Neo-literate Adult Dyslexia and Literacy Policies: A Neurocognitive Research Review of a Curious Unexplored Phenomenon

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There are approximately 750 million illiterate adults worldwide who could (in principle) learn fluent reading. However, adult literacy programmes have thus far performed poorly. In this paper, the influence of some neurocognitive factors on poor adult reading performance is explored.

Automatic readers of a script detect letters and words effortlessly and involuntarily. Adults learning a new script detect letters slowly, may make mistakes, understand little, soon abandon the task, and may also forget what they have learned. When a neo-literate person (a person who does not yet know how to read the alphabet) glances at a text, they may only see a jumble of letters and may only process some of the features. They must activate reading consciously and sound out each letter. Their difficulties are perceptual, and interviews suggest that perceptual distortions may continue for decades. This phenomenon termed 'neo-literate adult dyslexia' (NAD) has received little attention to date. The problem occurs in the brain, and may originate at the early stages of development of the parietal cortex at the dorsal reading path, which constricts short-term visual memory. Parts of the visual cortex (the striate cortex V1, and perhaps the extra-striate cortex V4) may also be involved. Deficits affect the ventral path that provides parallel processing and direct print-to-meaning reading. Some neuronal groups may have a sensitive period that affects the capacity to collect frequency data and to integrate the appropriate features of letters and words. Then, adults do not learn to perceive letter shapes and words as easily as most children do. These difficulties for adults are not linguistic. Dysfluent readers simply cannot decipher the symbols within a sufficient time to acquire the meaning of texts (or they do so after considerable conscious visual effort). Some adults may become better readers than others. However, there seems to be a correlation between learning a script at increasingly later ages and worse reading outcomes, although no data exists to map this trajectory. To explore this curious phenomenon, this review brings together a range of insights from of neurocognitive research, notably studies on a) perceptual learning, b) neurocognitive studies aimed at dyslexic children, c) studies of adult suffering from brain damage that causes alexia, and d) performance of adult literacy programmes. The author posits the hypothesis that all people may become dyslexic toward new alphabets from the approximate age of 19 years, and that ability to read new alphabets fluently decreases with age.

Background

- Global adult literacy has increased from 56% in the 1950s to 86% in 2015.
- However, while this growth reflects the impact of children's schooling, it disguises the existence of some 745 million adult illiterates worldwide (mostly women) who have never been to school, and others who may have dropped out of school before learning to read fluently.
- Developing functional, usable, literacy for adults is the United Nations' Sustainable Development Goal 4 (target 4.6).
- The goal is to ensure that all youth, and a substantial proportion of adults, achieve literacy and numeracy by 2030.
- Many illiterate people are older, but a generation of illiterate school leavers is in the making.
- Schools in poor countries often use languages and teaching methods that require parental support and/or offer few books for reading practice.
- Some academics and donor staff found the concept of dyslexia for normal adults implausible or unbelievable.
- They tended to attribute the issue of illiteracy to social disadvantage, and the difficulties of educated adults to poor command of language or low personal motivation.

The neo-literate adult dyslexia hypothesis

- This article posits that all people potentially become dyslexic toward new alphabets at approximately 19 years of age, and this difficulty increases with age.
- The difficulties are not linguistic.
- Language competence seems to have little relationship

with the visuospatial tasks described in this document.
- Dysfluent readers cannot decipher symbols in sufficient time to ascertain the meaning of texts (or do so after considerably conscious visual effort).
- When beginning learners try to learn a language while trying to decipher a script, the process is clearly difficult and time consuming.
- An extensive research review attempts to integrate studies on a) perceptual learning, b) neurocognitive studies aimed at dyslexic children, and c) studies of adults suffering from brain damage that causes alexia.

Observations by an 'illiterate' reading specialist

- Since 1992, the author has interviewed and given informal reading tests to dozens of educated people who (as adults) learned various languages (such as Hindi, Arabic, Japanese, and Russian) with scripts different from those studied as children.
- The author did not encounter anyone who had learned a script beyond the age of 19 who claimed completely effortless reading.
- Interviews and tests were also given to two individuals who learned Hebrew reading as children and who read fluently despite a lack of language knowledge.
- Interviews and personal experiences suggest that acquisition speed decreases in mid-adolescence.
- Capacity for fluent and effortless reading seems to wane significantly by 19 years.
- Most people interviewed over time read slowly (approximately 10–20 words per min).
- These individuals cannot read involuntarily as automatic readers do.
- They must activate conscious pronunciation of the letters in their heads.

- Slow and effortful decoding fills working memory with letters and limits comprehension.
- The prevalence of illiterate reading specialists is noteworthy.
- Unless these specialists were native readers, nearly all remained illiterate in terms of the written (rather than spoken) word.
- Perennially slow and inaccurate reading (neo-literate) people may read too slowly for regular speech; hence, a delay results and the prediction of the word may be completely inaccurate.
- Illiterate adults seem to forget sound–letter correspondences within a few weeks when reading due to difficulty remembering letter shapes and sound correspondences in the long term.
- Letter neighbourhoods and locations matter along with independent letter identification, and only a few letters can be read ‘in real time’ before making a mistake due to systematic neglect of certain letters.
- Regarding feature integration difficulties and ambiguities, incorrect priming from meaning results in features that should correctly identify a word being neglected. This error may not be noticed until a sentence is incomprehensible and requires a second attempt.
- Some letters may be recognised faster than others, while letters with many features similar to others that require comparison are detected more slowly than letters that share few features.
- Reliance on unusual letter shapes means that unusual characteristics at a certain location can facilitate distinction.
- In general, people read longer words more slowly resulting in exaggerated word length effect.
- Increased practice in one script may speed up others.
- There may be an occasional and inconsistent activation of the print-to-meaning pathway.

- Perennially slower identification of letters representative of non-native sounds may occur.
- Difficulties in calligraphic reading is present.
- Awkward handwriting occurs.

The basic neuroscience of reading

- Many neuro-imaging studies have explored the brain regions involved with reading in both dyslexic and non-dyslexic children and adults.
- Findings show that specialised brain regions work together to form a reading network.
- As children learn how to read, the brain rewires itself so that one area working on visual matters and another working on auditory matters work together as a cohesive unit.
- From the eye receptors, a signal traverses the superior colliculi and pulvinar nuclei to the occipital lobe (the striate cortex [V1] area), then travels through paths that recognise shapes toward the parietal lobe, which connects letters to sounds to find meaning in the medial temporal lobe.
- As visual information exits the occipital lobe, it follows two main pathways (or streams).
- The ventral stream (also known as the 'what pathway') is involved with object and visual identification and recognition.
- The dorsal stream ('where pathway' or 'how') helps process the object's spatial location relative to the viewer and with speech repetition.
- The dorsal pathway stretches from the primary visual cortex (V1) in the occipital lobe forward into the parietal lobe. It is interconnected with the parallel ventral stream, which runs downward from the V1 into the temporal lobe.
- The ventral pathway identifies complex multipart objects. Words are encoded through a posterior-to-

anterior hierarchy of neurons tuned to increasingly larger and more complex word fragments, such as visual features, single letters, bigrams, quadrigrams, and possibly whole words.

- Data from children support the proposed distinction between the phonologically mediated dorsal pathway and the direct print-to-meaning ventral pathway.
- As children become better readers, reliance shifts from the dorsal to the ventral pathway.
- Visual working memory is critical for many tasks in the parietal lobe.
- This type of memory permits the maintenance of object identities and their locations across brief delays, such as those accompanying eye movements.
- The parietal lobe may have a general role in remembering various types of visual information, mainly motor spatial attention and spatial memory.
- Beside the cortical structures involved in reading other areas also play a role.
- The pulvinar of the thalamus sends signals about sudden, unpredicted, motion in the environment to the cortex.
- Neuroimaging studies show early involvement of the thalamus in reading tasks before signals enter the cortex.

The role of implicit memory in reading

- Long-term memory is divided into two systems: a) explicit or declarative conscious recollections of events and facts, and b) implicit memory; instructions on how to do things.
- Explicit memory includes personal recollections (episodic memory) and conscious knowledge of facts (semantic memory).
- Implicit memory includes memory of procedures (procedural memory), priming, conditioned responses, and habituation to the environment; social learning and

adaptive imitation also form parts of procedural memory.

- Implicit memory reconfigures functional networks of the brain early on, creating focal points at the cerebellum, the basal ganglia, and related subcortical structures.
- One important feature of implicit memory is task specification, which suggests that training for one script does not transfer to another.
- Letters and words taught to adults seem not to transfer completely into implicit memory; rather, they remain in semantic memory, which is vulnerable to forgetting.

Statistical learning of visual stimuli

- Statistical learning is a fundamental brain mechanism that extracts and represents regularities within our environment.
- It results in faster and more accurate responses to high conditional probability events compared to those of low conditional probability ones.
- Neurons in the later parts in the parvocellular ventral visual stream are tuned to increasingly complex combinations of visual features; they are related to the extraction of regularities from the visual environment (often without awareness) and they can identify which image features tend to appear together.
- For dyslexic people, the impairment limits their ability to identify which visual features tend to go together. Thus, neurons in the ventral visual stream usually shaped by such learning will not effectively support visual word and object recognition.
- There is a positive link between reading ability and statistical learning in the general population.
- Neo-literate adults experience difficulties related to statistical learning and possibly prediction of speed.

Perceptual learning: letters as objects, then words as faces

- Perceptual learning is a sustainable, long-term performance improvement of a perceptual task following training or visual experience.

- Perceptual learning effects are best understood as a change in the ability of higher-level integration or association areas to assimilate sensory information in the service of certain decisions.
- Perceptual learning seems to have an evolutionary value for animals and mainly occurs without effort in the implicit memory system.
- People typically think of reading in terms of language; however, reading is a perceptual process.
- In nearly all writing systems, visual stimuli must be coupled with associated sounds.
- Perceptual learning competently links visual symbols and sounds, particularly when they demonstrate one-to-one correspondence.
- Fluent reading requires unambiguous deciphering of a text in milliseconds.
- A temporal window in early life exists, which is a critical period during which the visual system is highly plastic; it is subject to a major rewiring that leads to the acquisition of important visual abilities.
- However, it is possible for an adult to acquire a new skill after the critical period.

Feature integration in perceptual learning

- Spatial attention seems to bind visual object features that co-occur at the same location and integrate them into a coherent object representation.
- When multiple objects are simultaneously present in a scene, the visual system must correctly integrate the features associated with each object and separate them.
- The processes underlying feature integration create a *gestalt* phenomenon: circles that are almost closed are seen as completed, and interrupted lines are seen as whole; bottom-up processing evolves into holistic

processing as different parts are joined into a whole.

- Aging brings about changes in the ability to concentrate on one item while ignoring others.
- Age also seems to restrict visual working memory; thus, fewer features are identified at one time and whole shapes may not be easily detected.
- Line terminations and horizontals appear to be the two most important features for letter identification.
- The multiple accounts of inefficient reading acquisition beyond adolescence suggest the existence of a sensitive period affecting the early parts of the visual system, feature integration, or face recognition.
- Sensitive periods affect certain perceptual and motor skills early in life.
- Higher-order functions pertaining to abstract thought (such as analysing or learning grammatical rules) are not particularly sensitive to increasing age.
- The hypothesised sensitive period(s) affects implicit memory; thus, the reduced plasticity of a low-level function may affect complex behaviours upon which it depends.
- A sensitive period for reading automaticity is reminiscent of language learning in childhood.
- Many people who learn of neo-literate adult dyslexia (NAD) believe it should be expected given the difficulties experienced by adults when learning languages.
- Effortless, implicit, language learning during youth declines, but explicit memory and complex cognition can take over.
- Processing speed peaks in a person’s late teens and starts to decline at approximately 25 years.
- Visual reproduction peaks before the age of 20, while visual search and short-term memory for faces and family pictures and visual recognition all peak at approximately 20 years.
- Research shows the involvement of the visual word form

area (VWFA) of the fusiform gyrus in recognising words (reading), musical notation, and numbers.

- The face recognition function provides flexibility in recognising words; we identify cursive and decorative letters, just as we identify people in profile and sideways (with or without long hair).
- In all cultures, people use the same brain structures to read.
- Depending on the orthographic depth and type of script, the activation patterns may differ, although the same principles apply.
- Approximately the first 170 ms of the process are visual; linguistic information and comprehension are added about 0.5 s later.
- From the VWFA, electrochemical signals of the visual stimuli move to areas connected to phonology and to meaning; fluent readers receive almost instant feedback about sounds and meaning through recurrent loops.
- The neural signature of dyslexia is a disruption of the posterior reading system.
- Some research suggests that developmental dyslexia involves deficits arising from the workings of the magnocellular layers of the lateral geniculate nuclei in the dorsal visual pathway.
- People with dyslexia have disruptions in the connectivity of neuronal bundles of neurons that link the visual cortex to the VWFA.
- Dyslexic readers are impaired in their recognition of faces and other complex objects and show hypoactivation in ventral visual stream regions that support word and object recognition.
- People with dyslexia tend to present early signs (such as white-matter deficits) in children that are clearly not shared by non-dyslexic readers.
- Illiterate people who perform worse than those who are literate on visuo-spatial tasks and who exhibit less consistent visual scanning paths demonstrate

difficulties in discriminating between mirror images. They maintain a holistic mode of visual processing rather than adopting analytic strategies.

Performance of unschooled illiterate people during or after reading instruction

- When illiterate adults are taught, their brain reorganises to accommodate the new skill; however, the activation patterns only partly resemble those of individuals who learned literacy during childhood.
- Illiterate adults can learn to decode, but can only read laboriously and deliberately.
- Most studies show that the ventral pathway is not engaged (or is engaged insufficiently); the VWFA is not consistently or sufficiently activated.
- Some studies show that reading speed is related to the intensity of arousal observed in the VWFA.
- Moreover, brain imaging demonstrates that neo-literate people engage brain areas associated with effortful serial reading of letters, much like dyslexic people.
- In comparison to childhood literates, neo-literate adults demonstrated anatomical connections linking the left and right angular and dorsal occipital gyri through the area of the splenium of the corpus callosum; it was found that white matter in these brain regions was more dense in late-literate than illiterate people.
- Some studies revealed decreased grey matter intensities in functionally illiterate people compared to normal readers in several reading-related brain regions, such as the superior temporal gyrus, supramarginal gyrus, and angular gyrus.
- The findings suggest that poor literacy skills are associated with several structural abnormalities in reading-related brain areas.
- This also suggests that adults who read fluently, but slowly, may improve reading skills with training; then,

structural brain differences disappear.

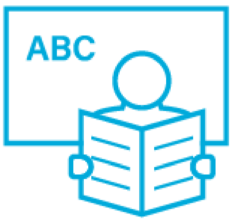
Educational programmes for teaching illiterate adults: results

- Poor results in adult literacy instruction appear to be due (in part) to ineffective instructional methods.
- Generations of university students have been trained in the belief that adults are self-directed learners who need a facilitator rather than a teacher.
- One common sense idea has been to focus on the meaning of texts and their relevance in adults' lives.
- Textbooks are typically short, with large pictures and small letters, and learners are often encouraged to talk about their social situations rather than read.
- For example, a UNESCO-sponsored Freirean method (REFLECT) in Burkina Faso saw learners score 2.4 out of 10 in text reading.
- Many studies have shown that instruction on individual letters and associated sounds engender much better results than an early focus on meaning.
- Better reading performance depends on phonological awareness, letter recognition speed, and verbal reasoning.

Where are neo-literate adult dyslexia deficits located? Some hypotheses

- When children start reading they rely on the dorsal pathway.
- As they attain fluency, processing shifts to the ventral pathway that offers a direct print-to-meaning connection.
- The dorsal pathway locates the symbols in space and sequence. This seems related to phonological activation (letter-by-letter reading).

- The dorsal stream relies on the right parietal lobe, which is critical in visual working memory.
- It is possible that a restriction of visual short-term memory results in fewer features being identified at one time after a certain age.
- The origin could be at an early stage in the visual system; for example, the lateral geniculate nucleus and the V1 area of the occipital lobe. This area is activated by spatial cognition tasks and episodic memories and is heavily implicated in both spatial and object-based forms of contextual/predictive processing and associative learning in scene perception.
- A critical area may lie between the thalamus and along the dorsal path, including the input neurons from the thalamus to the parietal cortex.
- It is also possible that it could be in the spatial attention network of the parietal cortex.
- The parietal cortex is involved in spatial attention and binds features into larger shapes when the features are shown simultaneously at different locations.
- Another suspect area may be the ventral occipitotemporal cortex that integrates visual input with higher-order experiences.
- Furthermore, temporoparietal connectivity may develop deficits.



Conclusions and implications

The research highlights some issues that are relevant to policy and instruction, as follows:

- Difficulties with literacy are perceptual rather than linguistic.
- The suspected problem seems to lie somewhere along the dorsal stream.
- A sensitive period may involve declining circuits but also oscillations of brain waves that are out of sync with the neuronal groups where a signal is to be transmitted.
- Interviews with educated neo-literate adults suggest that the problem becomes significant by the age of 18 years approximately and deteriorates thereafter.
- Clearly, some people perform better than others, as suggested by perceptual learning research.
- Larger visuospatial memory may help, and some people may have better genetic connectivity among various regions.
- A slightly larger VWFA and/or an enhanced ability to recognise faces may compensate for upstream deficits.
- Exceptional executive functions and perseverance may also help maintain effort.
- The qualitative information available on educated readers and quantitative data on unschooled neo-literate people who have sought to learn to read suggest that we all become dyslexic toward new scripts by the age of 19 years approximately.

Instructional and policy implications

- Research suggests that because of being unschooled earlier in life, illiterate adults have shorter working memory, phonological awareness deficits, and language processing limitations.
- They are often poor and from rural populations.
- Given current knowledge, hundreds of practice hours are needed to automatise a script, and learners may possess neither the time nor the materials.
- Complicated literacy instruction requires extensive training of poorly paid instructors who may be expected

to plan lessons, complete administrative tasks, and test students, while often being poorly educated themselves.
- To avoid these problems later in life, children should acquire fluency by mid-adolescence.

Potential remedies for performance improvement

- Hundreds of practice hours are needed to streamline the output of brain circuits that carry the various signals.
- Transparent orthographies are clearly the simplest to teach and practice.
- Reading instruction should build and optimise each of the tasks that seem to affect the dorsal stream.
- This suggests first adopting approaches that optimise visual perceptual processes and matching them with sounds until they are automatised, taking only a few milliseconds to process.
- Intensive courses involving extensive perceptual learning practice (longer than 30 min at a time) with short breaks are recommended.
- Learners should spend most class time in individual practice and do homework if possible.
- Teaching and practicing letters, one by one is recommended.
- Every learner should have a textbook with (for example) 10,000 words of text in spaced and large letters from which to practice.
- It should be ensured that characters are large and spaced, gradually decreasing in size over time.
- Repeated reading practice is required to increase speed.
- Practicing within 3.5 hours following formal class instruction may facilitate consolidation.
- Using mnemonics and memorisation techniques to facilitate long-term consolidation (at least in explicit memory) is recommended.
- Multisensory methods, such as touching letters in relief, help adults connect shapes and sounds more than

just visually.

- Focusing on stimuli for extended periods is recommended.
- Learners should practice extensive writing, including copying and dictation.
- Facilitating feature integration by guiding students to letter locations is important for discrimination.
- Using computer media can help as many techniques and methods are best delivered through computers, cell phones, and tablets.
- The dorsal system should be prepared for reading through exercises to detect coherent dots motion.
- Learners should practice perceiving moving small objects in low-contrast lighting conditions.
- Fast action videogames may evoke emotions and thus consolidate shapes into implicit memory.
- Stimulating the vagus nerve may speed up consolidation of individual letters.
- Auditory practice of the same skill is recommended to continue learning.
- In the past, essential fatty acids have been shown to offer some effectiveness in improving children’s reading skills.