How literacy acquisition affects the illiterate mind

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Two influences on the human mind

1) literacy: the ability to read and write

2) characteristics of the particular writing systems(s) an individual is exposed to
Literacy – A historical perspective

- writing, a human cultural invention, is on an evolutionary scale a very recent occurrence

- moreover, until recently, literacy has been restricted to specific minority groups

- literacy was largely a preserve of the wealthy who could afford a formal higher education and the clergy
Literacy – A historical perspective

![Literacy Rate in India](source: 2001 Census of India)
- in England, 1840, about 40 percent of people still signed their marriage certificate with their 'mark' (usually an X or some other personalized sign) because they could not write even their own name
Literacy today → Illiteracy is not a thing of the past
Literacy – A historical perspective

→ until very recent times and throughout most of human history, cognitive processing was not influenced by processing and/or knowledge of written language

→ 1 in 5 humans today is illiterate

despite this almost all research in psychology and neuroscience has been carried out with literate participants
Writing systems

The unlabeled scripts of India are:
(west) Gurumukhi, Gujarati, Kannada, Malayalam,
and (east) Tamil, Telugu, Oriya, Bengali.
Different scripts – different mapping challenges

- a great number of symbols

-tree
-wood
-forest

→ few Chinese speakers are able to write all the spoken words they can understand

- many writing systems are hybrid systems
→ Japanese writing, for instance, is a mixture of Chinese characters and a syllabary (writing systems in which each character represents a consonant and the following vowel)
Different scripts – different mapping challenges

- ‘modified consonants’

→ Alphasyllabaries (or 'syllabic alphabets') such as the Indian Devanagari represent consonant and vowel sounds (with vowel sounds represented with diacritics, i.e. modifiers to the consonant symbols)

ने जंतर मंतर पर जन लोकपाल विधेयक और
विसल ब्लोअर

का k + a = ka    कु k + u = ku
Different scripts – different mapping challenges

- mapping one language to different scripts
  → Hindi (Devaganari script), Urdu (Arabic script)

same Hindi/Urdu poem
Different scripts – different mapping challenges

- no characters for vowels
→ Arabic, Hebrew

→ despite all this diversity in writing systems, the vast majority of research in psychology and neuroscience has been carried out with participants who can read Latin-based scripts only
What is the effect of differing levels of literacy and writing systems on the mind/brain?
Literacy & cognition: Early claims

- writing is an inhuman, alien technology which weakens the mind and has detrimental effects on memory (Plato)

- literacy led to explicit definitions of terms and logical analysis and by extension modern society (Havelock, 1963)

- writing facilitates critical debate and thinking (Goody & Watt, 1968)

- writing transforms spoken language into an object of thought and reflection (Ong, 1982; Vygotsky, 1978)

- the alphabetic system has often (mostly in the West) been regarded as a superior writing system (e.g., responsible for the intellectual dominance of Greek culture over other ancient cultures, Havelock 1976)
→ no experimental evidence to support such a claim
Literacy & phonological processing

*phonological awareness*: knowledge that all words can be decomposed into smaller segments and the ability to manipulate these segments

- proficient reading requires awareness of the compositional nature of the units of speech
  → arbitrary script characters must be mapped onto the corresponding units of spoken language
Literacy & phonological processing

Morais et al. (1979): 30 illiterates and 30 late literates who had taken part in adult literacy programs after the age of 15 were asked to add or delete one phoneme (e.g., /p/) of an utterance

- result of such phoneme addition or deletion was an existing Portuguese word or a non-word (e.g., 'alcaho' resulted in 'palcaho', or 'purso' in 'urso')

- only non-word trials provide information about participants’ segmentation abilities and phonological awareness because task can be done by searching memory for similar sounding words

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<th>Trials</th>
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<td>R</td>
<td>91 (33)</td>
<td>71 (13)</td>
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Mean percentages of correct responses for each type of trial, task, and group of subjects. In parentheses, the percentage of subjects who attained 100% of correct responses.
Literacy & phonological processing

“big”

“/b/ /i/ /k/ /ə/ /r/ “
Literacy & phonological processing

Morais et al. (1986): “while sensitivity to rhyme and analysis into syllables can develop up to some point in the absence of the experience normally provided by reading instruction, analysis into phonetic segments requires that experience”

Reid et al. (1986): contrated phonemic awareness of Mandarin Chinese readers who had no alphabetic knowledge with Mandarin Chinese readers with alphabetic knowledge

- phonemic awareness of Mandarin Chinese readers who had no alphabetic knowledge was similar to illiterates

- phonemic awareness of Mandarin Chinese readers who had alphabetic knowledge in contrast was similar to those of late-literate

→ it is the not the ability to read and write per se but the knowledge of an alphabetic script which causes the improvement in phonemic awareness tasks
Literacy & phonological processing

*pseudoword repetition*:
- uncertain whether tasks which tap explicit phonological processing such as phonological awareness tasks are ecologically valid (cf. Reis & Petersson, 2003)

- phonological awareness appears not to be necessary for speech communication

- pseudoword repetition is a task that is likely to require both explicit and implicit phonological processing

Reis and Castro-Caldas (1997): illiterates performed much worse than literates in repeating pseudowords but performed as well as literates when they had to repeat real existing words

→ illiterates' difficulty in pseudoword repetition may be caused by impaired processing at the level of sublexical phonological structure
Our literacy research in India (with Universities of Allahabad & Hyderabad)

- since 2009

→ with young adults
(illiteracy in India is mainly due to no or very little formal schooling as a result of poverty and other socioeconomic factors rather than deficiencies in individual social or cognitive abilities)

→ focus on online experiments
(rather than offline meta-linguistic tasks)

- prediction in language processing
- phonological processing
- cognitive efficiency (‘speed of processing’)
- visual search
Literacy (India)
Participants
Literacy & phonological processing

- phonological effects are typically transitory and dynamic in nature because phonological processing happens over very short periods of time

→ online methods which focus on moment-by-moment phonological processing are crucial

→ these methods allow the researcher to measure ongoing processing while participants’ task activities can continue without being interrupted
Literacy & phonological processing

Huettig, Singh, & Mishra (2011, *Frontiers*):
- 42 high literates (mean age = 24.3 years, 15 mean years of formal education, students)
- 32 low literates (mean age = 27.5 years, 2 mean years of formal education, workers)
- pre-test: reading 96 words (HL: 93.8 correct, LL: 6.3 correct)

**Visual world study:**

“… magar…”, crocodile

- semantic comp.: kachuwa (turtle)
- distractor
- distractor
- phonological comp.: matar (peas)
Literacy & phonological processing

- High literates (semantic competitors)
- High literates (distractors)

Change in $p$ (fixation)

Time from target word onset (ms)
LL do not map spoken words and visual objects at phonological level

Alternative explanation: LL did not retrieve names of pictures?
- but even 18-months-old infants do that (cf. Mani & Plunkett, 2010)

Experiment 2 - semantic comp. replaced with additional distractor: Can LL ever use phonological information to guide attention?
- 29 high literates (15 mean years of formal education) and 27 of the 33 low literates (2 mean years of formal education) who took part in Experiment 1

→ LL can use phonological knowledge when “pushed” (i.e. semantic matches are impossible) but eye gaze not closely time-locked to unfolding acoustic information
What causes these literacy-related differences?

→ relevant notions in related research areas:

**Grain Size Theory** (Ziegler & Goswami, 2005): connects exposure to the written forms of words to increased granularity of phonological processing

- based on results from meta-linguistic phonological awareness tasks

**Cognitive efficiency** (Salthouse, 1996): efficiency of processing may have consequences for performance on many cognitive tasks

- speed with which neural signals are conducted along axons is related to their degree of myelination (Gutierrez et al., 1995) & learning increases myelination (cf. Bengtsson et al., 2005)
Modeling literacy

- current models of human language processing are based on behaviour of alphabetic literates, and do not take into account the influence of literacy

- they are likely to underrepresent consequences of literacy because of their inclusion of pre-specified componential phonological representations

Smith, Monaghan, & Huettig (2014, Cog Psych):

Hypotheses:
1) literacy leads to more fine-grained processing of sub-syllabic phonological structure (cf. grain size theory)

2) manipulations of processing efficiency will have a greater impact on semantic than phonological effects
→ semantic information is more sensitive to the efficiency of information transfer within networks as it is not directly activated by visual or auditory input but instead is activated as a consequence of information flow through the network
Emergent effects from an amodal shared resource (ASR) computational model

- Recurrent Neural Network
- Hub-and-spoke framework: amodal central resource (hub) which integrates multiple modality-specific sources (spokes)

![Diagram of an amodal shared resource (ASR) computational model](image-url)
Emergent effects from an amodal shared resource (ASR) computational model

Smith, Monaghan, & Huettig (2014, *Cog Psych*):
- modelling results successfully replicated differences observed in Huettig, Singh and Mishra (2011)

- differences in the granularity of phonological processing can modulate the phonological effect

- cognitive efficiency had only a marginal effect on semantic processing and did not affect performance for phonological processing

- however, both cognitive efficiency and phonological grain-size differences were required to simulate the detailed data on phonological and semantic processing in literate and illiterate participants

→ two competing theories of effects of literacy on language learning may well be compatible and complementary contributors to language processing
Literacy & visual attention

Visual tasks and directional biases
- in the broader human population there is a general left hemifield (i.e. right hemisphere) bias in tasks requiring fine discrimination of visual stimuli (Kimura, 1966; Jewell & McCourt, 2000; Nicholls & Roberts, 2002; Landau & Fries, 2012)

- several studies with illiterate and literate participants have shown that there is an additional direction bias due to the direction of the writing system (e.g., left-to-right or right-to-left)
Literacy & visual attention

Padakannaya et al. (2002):
- illiterate Urdu speaking adults did not show any right-left bias in two tasks: naming linearly arranged pictures and recall of linearly arranged pictures after brief exposure

- Urdu speaking literate adults and Arabic speaking literate adults however did show such a right-to-left scanning bias

→ directional scanning habits are related to reading habits
Literacy & visual attention

**Visual search**

Bramao et al. (2007):
- required illiterate and literate participants to touch visual targets such as a red square among yellow squares (which appeared on a computer screen) as quickly as possible

- literates were faster in detecting targets on the left side of the screen, illiterates' performance did not show such a directional bias

- illiterates were overall slower

but:
- what about influence of experience with abstract geometric stimuli?

- does slowness reflect perceptual and attentional processes or processes at stages after target selection has taken place (i.e. decision processes, or response selection)?
Literacy & visual attention

Instructions:
Look for the red chicken amongst green chicken

Press ← (Left arrow) for left-facing skinny chicken.
Press → (Right arrow) for right-facing skinny chicken.

Olivers, Huettig, Singh, & Mishra (2014, VisCog)
Literacy & visual attention

Instructions:
Look for the skinny chicken amongst fat chicken

Press ← (Left arrow) for left-facing skinny chicken.
Press → (Right arrow) for right-facing skinny chicken.

Olivers, Huettig, Singh, & Mishra (2014, VisCog)
## Groups

### Group characteristics for Experiments 1 and 2

<table>
<thead>
<tr>
<th></th>
<th>High literacy group</th>
<th>Low literacy group</th>
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<tr>
<td><strong>Experiment 1</strong></td>
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<tr>
<td>Mean age (yrs)</td>
<td>23.2 (21–30)</td>
<td>21.7 (17–32)</td>
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<td>Sex</td>
<td>F = 7; M = 13</td>
<td>F = 0; M = 20</td>
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<td>Years of schooling</td>
<td>16.1 (14–17)</td>
<td>4.1 (1–5)***</td>
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<td>Raven’s progressive matrices</td>
<td>45.7/60 (42–49)</td>
<td>42.5/60 (30–49)*</td>
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<td>Word reading scores (for mono-, di-, trisyllabic words)</td>
<td>30/30, 29.9/30, 29.9/30</td>
<td>24.3/30, 23.7/30, 20.3/30***</td>
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<tr>
<td><strong>Experiment 2</strong></td>
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<td>Mean age (yrs)</td>
<td>20.9 (19–25)</td>
<td>24.7 (16–33)**</td>
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<td>Sex</td>
<td>F = 8; M = 9</td>
<td>F = 0; M = 20</td>
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<tr>
<td>Years of schooling</td>
<td>15.5 (14–18)</td>
<td>1.8 (0–5)***</td>
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<td>Raven’s progressive matrices</td>
<td>49.2/60 (43–54)</td>
<td>34.6/60 (28–43)***</td>
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<td>Word reading scores (for mono-, di-, trisyllabic words)</td>
<td>30/30, 29/30, 29.1/30</td>
<td>12.5/30, 11.0/30, 9.4/30***</td>
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<td>Phonological awareness (phoneme deletion, phoneme substitution, syllable deletion, syllable substitution)</td>
<td>22.2/25, 22.8/25, 23.4/25</td>
<td>11.7/25, 10.1/25, 11.6/25, 11.2/25***</td>
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</table>
Results (Exp. 1)

Olivers, Huettig, Singh, & Mishra (2014, VisCog)
Results (Exp. 1, Difference in search RTs between high and low literates)

Olivers, Huettig, Singh, & Mishra (2014, VisCog)
Results (Exp. 2, Difference in search RTs between high and low literates)

<table>
<thead>
<tr>
<th>easy search</th>
<th>difficult search</th>
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<td><strong>C. Eccentricity effects: ΔRT</strong></td>
<td><strong>D. Eccentricity effects: ΔRT</strong></td>
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Olivers, Huettig, Singh, & Mishra (2014, VisCog)
## Results (Exp. 2, Eye movements, difficult search)

### A. HIGH LITERACY

<table>
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<tr>
<th>Fixation 0</th>
<th>Fixation 1</th>
<th>Fixation 2</th>
<th>Fixation 3 &amp; 4</th>
<th>Fixation 5, 6 &amp; 7</th>
<th>Fixation 8 and up</th>
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### B. LOW LITERACY

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### C. DIFFERENCE

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*Figure 6.* Fixation densities as a function of fixation number. Fixation 0 is the initial central fixation. Panel C shows the difference between high (Panel A) and low (Panel B) literates. (Results of Experiment 2.) To view this figure in colour, please see the online issue of the Journal.
Literacy & visual search

- low literacy was associated with substantially longer RTs in both experiments

What causes this overall slowing?
- low literacy group was slower in making an eye movement towards the pop out target in the colour search
  → partly some slowing in display-wide (i.e., parallel) sensory processing
- low literates needed more time between fixating the target and generating the manual response
  → largest part lies in post-selection processes, after the target has been found
  → target verification (is the item I have selected really the target)?
  → stimulus–response mapping
  → actual response execution

Olivers, Huettig, Singh, & Mishra (2014, VisCog)
Literacy & visual search

- high and low literacy groups differed in the way search performance was distributed across the visual field

RTs:
- literates were relatively better when the target was presented closer to the fixation point, especially on the right

Eye movements:
- in the high literacy group, more initial; eye movements were directed towards the top left of the display than to other areas

- later eye movements ended up in bottom right areas, consistent with a reading-based scan strategy

Olivers, Huettig, Singh, & Mishra (2014, VisCog)
Literacy & visual attention (summary)

- learning to read has two main consequences with regard to visual search abilities:

1) a shift in the distribution of covert visual attention to central and right parts of the visual field that goes beyond the skill of reading alone

2) the adoption of certain scanning strategies that are roughly compatible with reading direction

Olivers, Huettig, Singh, & Mishra (2014, VisCog)
How literacy acquisition affects the illiterate mind

Literacy has important cognitive consequences which go beyond the processing of orthographic stimuli
- phonological processing
- cognitive efficiency (‘speed of processing’)
- prediction in language processing
- visual search

- distinction between proximate (‘more directly due to reading ability’) and distal (‘due to formal education’) effects of literacy
How literacy acquisition affects the illiterate mind

Literacy has important cognitive consequences which go beyond the processing of orthographic stimuli
- phonological processing proximate
- cognitive efficiency (‘speed of processing’) distal
- prediction in language processing proximate & distal
- visual search proximate

- distinction between proximate (‘more directly due to reading ability’) and distal (‘due to formal education’) effects of literacy

Reading as a recent cultural invention has not been shaped by evolutionary processes
- literacy research is powerful tool to investigate how cultural inventions impact on cognition and brain functioning