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Review Article

Can Adults Become Fluent Readers in Newly Learned Scripts?

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Adults learning new scripts have difficulty becoming automatic readers. They typically read haltingly, understand little of what they read, and may forget letter values. This article presents the hypothesis that halting reading among adult neoliterates is due to low-level perceptual functions in the brain that have a sensitive period. These may be related to feature integration; whether illiterate or educated, adults learning a new script may be perceiving letters as connected segments rather than unbreakable units. The time needed to resolve ambiguities and determine how the segments are combined may delay identification and result in letter-by-letter reading. This phenomenon could be called "adult neoliterate dyslexia." It has received little research or attention, possibly because few adults need to learn new scripts. Also unschooled illiterates are rare in industrialized countries where most reading studies are carried out. Research is needed to probe into the neuropsychological origin of the adults' fluency difficulty. Potential remedies may include action videogames and thousands of trials through computerized media.

1. Introduction

There are at least 800 million illiterates on this planet [1]. For decades governments and international donors have financed adult literacy programs for the unschooled populations of low-income countries, in hopes that the poor will read information that may improve their lives. Literacy curricula use various formats. Some teach literacy only (300–900 instructional hours), while others include arithmetic and activities aimed at income generation (see [2] for a review). But one characteristic that programs have in common is disappointing results. Few learners acquire usable and stable literacy skills.

A 1970s evaluation found that roughly speaking, about half of those who completed a course passed performance criteria, and about half of those passed later lapsed back into illiteracy [3]. In the 1990s, the international donor community made many efforts to design culturally suitable courses and finance nongovernmental organizations that specialized in adult literacy. However, performance remained modest. A 2002 review of World Bank adult literacy projects and other evaluations found that only about 44% of participants passed the course examinations, while 12–60% of them lapsed into illiteracy [4].

Adults of lower-income countries are certainly interested in learning, and many flock to literacy courses when they are available. But over time they continue to read haltingly. For example, after successful training, Ugandan learners could read only 2-3 paragraphs and answer a few questions but not read volumes of text [5]. Illiterate foreign adults in Germany who signed up for a year-long literacy course improved in phonological processing variables but did not attain the level of literate people [6]. Learners in Burkina Faso who had successfully completed a literacy course read more slowly and less accurately than second graders in both Burkina Faso and the United States (about 2.2 seconds per word and 80–87% correct; [7]). Fluency is necessary for comprehension; due to the limited capacity of working memory, halting readers may forget by the end of a sentence what they read in the beginning. Inability to function as a literate person may lead to disappointment and dropout.

Likely explanations for the learners' poor performance have centered on social reasons: poverty, time and resource limitations, lack of reading materials in rural areas, or lack of relevance to learners' lives [1]. These issues are difficult to remedy through specific programs, so donor agencies have all but abandoned adult literacy. To cut costs and maintain access, adult literacy agencies of low-income countries often rely on volunteer teachers, supervise poorly, and cannot document outcomes sufficiently. The UNESCO Institute of Lifelong Learning has worked hard to maintain interest in adult literacy and find solutions, but the outlook is dim. Six International Conferences on Adult Education (CONFINTEAs) and a Global Report on Adult Learning and Education (GRALE; [1]) attest to the policy dilemmas besetting adult literacy worldwide.

The limited interest by donor agencies since around 2000 has also eliminated funding for research. Thus, few studies have explored how unschooled adults acquire reading or how to improve instructional efficiency. Some academics remain interested, but they tend to be in adult education departments and may focus on the sociological or ethnographic aspects of literacy (see e.g., [8]).

Social factors are certainly important [9] but do not adequately explain the learning difficulties of neoliterates. In the same environments, children who attend effectively run schools may become fluent readers after a few months and may even maintain fluency if they drop out later [10].

The performance of the neoliterates has curious similarities to that of a very different group: educated people who master in adulthood languages that have scripts different from their native scripts. These may be staff of international organizations, civil service agencies, volunteer graduates, private sector, or universities who need language such as Thai, Hindi, Nepali, Arabic, Bengali, or Amharic. These learners are often highly educated people with sophisticated phonological processing skills. Many acquire a high-level command of the languages and may live abroad for extended periods. However, they report protracted difficulties in reading: limited fluency, high error rates, dependence on sounding out to understand meaning, and tendency to forget letters soon. Interviews with educated "neoliterates" show the following difficulties [11].

(a) Relative Ease of Learning Individual Letters. Adults can certainly learn letter shapes and do so within a few days of instruction. However, they tend to identify them slowly, one at a time. Complex shapes take longer to discriminate from similar shapes, and artistic letters or simple handwriting are hard to decipher. In particular, the connected Arabic letters that change shapes in different combinations may be quite hard to decipher quickly; matching the location of dots with the underlying letter shapes in Arabic becomes a perennial puzzle. Dense writing is harder to decipher, as is with dyslexics [12].

(b) Limited "Chunking." Words of 2-3 letters and very high-frequency words may be recognized immediately, but the rest must be deciphered letter by letter. The foreign readers see jumbles of letters rather than the effortless print of the script(s) they learned in their youth. They seem unable to create a visual dictionary that bypasses sound (as in [13]). Thus every word must be read out, and readers cannot scan for needed information. When asked to read aloud a text of known vocabulary, foreign readers often read haltingly. They show a "word length effect"; that is, they take longer to read longer words whereas automatic readers read long and short words in about the same timespan. Speed may increase after practice, but it may drop again if reading stops for a few days.

(c) High Error Rates. Errors seem to be one more hallmark of neoliterate adults. Readers who know the languages can predict likely words, but predictions are often incorrect. This is because some letter details may not be processed. Certain letters may be recognized faster than others, and readers may perceive them first, often coming up with guesses that include the letters in a scrambled order. The errors and slow identification result in wrong interpretations and much dependence on context. It is thus impossible to read volumes of text.

(d) Self-Limiting Reading Practice. Lack of automaticity may persist for decades. Perhaps automaticity is achieved after years of consistent practice, but laborious decoding is aggravating and may lead to avoidance. Unlike automatic readers who cannot help but read the text they see, neoliterates may constantly pass by street signs and just ignore them unless they really need the information. Thus, reading fluency may fail to improve and may even deteriorate despite constant exposure to print.

This situation has been a personal preoccupation for the author, who is a polyglot and has studied nine scripts in adulthood. Interviews over a period of 20 years suggest that *everyone* who becomes fluent after the age of about 17 may be affected. Even after decades of speaking and obligatory use of print, reading may remain slower and not enjoyable. The educated learners felt they had not studied hard enough, were not sufficiently motivated, or that they were not smart enough. Many have been embarrassed to disclose their deficits, and others made up excuses. For example, a Sanskrit scholar who was asked to read a sentence in Hindi said that he could only read the Devanagari script in Sanskrit. (Given a few extra moments, he looked at the text more carefully and decoded it.) Remarkably, even reading specialists from high-income countries who ought to become fluent in the scripts they work on in the developing world (such as Khmer or Arabic) have failed to learn or avoided the task.

If there is widespread difficulty in attaining fluent reading among literate or illiterate adults, why is this phenomenon unknown? These issues have been rarely reported in publications. Multiple explanations are possible. Attribution of illiterate learners' failures to sociological factors has stopped further exploration. At any rate, unschooled illiterates are rare in high-income countries. Educated "neoliterates" are also rare, since most languages are written in the Latin script. Furthermore script decoding problems may be attributed to language limitations by the foreign readers. For all these reasons, "adult neoliterate dyslexia" has not yet been studied.

In the last decade, much has been learned about the neuroscience of reading, memory functions, and brain plasticity. Insights from this can help pinpoint the problem precisely and perhaps lead to methods that can help automatize reading. This paper uses existing research to formulate hypotheses about the nature of the problem. Research pertinent to the performance of literate and illiterate adults is presented. As is shown below, the two populations may have important differences, but the source of the problem may ultimately be the same.

2. Neurocognitive Research and Its Implications for Adult Reading Automaticity

At its most basic form, reading largely involves "low-level" neurological functions and requires reactions that must occur within milliseconds. Learning to read involves perceiving the letters as distinct shapes, instantly telling each one apart from the others, and instantly connecting the shapes to sounds. Our mind chunks letters into syllables progressively; bigger chunks of letters are formed incrementally by mastering and combining smaller chunks.

Fast reading is necessary because our working memory, which has limited capacity, must be able to retain a message long enough to make sense of it. Therefore, texts can be understood only after the visual signs have been interpreted and a minimum reading speed has been attained. (This seems to be about 1–1.5 words per second or 45–60 words per minute for about 80% comprehension of simple text; see Abadzi and Prouty, forthcoming, for a review). Sustained practice decreases reaction time to letters until a certain area in the brain is activated. That area (commonly called the visual word form area, VWFA in the fusiform gyrus) processes words as if they were faces and enables the decoding of multiple letters simultaneously[1]. When activation exceeds a certain threshold, reading speed rises abruptly. The use of a shape or face recognition device for reading has certain implications. Not only are entire words recognized, but there is also perceptual constancy; people recognize handwriting just as they recognize faces that have been altered. Habituation to deviations, such as degraded faces, takes placed within a few hours of training and is retained for the long term [14, 15]. These processes are necessary for all humans, and take place in all languages and scripts. (See e.g., [16–18].)

To perceive letters, people initially process their individual features and integrate them [19]. This function involves the ventral occipitotemporal cortex, a circuit that runs across the VWFA. Sensory input to this area is integrated with higher-level associations derived from prior experience, such as speech sounds, actions, and meanings [20]. Connections must be made correctly and in milliseconds in order to process volumes of text.

Object recognition researchers have studied the effects of script learning. Pelli et al. [19] tested observers ranging widely in age (3 to 68) and experience (none to fluent) with many scripts (including English, Arabic, Armenian, Chinese, Devanagari, Hebrew). They used three- and five-letter words, various types of fonts, sizes, contrasts, durations, and eccentricities. They found that foreign alphabets are learned quickly; in just 3000 trials, new observers attained the same proficiency in letter identification as fluent readers. However, the observers did not recognize random strings of these characters. They performed as poorly as observers seeing them for the first time. Moreover, learners recognized only 1-2 letters per saccade, while fluent readers recognize about 5 letters per saccade. This could be expected, since readers had not been trained to chunk letters together. The purpose of the study was to determine features of letter identification, so insights about words could not be given. But the study offers the encouraging finding that adults can be trained to perceive individual letters very fast.

The process of integration can be disrupted, as in the case of people suffering from a brain damage type called *alexia*. Alexic patients can only read letter by letter; they confuse letters easily and take a long time to do so. They may read a 3-letter word in about 2 seconds and longer words in 4–6 seconds each, making it difficult to hold an entire sentence in working memory. They can only hold one or two letters in their visual span [19, 21–24]. Clearly this pathology does not afflict neoliterates, but it may help point to pathways where the problem originates[2].

The various stages of reading acquisition have been probed through neuroimaging. Some of the research has been conducted using some of the few remaining unschooled illiterates, mainly in Portugal. The studies show that the schooling process changes brain architecture in multiple ways, linking speech and visual areas [25, 26]. The schooling process includes many tasks besides literacy, but it seems to create differences in the ways the two brain hemispheres share functions. For example, the corpus callosum of adult illiterates was thinner on the section of interparietal crossing compared to literate adults and did not grow when they became neoliterate [27]. Studies also showed a close connection between reading and writing when learned in childhood, but adults seemed to be copying internal images of letters and words and did not develop proprioceptive memories [28]. On the other hand, some educated adults who learned a script around age 19 reported writing fluently, despite reading difficulties.

These limitations suggest that unschooled adults may find it hard to attain the reading and writing fluency of children. However, educated adults learning new scripts have these circuits in place, so the missing circuits do not prima facie account for the missing fluency. This research implies therefore, that unschooled adults may face multiple obstacles at various points in the reading process. They may have neurological obstacles from brain organization as well as perceptual obstacles.

Nevertheless, the brains of adults learning to read (whether for the first time or for a new script) do show activation of the VWFA. Hashimoto and Sakai [29] taught a few Korean letters to Japanese subjects who were monitored through functional magnetic resonance imaging (fMRI), a technique that measures brain activity by detecting associated changes in blood flow. In two days, the VWFA showed increased activation when letters were linked to sounds, and the degree of activation predicted individual performance improvement. Dehaene and Cohen [16] found similar activation among unschooled illiterates who were taught to read. The researchers tested Brazilian and Portuguese illiterates, ex-illiterates who were taught to read, along with people made literate in childhood. Reading speed was related to the intensity of arousal observed in the VWFA. Thus, the VWFA was found to be highly plastic, even in adults, and quickly enhances its response to letter strings as soon as the rudiments of reading are in place [30–32]. However, the Brazilian and Portuguese neoliterates who were studied read more slowly than people made literate in childhood and showed less arousal intensity in that area. They only read 10–25 words per minute compared to 60 or more for childhood literates. Moreover, brain imaging showed that they engaged brain areas associated with effortful serial reading of letters[3].

The data from Dehaene and Cohen [16] suggest that neoliterates may read effortlessly if the VWFA is activated more intensely (Figure 1). The question is how much more practice it takes to obtain that and what obstacles stand in the way of adults. Some hypotheses are explored below.

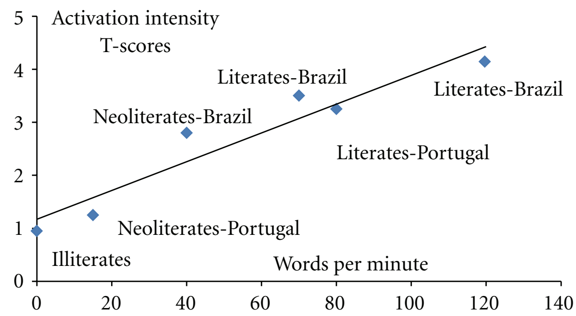

Figure 1: Activation of the visual word form area as a function of reading speed (adapted from [16]).

Figure 2: Trajectory of sensitive periods (adapted from [33]).

3. Adult Neoliterate Dyslexia: Hypotheses and Research Questions

One possible avenue to explore in understanding the problems of the neoliterates is brain plasticity. The properties of critical periods or “sensitive” periods are now becoming better understood. Higher-order functions pertaining to abstract thought, such as analyzing or learning grammatical rules, are not very sensitive to age changes; people can learn the reading strategies or even letter shapes in old age. However, some low-level perceptual stimuli and motor skills are affected by sensitive periods early in life ([33]; Figure 2)[4]. And the reduced plasticity of a low-level function may affect complex behaviors that depend on it. The acquisition of literacy relies on low-level perceptual skills, so it is possible that a sensitive period affects certain components.

Some circuits related to visual integration are known to have a sensitive period. For example, children with cataracts who were deprived of good visual input from faces before the age of 6 months showed lasting impairment in acquiring “configural” face processing skills, an expert level of face recognition involving the integration of facial features [34]. Other areas may also have such effects[5]. One “suspect” area may be the ventral occipitotemporal cortex, that integrates visual input with higher-order experiences. Adult neoliterates seem stuck at the point of maximal activation that is recorded for this area: ability to make predictions but with high error rates and effort [20, 35]. It is possible that some circuits involved in this process have a sensitive period, and transmit information too slowly or inefficiently[6]. Script features may just not arrive fast enough to be perceived as entities in the visual word form area.

What can be deduced about these circuits? Some research suggests that children below age 12 perceive visual information differently than adults [36]. The learners’ perceptual difficulties offer some hints. Children may see letters as *unbreakable units* (see the unitization concept in Goldstone [37], but adults may find it hard to identify instantly deviations from standard fonts. The author believes that neoliterates see the new letters as consisting of multiple features or components. It is known that people recognize letters from features which must detected rigorously and individually [19]. Neoliterate adults may be recognizing these features inefficiently within the time reasonably available for reading, skipping some of them. The missing features then result in incorrect interpretations.

For example, the Arabic shape for jeem has versions with a dot above, below, and without a dot (Jeem, ha, kha خ ح ج) The children may automatize the entire shape that includes the dot in a specific position. Then they may follow the transformations of that shape, looking for the dot far above or below the main shape. By contrast, adult neoliterates may see a basic jeem shape in three versions according to dot placement. Deciding which version it is requires time and is prone to errors. And somehow the components do not get integrated after additional practice. This lack of integration into one shape may also make readers prone to visual illusions, such as the gestalt forms. Some Arabic fonts thicken the bottom parts of letters, creating the impression of a line that splits the letters. Similarly Devanagari and other north Indian scripts create an illusion of a line above the characters. Automatic readers do not notice these features, but neoliterates puzzle over breaks on the top line of Indian scripts or cannot decide which Arabic letter carries a set of dots. A few milliseconds’ lag in recognition per letter may add up to significant reading difficulty.

Perhaps age delays the recognition of other objects learned in adulthood. But the delay may be in the order of milliseconds and not noticeable with individual objects. However, reading involves scores of objects. Hundreds of instant discrimination tasks are needed among minimally different shapes, and the milliseconds may add up to significant delays.

Other examples may exist of potentially diminishing automaticity to multiple visual stimuli. One candidate is musical notation, which requires parallel processing similar to reading. Yet another may be the automaticity of air traffic control patterns. Perceptual speed has been shown to be negatively correlated with age. In highly speeded tests, age influences the ability to identify solid figures made from an unfolded pattern and similarities in drawings of objects [38]. Commonly the maximum training age for air traffic control is 30. And the neural circuits involved seem to influence visual perception specifically. Auditory perception may be unaffected; for decades, thousands of adults learned to decipher Morse code messages adeptly.

What is the long-term outlook for improving reading fluency? The author's personal observations over 25 years offer ambivalent prospects. Three Burkinabés who learned to read in their 20 s could read newspapers fluently in the Mooré language but had trouble reading their own handwriting. The author's unschooled aunt learned to read in her 40s, spent a lifetime in a Greek city surrounded by print, and yet could only decipher slowly when she was 100. The vast majority of the educated neoliterates professed continuous poor skills. Some had lived in the environment of the relevant scripts for only a year or two, but others did so for decades. A highly fluent resident of Bangladesh for 25 years read like a second grader and got embarrassed when people gave him papers to look at. Three civil servants from Laos and Egypt had studied in the United State and the former Soviet Union and learned the Latin and Cyrillic script in their late teens. They read proffered documents slowly and in a loud voice, perhaps no faster than 60 words per minute. Two Greek acquaintances who had studied and lived in Israel for 30-40 years reported reading mainly when necessary, while two others reported complete reading ease.

An indicative example pertains to an American family that has spent decades in Greece. The father moved there as a youngster in the 1930s and spent most of his life in Greece. However, he was sent to German schools and spend some of his adolescence in the United States, so he was never explicitly taught to read in Greek. Up to his old age, he professed not to be comfortable reading Greek, though the script shares many letters with the Latin script. By contrast, one of his children attended a Greek-medium school only in grade 1, where he learned fluent reading. He left Greece at age 16, but maintained reading fluency into his 50s.

The oldest person who claimed to the author to become automatic in a script learned as an adult was a translator to a Tibetan Lama; he reportedly started learning Tibetan when he was 19.

From the impressions obtained by the author thus far, the difficulty may become significant around age 17, but its subsequent trend is not predictable without quantitative data. Some people may be better at integrating components and acquiring automaticity at later ages, but ultimately everyone seems to be affected. Surely the ability to automatize is a function of practice, but the amounts of practice needed to attain fluency past the teen years may often turn out to be unattainable.

There is research aiming to reverse sensitive periods, but it is in its infancy. Action videogames have been found to be effective in changing feature perception and developing discrimination of shapes [39]. In some cases, alexia patients have been known to improve from letter by reading, and right-hemispheric structures eventually developed alternative connections to compensate for the disrupted VWFA [22]. Potential treatments would include hints from alexia and dyslexia treatments, such as multichannel inputs, exposing a visual pattern to the eyes for a long time, increasing the contrast between letters and background by putting computer-generated frames around each word read, or same-language subtitling with words shaded when they are heard. Thousands of trials in developing feature integration may make a difference, probably through computers rather than print. One might expect that adults who consciously and diligently engage in practice may eventually achieve automaticity. Neural plasticity may be reduced after childhood in certain parts of the brain but does not disappear entirely.

The above discussion leads to a set of research questions that future studies may address. The following are some of them.

(i) Are there indeed neural networks involved in visual perception that have sensitive periods and affect reading fluency? How do they bring about this effect? If so at what rate does their function decline with age?

(ii) What methods or treatments may effectively improve reading speed among adults learning to read? Are computerized modes of delivery with thousands of trials effective in bringing about automaticity? Would more futuristic treatments offer promise, such as transcranial magnetic stimulation or fast action videogames? [39, 40].

(iii) How does the top reading speed that people can develop vary by age of literacy acquisition? If students, for example, become literate at age 15 rather than the usual age of 6 will age limit the top speed they can develop?

(iv) If effective literacy acquisition programs are used, at what rate does the VWFA become activated in adults learning a new script? How does the activation intensity relate to words per minute read in various languages and scripts?

(v) How important is the advantage of language knowledge in automaticity acquisition, given the apparent importance of perceptual factors?

(vi) Unschooled adults typically are native readers and may have better language command than educated foreigners learning a new script. If both populations receive effective literacy programs, what differences in speed and sustainability of literacy will be found?

(vii) Given an effective instructional method, about how many hours of instruction would an average child require in a particular language to attain 60 words per minute compared to an average unschooled adult?

4. Adult Neoliterate Dyslexia: Conclusions and Implications

The problems of adult neoliterates suggest that all people become "dyslexics" for new scripts after adolescence. Ultimately all people may suffer from "adult neoliterate dyslexia". Fortunately most people of middle-income countries will not need this evanescent skill after their childhood.

But in low-income countries the difficulties may continue. Life expectancy among the poor is increasing, and many children drop out of school illiterate. The need to serve adult illiterates, therefore, is critical. Ability to read and process information rapidly may lead to decisions that could have a life or death influence over people and their families.

To design youth and adult literacy programs as well as instruction programs for the diplomatic agencies worldwide when different scripts are concerned, it would be crucial to understand the multiple obstacles likely to be faced by this population. The unschooled may face not only issues at the perceptual learning level, they also have brain organization issues to contend with. Targeted research is needed to explore how far these populations can be pushed to achieve.

As a message, the hypothesis that adults cannot easily acquire fluency could be viewed as the final tombstone of adult literacy. However, it is not. It is akin to someone suffering from unspecified problems who finally gets a diagnosis. If the problem is manageable, the person will get better. And if it is not currently manageable, research still opens the door to cures in the future. Thus, facing this reality may turn out to be beneficial.

Issues pertaining to sensitive periods must be disentangled from instructional deficiencies. People seem to learn best through explicit instruction and phonics, with plenty of practice and through materials that are sufficiently readable [41]. But adult literacy programs are often developed on philosophies of andragogy and on the whole word approach. Many have unrealistically short duration (such as 300 hours) and are beset by absenteeism, poorly trained staff, very low budgets, dependence on volunteers, and textbooks unsuitable from the standpoint of reading acquisition [1]. So the neurocognitive issues are confounded with the effectiveness of adult literacy programs. Nevertheless, the problems of educated adults suggest that the difficulties of the unschooled are real. Perhaps they require programs that are three times longer than the current ones, but this is only a guesstimate.

Sufficient attention to illiterates' learning needs costs money but may get much better outcomes than the usual informal courses run by volunteers. For example, the South African Kha Ri Gude literacy campaign spent US$60 per student and has gotten retention rates of about 85%[7]. But decisionmakers need to become convinced that the expense will be worth the outcome. Many may have an intuitive sense that adults cannot do the work expected and may withhold funding. This is why learning more about the essential issues and specifying them may facilitate rather than hinder the financing of literacy. The studies to be conducted cannot be only educational. Neuroscience and psychophysics expertise is needed.

Interactions between automaticity acquisition and language can be studied through various experimental designs. Subjects would be students in local universities taking advanced classes in languages such s Arabic, Hindi, Russian, Korean, or Japanese. Some languages are written in two scripts, and readers of one can learn the other script. This method would minimize language mastery issues. For example, Hindi and Urdu (essentially the same language) are written in the Devanagari and Arabic scripts. Indian students could learn the Arabic script and Pakistanis could learn Devanagari to find out how quickly automaticity develops. (Also Wolof and other African languages are written in the Latin and in the Arabic scripts). The university students are a selected population that may find ways to compensate the low-level neural processes, but essential parameters may be thus studied in a convenient location.

With respect to schooled illiterates, research ought to take place in the countries where they reside. Repeated measurements would give information on incremental fluency changes as literacy skills change with instruction. Portable event-related potentials (ERP) equipment could also be used in this research. (At the time that this paper was being written, a doctoral dissertation was in progress using this method.). Better understanding would facilitate targeted interventions. In the short term, these would be instructional solutions. In the future it may be possible to improve the learning curve through interventions on the neural plasticity mechanisms. Pharmacological solutions could potentially become available.

Finally, the debate on sensitive periods has an important implication for education during students' school years, particularly in low-income countries: perceptual discriminations on which later academic skills rely must be automatized early. Even so, there is some risk that skills will be lost if early exposure is not followed up by continued use [33]. This means that children must become fluent readers while in school and not drop out illiterate, as it happens so often in low-income countries. By the time they become adults and join a literacy course, it may be too late.

Disclosure

This document exclusively represents the author's personal views and does not imply endorsement of the World Bank or Global partnership for Education.

Endnotes

1. Neurons in the fusiform gyrus detect fine-grained distinctions among stimuli that people are familiar with. There is a fast, coarse specialization for low-level letter-sequences and a specialization for processing letter sequences also at the whole-word level [42].

Thus this area supports perceptual expertise for visual word recognition and enables rapid perception of visual words. Children with dyslexia have deficits along the visual word-form system [43].

2. Alexia is caused by lesions affecting the prestriate cortex of the dominant occipital lobe (e.g., [22, 44]). It is possible to produce this effect in normal people by spacing letters too far apart, creating low contrast, and taking away gradient information though high-pass filters [44].

3. To achieve their modest reading performance, ex-illiterates engage a broader and more bilateral ventral network than literates and recruit additional posterior parietal regions associated with serial effortful reading. This observation is similar to the developmental finding that reading in young children initially involves a broad bilateral visual network that progressively restricts to the VWFA as greater expertise sets in [30].

4. Reduced plasticity may be due to various factors. Neuronal connections may be somehow depleted; initial learning (or lack thereof) may reduce the system's ability to detect changes in the environment that might trigger further learning [45]. Prior experience may place the system into a state that is nonoptimal for learning the new skill, and reconfiguring the system for a new task may take longer than it would have taken had the system been in an uncommitted state [45].

5. The visual system has a ventral "what" system and a dorsal "where" system [46]. Reading is most likely achieved through a collaboration of the two components of the cerebral visual system. The ability to read words stems from this general ability of the ventral stream to identify complex multipart objects. According to the local combination detector model, 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. In normal readers, the ventral pathway is traversed and a letter is identified usually within 150 ms [47].

6. See stage 2 in Price and Devlin [20] interactive account model.

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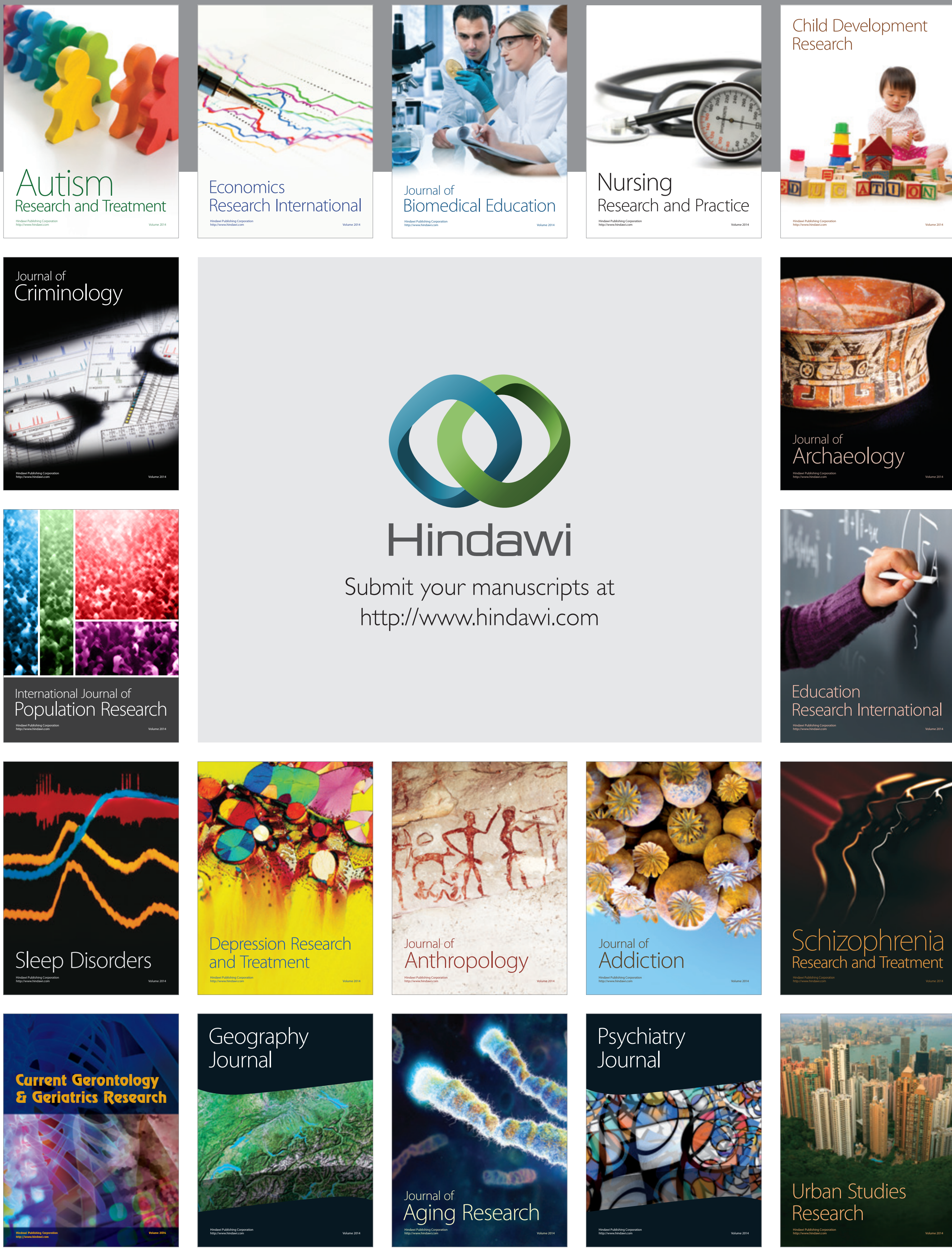
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