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Emergent Ventures, 9th India cohort

by Tyler Cowen *May 5, 2025 at 12:28 am in* **Education**

Ari Dutilh is a 19-year-old entrepreneur, community builder, and photographer. This grant is to help continue our work on UltraRice, a project to solve malnutrition in India by using ultrasonic treatment to create cost-effective, nutrient-scalable rice.

Rukmini S is Founder and Director of Data For India. Rukmini is an award-winning data journalist and won her first EV prize for her pandemic podcast, 'The Moving Curve'. Her first book, 'Whole Numbers & Half Truths: What Data Can and Cannot Tell Us About Modern India' awon literary awards.

Sworna Jung Khadka is an ESG entrepreneur. Stalwart International Private Limited is an agro startup funded by Emergent Ventures which leases unused government owned lands and non-agricultural but arable lands for the production of Cassava, drought resistant crops.

Suryesh Kumar Namdeo is a Senior Research Analyst at the Indian Institute of Science, Bengaluru, working on biosecurity policy and science diplomacy projects. He has received his EV grant to support his research and conference travels in biosecurity policy in India.

Susan Thomas — XKDR Forum aims to help litigants in India get more predictability about how their legal cases will progress in Indian courts. They propose to publish specific metrics of case progression, at a quarterly frequency, by developing a database of commercial cases from multiple courts in India. You can read more about XKDR Forum's work in this field here.

Jayesh Rohatgi is an entrepreneur and law student at LSE, with an educational startup, Dialogue Dynamics. Targeting top independent schools globally, Dialogue Dynamics focuses on the four most critical sub-skills of communication: presenting viewpoints, strategic questioning, identifying misinformation, and mastering persuasion.

Aakash Agrawal is a neuroscience and AI researcher who investigates the neural mechanisms that enable fluent reading. He aims to leverage his research and develop gamified cognitive tasks to help children improve their reading skills without adult supervision.

A compositional neural code in high-level visual cortex can explain jumbled word reading

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Abstract We read jubmled words effortlessly, but the neural correlates of this remarkable ability remain poorly understood. We hypothesized that viewing a jumbled word activates a visual representation that is compared to known words. To test this hypothesis, we devised a purely visual model in which neurons tuned to letter shape respond to longer strings in a compositional manner by linearly summing letter responses. We found that dissimilarities between letter strings in this model can explain human performance on visual search, and responses to jumbled words in word reading tasks. Brain imaging revealed that viewing a string activates this letter-based code in the lateral occipital (LO) region and that subsequent comparisons to stored words are consistent with activations of the visual word form area (VWFA). Thus, a compositional neural code potentially contributes to efficient reading.

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Introduction

Reading is a recent cultural invention, yet we are remarkably efficient at reading words and even jmulbed wrods (***Figure 1A***). What makes a jumbled word easy or hard to read? This question has captured the popular imagination through demonstrations such as the Cambridge University effect (***Rawlinson, 1976***; ***Grainger and Whitney, 2004***), depicted in ***Figure 1A***. Reading a word or a jumbled word can be influenced by a variety of factors such as visual, phonological and linguistic processing (***Norris, 2013***; ***Grainger, 2018***). At the visual level, word reading is easy when similar shapes are substituted (***Perea et al., 2008***; ***Perea and Panadero, 2014***), when the first and last letters are preserved (***Rayner et al., 2006***), when there are fewer transpositions (***Gomez et al., 2008***), when word shape is preserved (***Norris, 2013***; ***Grainger, 2018***). At the linguistic level, it is easier to read frequent words, words with frequent bigrams or trigrams as well as shuffled words that preserve intermediate units such as consonant clusters or morphemes (***Norris, 2013***; ***Grainger, 2018***). Despite these insights, it is not clear how these factors combine, what their distinct contributions are, and more generally, how word representations relate to letter representations.

Here, we hypothesized that, viewing a string of letters activates a visual representation that is compared with the representation of stored words. To probe visual processing, we devised a visual search task in which subjects had to find an oddball target string among distractor strings. This task does not require any explicit reading and is driven by shape representations in visual cortex (***Sripati and Olson, 2010a***; ***Zhivago and Arun, 2014***). An example visual search array containing two oddball targets is shown in ***Figure 1B***. It can be seen that finding OFRGET is easy among FORGET, whereas finding FOGRET is hard (***Figure 1B***), showing that FOGRET is more visually similar to FORGET. This makes FOGRET easy to recognize as FORGET, whereas OFRGET is harder. Thus, the visual similarity of the jumbled words FOGRET and OFRGET to the original word FORGET

Emergence of a compositional neural code for written words: Recycling of a convolutional neural network for reading

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Contributed by S. Dehaene, September 3, 2021 (sent for review March 28, 2021; reviewed by Marco Zorzi and Kenneth Pugh)

The visual word form area (VWFA) is a region of human inferotemporal cortex that emerges at a fixed location in the occipitotemporal cortex during reading acquisition and systematically responds to written words in literate individuals. According to the neuronal recycling hypothesis, this region arises through the repurposing, for letter recognition, of a subpart of the ventral visual pathway initially involved in face and object recognition. Furthermore, according to the biased connectivity hypothesis, its reproducible localization is due to preexisting connections from this subregion to areas involved in spoken-language processing. Here, we evaluate those hypotheses in an explicit computational model. We trained a deep convolutional neural network of the ventral visual pathway, first to categorize pictures and then to recognize written words invariantly for case, font, and size. We show that the model can account for many properties of the VWFA, particularly when a subset of units possesses a biased connectivity to word output units. The network develops a sparse, invariant representation of written words, based on a restricted set of reading-selective units. Their activation mimics several properties of the VWFA, and their lesioning causes a reading-specific deficit. The model predicts that, in literate brains, written words are encoded by a compositional neural code with neurons tuned either to individual letters and their ordinal position relative to word start or word ending or to pairs of letters (bigrams).

reading | VWFA | neural network | literacy | compositionality

Reading acquisition relies on the development of a novel interface between vision and language, in charge of efficiently identifying letters and their ordering (1, 2). This orthographic analysis then feeds the language systems supporting semantics and phonology. Over the past 20 y, some basic features of this interface have been put to light. A specific region of the left ventral occipitotemporal (VOT) cortex, which was labeled the visual word form area (VWFA), is present at a similar location in the brain of every literate subject and is thought to underlie orthographic coding (3). Functional brain imaging has uncovered a host of functional features of the VWFA—for example, tuning to familiar vs. unknown alphabets (4, 5), partial invariance for retinal location (3, 6), invariance for uppercase/lowercase (7, 8), or sensitivity to the frequency of word occurrence (9, 10). Nevertheless, how this region becomes specialized for written words, or even whether it does so, remains a highly controversial issue (11–14).

Current evidence suggests that the VWFA site owes its functional specialization to a combination of two factors. First, according to the neuronal recycling hypothesis, reading preempts and repurposes part of the large region of ventral visual cortex that participates in visual object recognition (11, 15–17). The specific region involved may not only possess a generic architecture for invariant visual recognition, but also a bottom-up sensitivity to some of the shape features relevant to word recognition, such as a preference for high-resolution foveal inputs (18, 19), line junctions (20), and midlevel geometrical features (21). Because these properties are widespread in both hemispheres, however, a second hypothesis may be needed to explain the narrow, reproducible location of the VWFA in the depth of the left infero-temporal sulcus. According to the biased-connectivity hypothesis, this left-hemispheric site exhibits a preexisting biased connectivity, or "connectivity fingerprints," with distant language areas (22–27). Indeed, in agreement with this idea, the precise location of the VWFA in 8-y-old readers can be predicted from their long-distance anatomical connectivity to other brain areas at 5 y of age, before they learned to read (27).

In the present work, we assess to what extent a minimal computational model of those two hypotheses may suffice to account for the emergence of the VWFA during reading acquisition. This study complements a recent work (28) that investigates the emergence of letter representation using unsupervised learning. Here, we focus on the learning of words and how their combinations of letters are represented. Specifically, we simulate a deep neural network whose architecture was not designed for reading, but is inspired from that of the ventral visual cortex and which was shown to provide a good fit to both behavioral and electrophysiological observations on face and object recognition (29). We examine what happens when this

Significance

Learning to read results in the formation of a specialized region in the human ventral visual cortex. This region, the visual word form area (VWFA), responds selectively to written words more than to other visual stimuli. However, how neural circuits at this site implement an invariant recognition of written words remains unknown. Here, we show how an artificial neural network initially designed for object recognition can be retrained to recognize words. Once literate, the network develops a sparse neuronal representation of words that replicates several known aspects of the cognitive neuroscience of reading and leads to precise predictions concerning how a small set of neurons implement the orthographic stage of reading acquisition using a compositional neural code.

Author contributions: T.H., A.A., L.C., and S.D. designed research; T.H. and A.A. performed research; T.H., A.A., and S.D. analyzed data; and T.H., A.A., L.C., and S.D. wrote the paper.

Reviewers: M.Z., Universita degli Studi di Padova; and K.P., Haskins Laboratories.

The authors declare no competing interest.

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NEUROSCIENCE

PSYCHOLOGICAL AND COGNITIVE SCIENCES

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ORIGINAL MANUSCRIPT

NSP-SCD: A corpus construction protocol for child-directed print in understudied languages

Sonali Nag[1] · **Sunila John**[2] · **Aakash Agrawal**[3,4]

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Abstract

Child-directed print corpora enable systematic psycholinguistic investigations, but this research infrastructure is not available in many understudied languages. Moreover, researchers of understudied languages are dependent on manual tagging because precise automatized parsers are not yet available. One plausible way forward is to limit the intensive work to a small-sized corpus. However, with little systematic enquiry about approaches to corpus construction, it is unclear how robust a small corpus can be made. The current study examines the potential of a non-sequential sampling protocol for small corpus development (NSP-SCD) through a cross-corpora and within-corpus analysis. A corpus comprising 17,584 words was developed by applying the protocol to a larger corpus of 150,595 words from children's books for 3-to-10-year-olds. While the larger corpus will by definition have more instances of unique words and unique orthographic units, still, the selectively sampled small corpus approximated the larger corpus for lexical and orthographic diversity and was equivalent for orthographic representation and word length. Psycholinguistic complexity increased by book level and varied by parts of speech. Finally, in a robustness check of lexical diversity, the non-sequentially sampled small corpus was more efficient compared to a same-sized corpus constructed by simply using all sentences from a few books (402 books vs. seven books). If a small corpus must be used then non-sequential sampling from books stratified by book level makes the corpus statistics better approximate what is found in larger corpora. Overall, the protocol shows promise as a tool to advance the science of child language acquisition in understudied languages.

Keywords Written language · Child-directed print corpus · Lexical diversity · Akshara · Phoneme length

Children's books have a wide-ranging influence on child development. Their power is considered to lie in the language that books carry because this written language is typically more varied and complex in contrast to spoken language. According to an estimate that used English material, child-directed print carries two-and-a-half times more word types and three times more rare words than child-directed conversational speech (Massaro, 2015). In addition to more diverse and rare words, the language encountered in child-directed print has a larger proportion of longer, more abstract, and more morphologically complex words that are also often later acquired in development than the words found in child-directed speech (Dawson et al., 2021). It is not surprising then that books are a rich resource for enhancing children's language, literacy, cognitive and socio-emotional skills (e.g., Grolig et al., 2019; Kara-Soteriou & Rose, 2008; Mol & Bus, 2011; Nation et al., 2022; Parry et al., 2014). Book corpora have also been used as a comparison set for mapping early spoken production (Montag & MacDonald, 2015; Saiegh-Haddad & Spolsky, 2014), early language exposure at home (Hayes, 1988) and in school (Schleppegrell, 2001; Shu et al., 2003), and to draw out the characteristics of a writing system (Nag, 2014).

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recognizes jumbled words

Joel P. Joseph

Posted on Dec 30, 2020 in **NEUROSCIENCE** and **RESEARCH**

Our brains are quite proficient at recognizing jumbled words and reading them correctly. Researchers from the Indian Institute of Science, Bengaluru, studied this fascinating phenomenon and came up with a computational model that uses artificial neurons to simulate the way the brain processes jumbled words.

How does our brain read jumbled words correctly? Scientists led by SP Arun and K V S Hari from the Centre for Neuroscience, Indian Institute of Science (IISc), Bengaluru, have developed *(https://elifesciences.org/articles/54846)* a computational model that sheds light on this. According to this model, when we see a string of letters, our brain uses the letter shapes to form an image of the word and compares it with the closest visually similar word stored in our brain.

Reading words is a complex process in which our brain decodes the letters and symbols in the word (also called the orthographic code) to derive meaning. Earlier research has shown that our brain processes jumbled words at various levels — visual, phonological and linguistic.

At the visual level, it is easy to read a jumbled word correctly when the first and the last letters are retained and the other letters are jumbled or replaced with letters of similar shapes.

Yet, some arrangements are easier to read than others. For instance, 'UNIEVRSITY' is easier to read than 'UTISERVNIY.' We can also read words when numbers of similar shape replace letters, e.g. "7EX7___WI7H___NUM83R5."

At a linguistic level, it is easier to recognize words that we encounter more frequently or have frequently-used letters. At the phonological level, it is easier to recognize similar sounding words, e.g. tar/car, pun/fun etc. However, how these factors contribute individually or collectively to recognize words remains unclear.

"We show that our ability to read jumbled words comes from simple rules in the visual system, whereby the response to a string of letters is a weighted sum of its individual letters," Aakash Agarwal, first author of the paper, says.

The team asked fluent English speakers aged 22 – 27 years to search for the odd letter out within a group of letters (distractors) displayed on the screen. The researchers found that the more similar were the shapes of the odd letter and the distractors, the more time the subjects took to accurately spot it. The team could thus calculate an index of how similar or different English letters were to each other, based on the time taken by the subjects to spot the odd letter in this experiment.

Using this information, the team proceeded to design computational units (artificial neurons) that were mathematically tuned to gauge how similar or different letters were to each other, thereby mimicking the neurons in the brain. Using these artificial neurons, the team then predicted how much time human subjects would take to identify odd two-letter combinations hidden within an array of two-letter distractors and found that the predictions matched the experimental findings.

THE SCIENCES (HTTPS://SCIENCE.THEWIRE.IN/CATEGORY/THE-SCIENCES/)

How the Human Brain Recognises Jumbled Words

09/01/2021

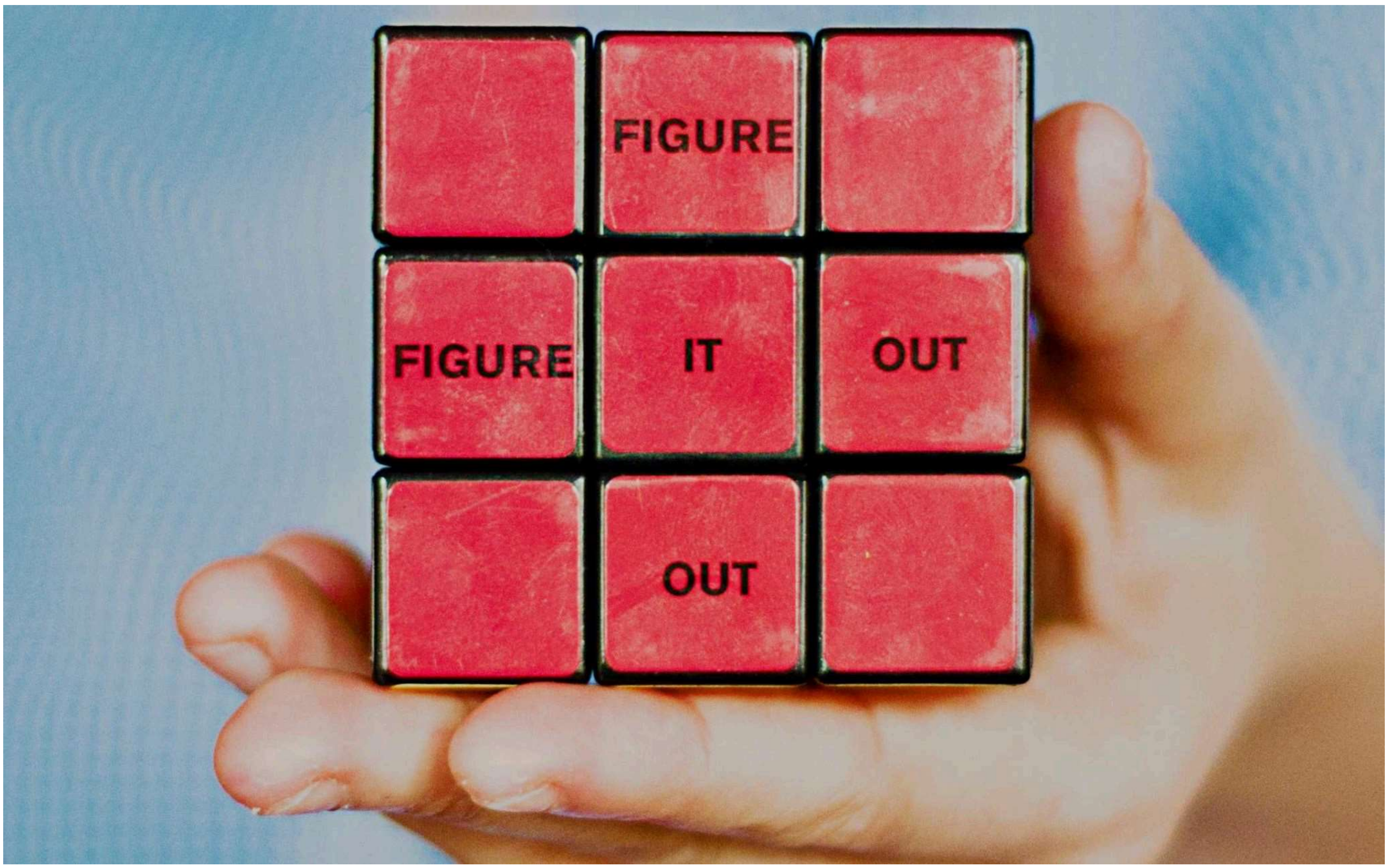

Photo: Karla Hernandez/Unsplash

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Also read: Three New Books on Human Consciousness to Blow Your Mind (https://science.thewire.in/culture/books/human-consciousness-books/)

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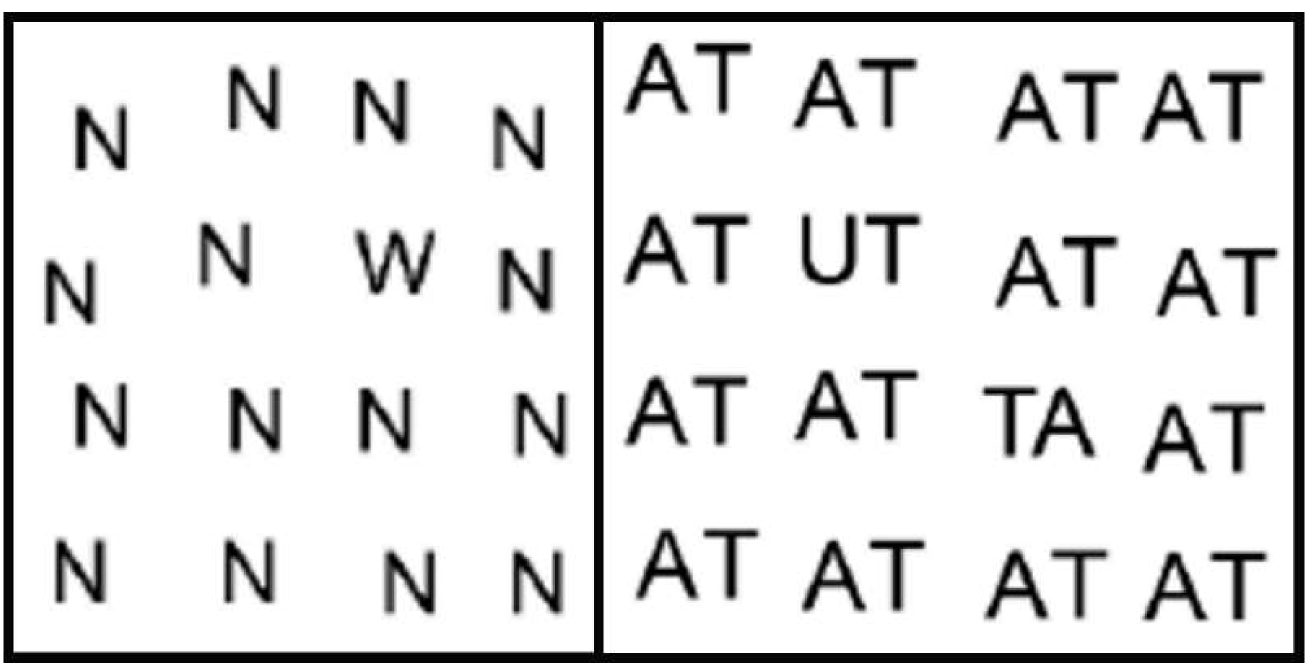

Left: An example of finding the odd letter from a group of distractors. Right: An example of finding the odd two-letter combination

COGNITIVE NEUROSCIENCE

Does the visual word form area split in bilingual readers? A millimeter-scale 7-T fMRI study

Minye Zhan[1]*, Christophe Pallier[1], Aakash Agrawal[1], Stanislas Dehaene[1,2]†, Laurent Cohen[3,4]†

In expert readers, a brain region known as the visual word form area (VWFA) is highly sensitive to written words, exhibiting a posterior-to-anterior gradient of increasing sensitivity to orthographic stimuli whose statistics match those of real words. Using high-resolution 7-tesla functional magnetic resonance imaging (fMRI), we ask whether, in bilingual readers, distinct cortical patches specialize for different languages. In 21 English-French bilinguals, unsmoothed 1.2-millimeters fMRI revealed that the VWFA is actually composed of several small cortical patches highly selective for reading, with a posterior-to-anterior word-similarity gradient, but with near-complete overlap between the two languages. In 10 English-Chinese bilinguals, however, while most word-specific patches exhibited similar reading specificity and word-similarity gradients for reading in Chinese and English, additional patches responded specifically to Chinese writing and, unexpectedly, to faces. Our results show that the acquisition of multiple writing systems can indeed tune the visual cortex differently in bilinguals, sometimes leading to the emergence of cortical patches specialized for a single language.

INTRODUCTION

Half of humanity speaks more than one language, and many adults can read more than one language and master multiple writing systems. How does the visual cortex accommodate the recognition of written words in two languages, possibly using two different scripts? Much of previous research has shed light on the mechanisms of reading acquisition in a single script. Within the left ventral occipitotemporal cortex (VOTC), the recognition of written words mobilizes a small cortical area that has been termed the visual word form area (VWFA) (*1*). This region emerges during reading acquisition (*2*–*4*) and becomes tuned only to the script that the person has learned to read (*5*, *6*). In readers of all languages, the VWFA occupies a reproducible location within a mosaic of cortical regions specialized for the recognition of various categories of visual stimuli such as faces, bodies, objects, or places. This reproducible specialization is thought to be based on a combination of factors including foveal bias (*7*), preference for geometrical features (*8*), and preexisting connectivity to distant language areas (*9*, *10*). Longitudinal studies of schoolchildren show that the VWFA acquires its specialization for written words within the first few months of schooling (*3*). Its lesion, in literate individuals, results in pure alexia, a selective reading impairment (*11*).

How populations of neurons in the VWFA encode written words is not known [for proposals, see (*12*, *13*)], but one of its key macroscopic features is a sensitivity to the statistics of reading: The response of the VWFA increases as letter strings increasingly respect the statistical distribution of letters in real words, with an increasing gradient of sensitivity along the posterior-to-anterior axis along the VOTC (*14*–*16*). Thus, it is plausible that, during reading acquisition, neurons in the VWFA internalize the statistics of letters and their combinations. However, because of the limited spatial resolution of imaging methods, which frequently smooth and average data across many individuals, it is not known whether the macroscopic gradient along the VOTC results from a continuous increase in sensitivity to overall word similarity or from a chain of discrete cortical patches, each possibly responsive to a hierarchically higher-level orthographic component such as letters, bigrams, and larger chunks of letters (*14*), in part through interactive bottom-up and top-down influences (*16*).

Here, we ask how plasticity allows this architecture to adapt to reading in two different languages in bilingual readers. Do distinct cortical patches implement reading in different languages? The statistical learning hypothesis above leads to contrasting predictions depending on whether the two languages use the same alphabet (e.g., English and French) or two very different scripts, typically alphabetic versus logographic (e.g., Chinese). When the two languages use the same alphabet, words share similar visual features in both languages, and the visual cortex projects to the same distant language areas (*17*). One may therefore predict that the same cortical patches would be used in both languages. Local patches of visual cortex would compile letter statistics without any consideration of which language they transcribe and should therefore be sensitive to the overall orthographic statistics (*18*), pooled across both languages (in proportions that may vary depending on the dominance of one language over the other for a given individual). There is currently no imaging evidence for language-specific patches in the VOTC, either between monolingual individuals (*19*) or within bilingual individuals (*20*). Accordingly, we know of no reports of developmental dyslexia or pure alexia differently affecting two languages using the same alphabet (*21*). Nevertheless, it remains possible that distinct cortical patches or columns are specialized for one or the other language and incorporate the orthographic statistics of only one language. This fine-grained specialization may have escaped the relatively coarse spatial resolution of previous 3-T functional magnetic resonance imaging (fMRI) studies, especially

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Letter processing in upright bigrams predicts reading fluency variations in children

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Abstract

Fluent reading is an important milestone in education, but we lack a clear understanding of why children vary so widely in attaining this milestone. Language-related factors such as rapid automatized naming (RAN) and phonological awareness have been identified as important factors that explain reading fluency. However whether any aspects of visual orthographic processing also explain reading fluency beyond phonology is unclear. To investigate these issues, we tested primary school children (n = 68) on four tasks: two reading fluency tasks (word reading and passage reading), a RAN task to measure naming speed, and a visual search task using letters and bigrams. Bigram processing in visual search itself was accurately explained by single letter discrimination and error patterns were unrelated to fluency or bigram frequency, negating the possibility of specialized bigram detectors. As expected, the RAN score was strongly correlated with reading fluency. Importantly, there was a highly specific association between reading fluency and upright bigram processing in visual search. This association was specific to upright but not inverted bigrams, and to bigrams with normal but not large letter spacing. It was explained by increased letter discrimination across bigrams and reduced interactions between letters within bigrams. Thus, fluent reading is accompanied by specialized changes in letter processing within bigrams.

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Author Contributions

All authors contributed to the overall study design. AA, SPA & SN designed experiments, AA implemented the experiment and collected data, AA, SN & SPA analyzed and interpreted data and wrote the manuscript with inputs from KVSH.

Context of the Research

The study originated through informal discussions between SN & AA/SPA/KVSH regarding the possible study of visual processing changes due to reading. We plan to conduct a longer term study to characterize changes in visual processing longitudinally as well as in early readers that might facilitate early reading skills.

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Research Article

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SAGE

Reading Increases the Compositionality of Visual Word Representations

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Abstract
Reading causes widespread changes in the brain, but its effect on visual word representations is unknown. Learning to read may facilitate visual processing by forming specialized detectors for longer strings or by making word responses more predictable from single letters—that is, by increasing compositionality. We provided evidence for the latter hypothesis using experiments that compared nonoverlapping groups of readers of two Indian languages (Telugu and Malayalam). Readers showed increased single-letter discrimination and decreased letter interactions for bigrams during visual search. Importantly, these interactions predicted subjects' overall reading fluency. In a separate brain-imaging experiment, we observed increased compositionality in readers, whereby responses to bigrams were more predictable from single letters. This effect was specific to the anterior lateral occipital region, where activations best matched behavior. Thus, learning to read facilitates visual processing by increasing the compositionality of visual word representations.

Keywords
reading, object recognition, visual search, neuroimaging, open data

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Reading a word involves processing its visual form, associating it with spoken sounds, and processing its overall meaning. Consequently, learning to read alters a variety of brain systems, including the visual, auditory, and language regions (Dehaene, Cohen, Morais, & Kolinsky, 2015). In particular, reading has a profound influence on the visual regions. It leads to the formation of the visual word-form area (VWFA) in the left occipitotemporal sulcus; the VWFA is selectively activated by words of familiar scripts and by intact words over scrambled controls, and activation levels in this region predict reading fluency (Dehaene et al., 2015). But reading also causes widespread changes throughout the visual cortex, as shown by greater activation for intact words relative to scrambled controls (Dehaene & Cohen, 2011; Dehaene et al., 2010; Lochy et al., 2018; Szwed et al., 2011) as well as for familiar over unfamiliar scripts (Bai, Shi, Jiang, He, & Weng, 2011; Baker et al., 2007; Krafnick et al., 2016; Szwed, Qiao, Jobert, Dehaene, & Cohen, 2014).

Despite these insights, several fundamental questions remain regarding how reading affects letter and word representations. Does reading alter single-letter representations? Does it alter word representations beyond the effect on single letters? These questions have been difficult to answer for two reasons. First, letter representations with and without reading expertise are difficult to characterize because many Western languages use the same script, making it difficult to find subjects fluent in distinct scripts without introducing confounding factors such as phonological mapping, writing systems, and literacy (Dehaene et al., 2015). Indian languages offer a unique opportunity to investigate these issues because of their diverse alphabetic scripts with shared phonological mapping and writing systems

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RESEARCH ARTICLE

Cracking the neural code for word recognition in convolutional neural networks

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Abstract

Learning to read places a strong challenge on the visual system. Years of expertise lead to a remarkable capacity to separate similar letters and encode their relative positions, thus distinguishing words such as FORM and FROM, invariantly over a large range of positions, sizes and fonts. How neural circuits achieve invariant word recognition remains unknown. Here, we address this issue by recycling deep neural network models initially trained for image recognition. We retrain them to recognize written words and then analyze how reading-specialized units emerge and operate across the successive layers. With literacy, a small subset of units becomes specialized for word recognition in the learned script, similar to the visual word form area (VWFA) in the human brain. We show that these units are sensitive to specific letter identities and their ordinal position from the left or the right of a word. The transition from retinotopic to ordinal position coding is achieved by a hierarchy of "space bigram" unit that detect the position of a letter relative to a blank space and that pool across low- and high-frequency-sensitive units from early layers of the network. The proposed scheme provides a plausible neural code for written words in the VWFA, and leads to predictions for reading behavior, error patterns, and the neurophysiology of reading.

Author summary

Reading is a fundamental skill in modern society, yet the neural mechanisms that allow us to quickly recognize words remain poorly understood. Our research aims to unravel how the brain achieves invariant word recognition—the ability to recognize words regardless of their position, size, or font. We studied artificial neural networks trained to recognize words, mirroring human learning. Our findings reveal that these networks develop specialized units for word recognition, similar to the Visual Word Form Area in the human brain. These units are sensitive to specific letters and their positions within a word. Crucially, we discovered that they achieve this by detecting the spaces around words as reference points. This creates a hierarchical system where early layers detect basic features and spaces, while higher layers combine this information to recognize specific letters at certain positions relative to word edges. This "space bigram" model reconciles previous theories of letter bigrams and letter-position coding. Our results suggest that most written

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