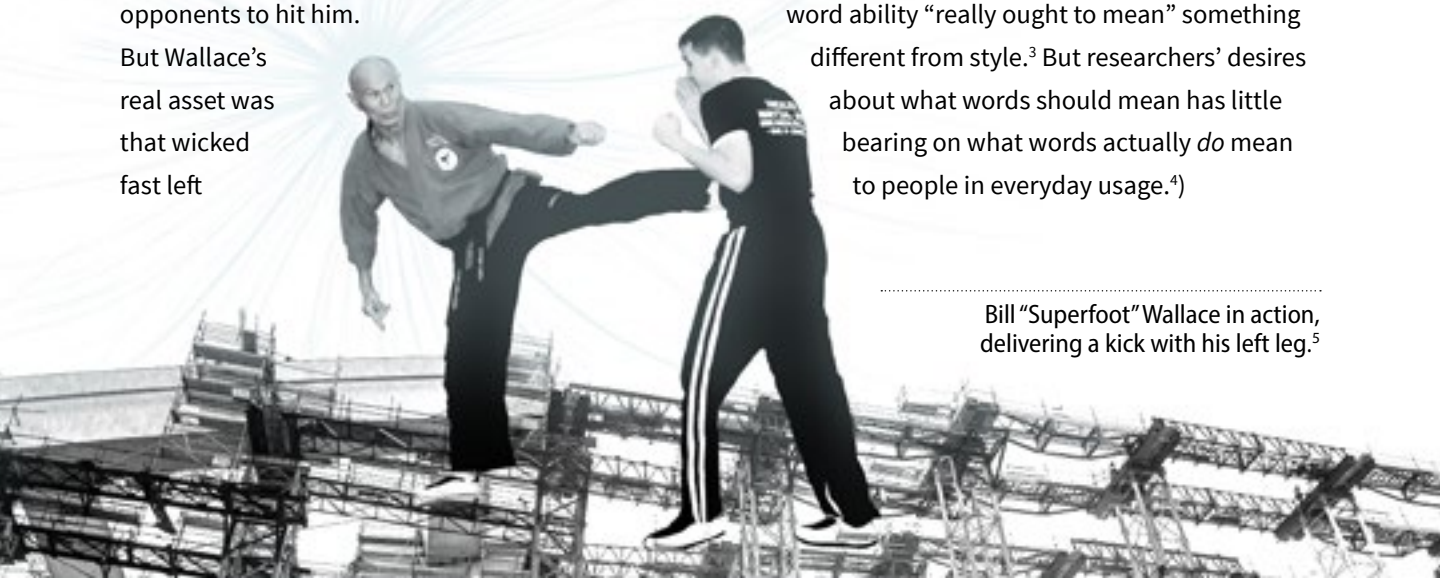
It seems like a clear difference. But what if ability *affects* style?[2] Let's draw again on sports, as Willingham did, to show you what I mean.

Bill Wallace was a prominent American martial artist famous for his left leg kicks, delivered with such extraordinary speed that they earned him the moniker "Superfoot." Wallace fought using a distinctive style—he often stood sideways, left leg toward his opponent. The sideways stance reduced his target size, making it more difficult for opponents to hit him. But Wallace's real asset was that wicked fast left foot—his roundhouse and hook kicks were clocked at 60 miles per hour.

The ultimate question, however, is this: Was Wallace's left-footed approach his style? Or his ability? Or let's throw our own hook in here: Was Wallace's distinctive style perhaps related to the flip side of ability—that is, to his *disability?*

Behind Wallace's characteristic style, as it turns out, lay an injury. Wallace damaged his right knee during a practice session in his early years. The injury meant that his practice centered on developing his left leg while holding his right leg as his point of stability. This lopsided practice gave Wallace an extraordinary ability with his left leg, which allowed him to outclass his opponents. He would ultimately become the Professional Karate Association World Full-Contact Champion, ending his career with a 23-0-0 record. In other words, Wallace's style grew from his *ability* with his left leg. This ability grew from the *disability* in his right leg, pushing him to practice excessively with the left.

As Wallace's example shows, the terms *ability, disability,* and *style* shade into one another in a sort of "stylability" mashup. If style might be caused by ability, there would often be a strong correlation between the terms. Placing a neat divide between these concepts that works for every context would be impossible. (Willingham himself notes that the word ability "really ought to mean" something different from style.[3] But researchers' desires about what words should mean has little bearing on what words actually *do* mean to people in everyday usage.[4])



Bill "Superfoot" Wallace in action, delivering a kick with his left leg.[5]

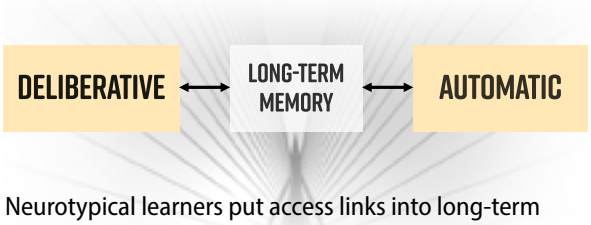
Ambiguities in words abound. One recent study found that "at least ten to thirty quantifiably different variants of word meanings exist for even common nouns."[6] Further, people are unaware of this variation and exhibit a strong bias to erroneously believe that others share their semantics. Ultimately, there will always be points where ability and style share so much context that it will be tough to tell whether you are talking about ability versus where you're talking about style. Just like with Bill Wallace.

Let's back up a moment and think about the term *ability* in contrast with *disability*. Modern ways of thinking often devolve to the idea that there's no such thing as a disability—there are just differing abilities. But Jill Escher, the mother of two profoundly disabled autistic children and president of the National Council on Severe Autism, poignantly reminds us: "While revisionist histories have preached that autism is natural neurodiversity that has always been here but we somehow never noticed it, in the real world the numbers of disabled autistic adults in need of lifespan care are swelling, and fast."[7] When neural diversity might go to an extreme, the result can be profoundly disabling.

There can be a sweet spot, however. Cognitive disability in certain areas can, it seems, sometimes lead to enhanced cognitive ability in other areas. Many would call the result a difference in a learner's style. Whatever terms you use, thinking about trade-offs is vital, as neuroscientist Michael Ullman's pioneering theories have shown.[8] Ullman's exploratory research has helped us better understand the interplay between two major learning systems in the brain: deliberative and automatic. Differences in how these systems function can mean profound differences in how a student prefers to learn.

Deliberative Versus Automatic Learning

Evidence is clear that learning involves creating links between neurons in long-term memory. Those links are generally stored in and retrieved from long-term memory in the brain through two different pathways. We'll call them the deliberative and automatic pathways.[9] The two different pathways produce links with different characteristics. Most people use the links created by both pathways to do their learning and thinking.



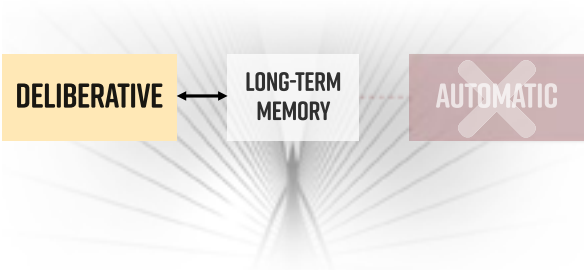
Neurotypical learners put access links into long-term memory in a balanced way using either their deliberative or automatic systems, depending on the task.

For example, you are reading this page because you can do quick, unthinking parsing of the squiggles of letters into words because of years of practice that have helped you build powerful automatic links. But your understanding of the meaning of the sentences and paragraphs is largely due to the processes of your deliberative system. (If you're aware of Nobel Prize-winning psychologist Daniel Kahneman's work *Thinking, Fast and Slow*, the deliberative pathway involves "slow" thinking, while the automatic pathway involves "fast" thinking.)

Interestingly, it's often possible to learn the same thing with either system—it's just that specific systems are better for certain types of activities, so there can be awkwardness if the other system is used. We can begin understanding students' differences in "stylabilities" by understanding differences in deliberative and automatic learning systems.

The Dyslexia Spectrum

Sometimes, either the deliberative or the automatic learning system is disrupted. We see this, for example, in children with dyslexia—a syndrome frequently affiliated with dysfunction in the automatic system.[10] Remember what I mentioned earlier, that "quick, unthinking parsing of the squiggles of letters into words"? In dyslexia, that effortless, natural, automatic ease with reading isn't possible.



Dyslexia often seems to be associated with challenges in the automatic learning system.

This means that, for children with dyslexia, listening to someone speak is often a lot easier than reading those same words. And so those with dyslexia often listen to spoken words to allow them to absorb materials that others might typically read silently.[11] Such students might easily begin thinking of themselves as auditory learners. In important ways, they are—even though, as we shall see, these students can also sometimes have unique abilities with visualization.

Depending on the country doing the diagnosing, between 3 percent and 15 percent of students have dyslexia, which is often affiliated with other syndromes that create challenges in learning.[12] All this can mean diagnosing dyslexia can be like chasing the edges of wispy clouds.[13] But the fact that only 32 percent of fourth-grade public school students in the U.S. are at or above the standard reading proficiency level hints that dyslexia, sub-clinical dyslexia (that is, a person who has some, but not all, of the symptoms of dyslexia), and related syndromes may be more widespread than commonly thought.[14] Or perhaps it is simply that many teachers use whole language approaches to reading that deemphasize automaticity, which is enhanced by phonics instruction. Oddly enough, this might result in difficulty with reading similar to that of dyslexia.

Some tests reveal that a particular group of students learn better by hearing than by reading.[15] "Ah," cries the teacher, "this provides strong evidence for learning styles!" Then you might reveal these are students with dyslexia, and suddenly researchers pull a terminological switcheroo: "No, no," they cry, "that relates to ability, not a learning style!" *Even if it has precisely the same result: a student who learns better by hearing.* It's no wonder that teachers are left confused. They see profound evidence in their classrooms that some students learn better by listening, but they are somehow expected to understand that what they see can't possibly be an auditory learning style.

There are substantial clues that those with dyslexia compensate for their automatic system challenges by leaning in on—and enhancing—their ability to learn deliberatively.[16] One effect may relate, oddly enough, to enhanced visualization abilities, which can involve the deliberative hippocampal system.[17] These differences can go hand-in-hand with an ability (or is it a style?) to see matters from a bigger-picture perspective and make perceptive connections that others miss. Research is revealing that dyslexia may grow from very specific auditory challenges, perhaps related to the neural circuits the brain pours energy into during times of

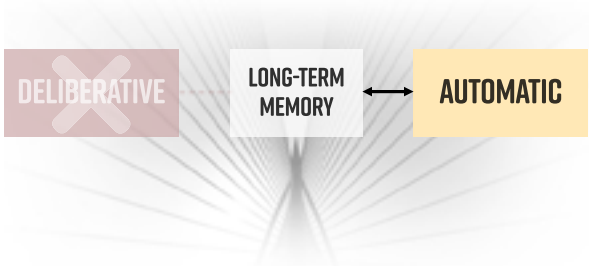
stress in infancy and toddlerhood.[18] Much research lies ahead.

An associated effect might involve enhanced abilities to memorize and remember. As Nobel Prize-winning microbiologist Carol Greider notes: "As a kid I had dyslexia. I had a lot of trouble in school and was put into remedial classes. I thought that I was stupid…. I kept thinking of ways to compensate. I learned to memorize things very well because I just couldn't spell words. So later when I got to take classes like chemistry and anatomy where I had to memorize things, it turned out I was very good at that."[19]

As one mathematician with dyslexia observed: "The dyslexia… I explain to people, it's sort of like you're strong in one thing, but it makes you weak in others."[20] Of course, causality may work the other way—weakness in some areas may lie behind the strengths in others.[21]

The Autistic Spectrum

There's evidence of a different group of learners who sometimes share challenges with their automatic learning systems, as with those with dyslexia. But these learners can sometimes be quite different, instead having *enhancements* of their automatic system.



Autism can be associated with enhancements in automatic system learning, sometimes coupled with challenges in deliberative learning.

By way of background, the automatic system underlies our ability to use motor and cognitive skills that we don't have to think about. It also involves our ability to perform habitual actions. Sadly, the automatic system is often characterized as merely the simple seat of rote learning. But automatic learning, which is exceptionally strong in children, also allows us to assimilate complex patterns, such as the grammatical structures of our native language.[22] Using the links laid by the automatic system, we can speak in our native language about complex ideas without thinking about the words we're using. By contrast, adults acquire new languages primarily through their deliberative systems. With much practice, these adult learners may be able to speak an additional language fluently. However, the heavy reliance on the deliberative system can still make expressing themselves slower and more tiresome than speaking their native language.[23]

Michael Ullman provides evidence that those on the autistic spectrum may have challenges with either their automatic or deliberative learning system, which can result in enhanced functioning of the other system as the learner compensates.[24] This explains why those on the autistic spectrum can sometimes quickly grasp holistic patterns in a way that neurotypical students find difficult—whether those patterns involve math, computer algorithms, language learning, art, or any other pattern-related activity. This pattern of learning, incidentally, has been dubbed "global" versus "sequential" in learning styles approaches.[25]

Enhanced automatic learning skills can also explain another significant challenge experienced by those on the autistic spectrum in today's classrooms—they can struggle to explain what they know. Automatic knowledge is complex and not

linear by its very nature—it doesn't lend itself to sequential explanations. We do these potentially deeply talented children with autism a disservice when we insist they must be able to explain (which uses the deliberative system) what they understand at a deep conceptual level through their automatic system. The odd result can be that parroted explanations with little proper conceptual understanding can earn top grades, while those who find it difficult to verbalize their knowledge can fail despite their evident expertise with the material. It is no wonder that gifted, neurodiverse students can become disenchanted with school.

Conflicting Perspectives on Learning Styles

It is no surprise that learning styles debunkers have often pooh-poohed the idea of learning styles.[26] In the wild west of the learning styles heyday, anybody could develop a learning styles inventory, and as a result, it seemed almost everybody did. Debunkers have used some of these old learning style tests to show they don't work, leading them to conclude that there is no such thing as learning styles.[27] Debunkers also fear that teaching to a student's supposed style—for example, always reading aloud to an auditory learner—will blinker that student's ability to learn by reading silently. (This matching of teaching approach with learner style is known as "the meshing hypothesis.")

But many learning style proponents, including Richard Felder—the Princeton-trained Hoechst Celanese Professor Emeritus of Chemical Engineering and inaugural winner of the lifetime achievement award from the American Society of Engineering Education—insist that the meshing hypothesis is an inaccurate characterization of how most teachers use knowledge of learning styles. They suggest that teachers commonly teach toward a balance of learning styles to ensure all the students in a typical class experience what is perhaps their "best" way of learning, even as they

are exposed to other ways of learning. In other words, a key idea from learning styles approaches is to ensure that the various modalities aren't missed. Felder makes the case that learning style debunkers use demeaning, straw-man arguments and refuse to engage with those they are maligning.[28]

The reality is that Finland's vaunted educational system focuses on learning styles as a key pedagogical approach.[29] This certainly hasn't hurt Finland in its climb to the top of the international educational rankings.[30] Even if teaching using learning styles is wrong and bad, it doesn't seem to hurt Finnish students. In business, Ray Dalio has relied on debunked style theory as an important part of his business practice.[31] This clearly hasn't hurt his company, Bridgewater Associates, which is the world's largest, most successful hedge fund.

> "There was an **UNWILLINGNESS** to look at the issue with **FRESH EYES** and an **OPEN MIND**…"

Debunkers imply, for example, that teachers all huddle in a corner reading aloud to "auditory" learners, harming their reading ability. But it seems the vast majority of teachers are prompted by learning styles theory to use visuals to read aloud sometimes to their classes and to encourage students to get their hands on things. Despite vocal claims to the contrary, whether teachers use these varied approaches because of a problematic learning style theory or because it's good general teaching practice may not make much difference. The sky is not falling. Exaggerating the horrors of learning styles may have had the unintended consequence of reaffirming learning styles for many teachers, even as these teachers lose further respect for academic research findings. Unfortunately, it's not like entire fields and even great theoreticians with tens of thousands of citations haven't wandered astray in the past.[32]

As a researcher, writer, and public speaker, I have long supported the debunking of learning styles. The debunking literature is in some sense solid—visual and auditory learners perform equivalently in tests involving visual and auditory materials. And there are clearly profound problems in many learning styles inventories. Yet having friends on both sides of the debate has caused me to become curious about this area. As I dug into the literature, I tried to emulate my most admired scientific heroes. That is, I tried to keep my mind open to fresh perspectives. The more deeply I dug over the years, the more I realized that both the learning styles literature and the debunking literature often hinge on superficialities that avoid the in-depth insights that neuroscience is beginning to provide.

As I began to work on this article and sent drafts to researcher friends, I was surprised to see how often they responded that there are no learning styles, case closed. There was an unwillingness to look at the issue with fresh eyes and an open mind—perhaps understandable when researchers must contend with the flood of confusing new data on their everyday studies. But then I was shocked to see how often feedback from debunker friends swirled around elusive definitional quibbles. Some debunkers took issue even with how their fellow debunkers, such as Dan Willingham, defined learning styles. Common feedback centered on using arcane definitions dug from the crevices of decades-old literature or devising their own closeted definition of learning styles that clearly veered far from the vernacular. Sadly, this is a game anyone

could play to disenfranchise another's ideas. I could say, "math only applies to counting livestock." Then, by my definition, most math wouldn't be "real" math. But that's not the vernacular definition of math.

Rightly or wrongly, some learning style proponents have gotten the sense that psychologists are subconsciously biased to use their own definitions of terms as a form of microaggression that demonstrates their superior knowledge, protects their disciplinary turf, and puts teachers in their place. Well-meaning teachers sometimes join psychologists to signal their awareness of latest research findings. The resulting divisiveness makes it doubly challenging to suggest insights from neuroscience, an unfamiliar subject for many psychologists and teachers. In the final analysis, many debunkers have decades on record denying the faintest hint of learning styles. The career stakes for these long-time debunkers of learning styles are high, which can make them hesitant to look at or acknowledge results from fields like neuroscience. No matter how convincing neuroscientific findings might be, underlying bias can incline debunkers, if they can even be brought to look at potentially contrary findings, to nitpick definitions or details of the results without acknowledging the big picture.

Some would say that providing information supporting learning styles gives aid and comfort to potential fraudsters. But dismissing differences in learning patterns out of hand has its own share of problematic outcomes. For example, some anti-learning style teachers insist that those on the autistic spectrum cannot think or learn differently because there's no such thing as learning styles. (The nuance of the style versus ability argument is lost on them.) Debunkers also raise the concern of wasted money on poorly vetted materials. This is a valid point—yet one can't help but wonder why some are given a pass in the target-rich environment of misspent educational dollars.[33] It seems that opposition to recognizing patterns of differences in learning, whatever the cause, has taken on a life of its own that's sometimes gone well beyond the original intentions of learning styles debunkers.

At the same time, debunkers are right when they point toward oversimplified learning styles theories that place students into rigid categories like "auditory learner" or "visual learner." Saying that someone learns better via auditory than visual modalities in certain circumstances is not the same as saying that someone learns better via auditory means in all circumstances and with all kinds of material, which is what traditional learning styles theory often points toward. That is easy to debunk and it has been debunked. But while debunking simplistic learning style theories, we can't overlook the real individual differences and nuanced patterns found among groups of students. We should remain open to the possibility of subtle patterns of differences in how people learn.

> "... DISMISSING DIFFERENCES in LEARNING PATTERNS out of hand has its own share of PROBLEMATIC OUTCOMES."

Bridging the Divide: Finding Common Ground

Neuroscience is revealing many exciting insights regarding learning and thinking styles. Michael Ullman's deliberative-automatic theories unlock new grounds for exploration, but there's more. For example, recent research published in *Nature*

Human Behaviour suggests that some people are averse to uncertainty, while others tolerate ambiguity with no problem.[34] This seems akin to the old learning style conceptions of "judgers (...seek closure even with incomplete data)" and "perceivers (...resist closure to obtain more data)."[35] Findings like these in *Nature* drive home an important point: we can now quantify categories of thinking and learning styles by directly observing differences and commonalities in how concepts are stored, accessed, and analyzed by the brain.

A debunker might observe that these ideas are sneaking close to conceptions of cognitive styles, a term which doesn't have the bad rap of learning styles. Again, we're back to overlapping conceptions. When is cognitive style different than learning style? The answer: when a learning styles debunker is involved. The reality is that, in everyday use of the terms, cognitive styles such as holistic versus analytic go hand in hand with learning styles.[36] No matter how specialists might say that these two concepts are entirely distinct, they are not. They overlap in how we think about them in the brain (the semantic locations of the concepts), in word vector analysis, and in vernacular use. If cognitive styles are valid, and learning styles are intimately tied in with cognitive style, then there would be something to learning styles.

Not only learning style researchers, but many prominent scientists, writers, and thinkers over the centuries have observed patterns of differences in how people think and learn. These patterns seem very real but may not necessarily be the kind of thing, at least initially, that you can quantify with a zippy 30-minute pen-and-paper test. There are lumpers contrasted with splitters; foxes versus hedgehogs; adroit, superficial learners as opposed to clumsier yet somehow deeper learners. (Unlike their lesser peers, Nobel Prize winners Santiago Ramón y Cajal and Friedrich Hayek attributed their success to their slow and blundering way of learning.)[37] What will neuroscience unveil that might

This image conveys a sense of how the uncertainty tolerant ("lumpers") tend to store related concepts closer together in the brain. The uncertainty averse ("splitters"), on the other hand, store related concepts further apart in the brain. This is seen specifically in the left inferior frontal gyrus ("LIFG").

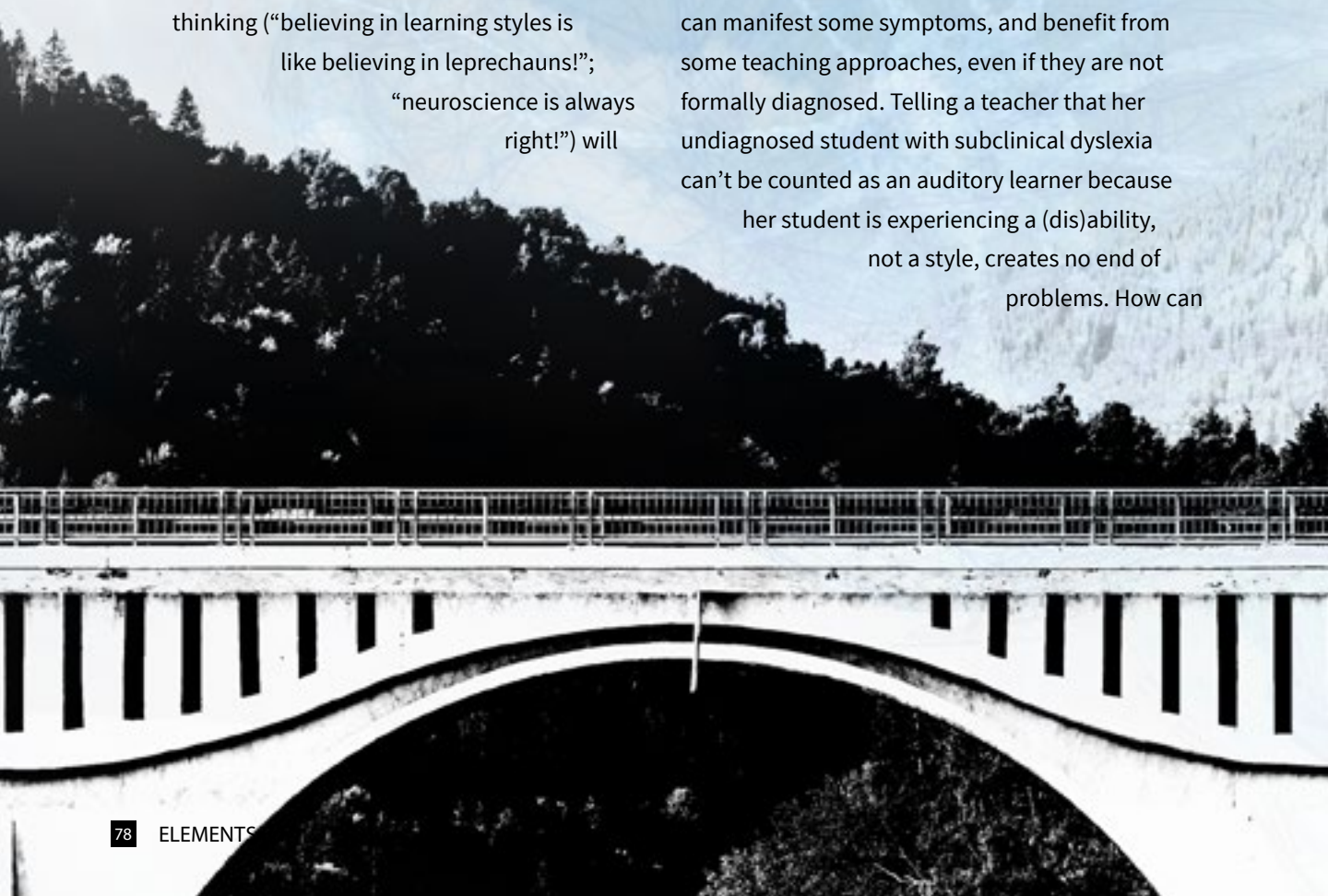
support or deflate these and many other ways of parsing patterns in how people learn and think?[38]

When one looks at how pedagogy treats neuroscience, a disturbing proportion of what's currently taught seems to involve neuromyths. Isn't it odd that a subject could be primarily taught by describing what it is not? Imagine the fields of geology or chemistry, for example, being taught by describing geological or chemical myths. I can't help but think that much educational neuroscience is being conveyed by psychologists and educators who are skittish about their lack of solid grounding in neuroscience. Hence the tendency to present neuroscientific findings in a reductive, negative way.

Science sometimes moves backward to move forward. A nuanced view that incorporates subtle insights from neuroscience and avoids binary thinking ("believing in learning styles is like believing in leprechauns!"; "neuroscience is always right!") will ultimately lead to more inclusive and integrative instruction.[39] Research on learning styles cries out for adversarial cooperation. This is a new approach where, instead of festering for decades with conflicts that can be tough for outsiders to adjudicate, researchers with differing views converge upon the truth by working together. Nobel Prize winner Daniel Kahneman spurred this approach with his "Adversarial Collaboration Project."[40]

> "... RESEARCH on LEARNING STYLES CRIES OUT for ADVERSARIAL COOPERATION."

The debate over learning styles has real pedagogical implications for today's highly neurodiverse classroom. Teachers need guidance grounded in evidence, not dogma, to teach responsively to students' varied aptitudes, abilities, and disabilities. There is a broad spectrum involved in syndromes like dyslexia and autism—students can manifest some symptoms, and benefit from some teaching approaches, even if they are not formally diagnosed. Telling a teacher that her undiagnosed student with subclinical dyslexia can't be counted as an auditory learner because her student is experiencing a (dis)ability, not a style, creates no end of problems. How can



teachers know? School districts certainly can't bear the burden of testing all their students for various syndromes. And even if they could, many students can fall into that shadowy spectrum between the full-blown, diagnosable syndrome and more typical behavior.

It's time to acknowledge the nuanced interplay between ability and style suggested by neuroscience and causality studies. Many teachers observe actual patterns of differences between learners that require inclusive, multifaceted instruction. Collaborative work between neuroscientists, psychologists, and educators can shape teaching practices and policies that neither ignore nor oversimplify patterns of differences in approaches to learning. This has the potential to improve outcomes for all students. Using insights from neuroscience, psychology, and education to move past the learning styles controversy will ultimately provide the best education possible to today's broad range of neurodiverse students. Ed

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Endnotes

1. Daniel Willingham, "Learning Styles FAQ," *Daniel Willingham: Science & Education* (blog), accessed August 13, 2023.

2. Some learning style debunkers, unlike Willingham, feel that the word "style" when used regarding dancing, fighting, basketball, and the like, isn't at all the same as "style" with respect to learning, although they may be hard-pressed to state why they feel this way. And they might refer to the definition of "ability" in various textbooks, as for example Bloom, Hastings, and Maddaus' 1971 *Handbook on Formative and Summative Evaluation of Student Learning*. But it's probably a good bet to say that 99 percent of instructors, even if they have read the 900-page Bloom, Hastings, and Maddaus volume or related works, don't remember to apply that specific narrow definition of the word "ability." They can't help but use the terms "style" and "ability" in the vernacular sense.

3. Willingham, "Learning Styles FAQ."

4. Qunlin Chen et al., "Common Brain Activation and Connectivity Patterns Supporting the Generation of Creative Uses and Creative Metaphors," *Neuropsychologia* 181 (2023): 108487, https://doi.org/10.1016/j.neuropsychologia.2023.108487; Timothy E.J. Behrens et al., "What is a Cognitive Map? Organizing Knowledge for Flexible Behavior," *Neuron* 100, no. 2 (2018): 490–509, https://doi.org/10.1016/j.neuron.2018.10.002; Dušan Stamenkovića, Nicholas Ichienb, and Keith J. Holyoak, "Metaphor Comprehension: An Individual-Differences Approach," *Journal of Memory and Language* 105 (2019): 108–18, https://doi.org/10.1016/j.jml.2018.12.003; Keith J. Holyoak and Dušan Stamenković, "Metaphor Comprehension: A Critical Review of Theories and Evidence," *Psychological Bulletin* 144, no. 6 (2018): 641–71, https://doi.org/10.1037/bul0000145; Emanuel Derman, *Models. Behaving. Badly.: Why Confusing Illusion with Reality Can Lead to Disaster, on Wall Street and in Life* (New York: Free Press, 2011); Mathias Benedek and Andreas Fink, "Toward a Neurocognitive Framework of Creative Cognition: The Role of Memory, Attention, and Cognitive Control," *Current Opinion in Behavioral Sciences* 27 (2019): 116–22, https://doi.org/10.1016/j.cobeha.2018.11.002.

. You can have fun comparing the semantic contexts of ability and style in ChatGPT by using a prompt like "Calculate the semantic similarity between 'ability' and 'style' using Word2Vec." The similarity is 0.63. Not identical, (which would be 1.0) but pretty high.

   Some debunkers take issue with the analogies we're using in these contexts, stating that all analogies break down at some point. This is true, but analogies and metaphors are also invaluable in the learning and transfer process and are an integral part of the creative thinking process. As the great quant Emanuel Derman has pointed out, even mathematical equations are metaphors.

5. Claus Michelfelder, *Bill Superfoot Wallace in Action*, photograph, Wikimedia Commons, September 19, 2011, https://commons.wikimedia.org/wiki/File:Kampfkunst_2011_067.JPG.

6. Louis Marti et al., "Latent Diversity in Human Concepts," *Open Mind* 7 (2023): 79, https://doi.org/10.1162/opmi_a_00072.

7. Jill Escher, "The Autism Surge: Lies, Conspiracies, and My Own Kids," *The Free Press*, July 20, 2023, https://www.thefp.com/p/the-autism-surge-lies-conspiracies.

8. Michael T. Ullman, "The Declarative/Procedural Model: A Neurobiologically Motivated Theory of First and Second Language," in *Theories in Second Language Acquisition: An Introduction*, 3rd ed., eds. Bill VanPatten, Gregory D. Keating, and Stefanie Wuff (New York: Routledge, 2020), 128–161; Michael T. Ullman et al., "The Neurocognition of Developmental Disorders of Language," *Annual Review of Psychology* 71 (2020): 389–417, https://doi.org/10.1146/annurev-psych-122216-011555.

9. Benjamin O. Turner, Matthew J. Crossley, and F. Gregory Ashby, "Hierarchical Control of Procedural and Declarative Category-Learning Systems," *Neuroimage* 150 (2017): 150–161, doi: 10.1016/j.neuroimage.2017.02.039.

   In this article, I'm calling these pathways deliberative and automatic. But neuroscientists (like Michael Ullman) generally call these pathways declarative and procedural. The declarative pathway largely relies on the hippocampus, while the procedural pathway largely involves the basal ganglia. The advantage of the neuroscientific terminology is that it's clear what anatomical systems are being used by each pathway. So, when Turner et al, for example, discuss how the brain switches back and forth between procedural and declarative systems with the aid of the cerebellum in their study "Hierarchical control of procedural and declarative category-learning systems," we know exactly what neural systems are involved. But the neuroscientific terminology can be confusing for laypersons because sometimes psychologists (as opposed to neuroscientists) think of "procedural learning" as a step-by-step declarative process. Psychologists prefer the terms explicit and implicit for the declarative and procedural systems, respectively. The problem is that these psychological terms are often also used to describe conscious and unconscious processes without specifying the actual neural systems. Terminology can be a bear to parse!

10. Ullman et al., "The Neurocognition of Developmental Disorders of Language"; Martina Hedenius, Jarrad A.G. Lum, and Sven Bölte, "Alterations of Procedural Memory Consolidation in Children with Developmental Dyslexia," *Neuropsychology* 35, no. 2 (2021): 185–96, https://doi.org/10.1037/neu0000708.

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