COGNITIVE PROCESSES INVOLVED IN READING & WRITING

Raffaella Ida Rumiati
Cognitive Neuroscience Sector

Scuola Internazionale Superiore di Studi Avanzati
Trieste, Italy
ACQUIRED DYSLEXIAS & DYSGRAPHIAS

These represent an inability to read and/or write caused by focal brain damage in patients who before disease onset had acquired a normal use of written language.

Written language is impaired in almost all aphasic language disorders but can in some rare cases be impaired in isolation with respect to the remaining language disorders: pure alexia, pure agraphia, alexia with agraphia.
PHILOGENETICAL OBSERVATIONS

- **oral language**: developed during natural evolution and is based on a genetically determined substrate.

- **written language**: was invented about 6000 years ago, and developed on a large scale only during the last century.
WRITING SYSTEMS

- **Ideographic system**: to each graphic symbol corresponds the meaning of a word.

- **Alphabetic or syllabic systems**: to each graphic symbol (or group of symbols) corresponds a sound (or group of sounds).

- The advantage of an ideographic system: **a unique script** can be shared by different languages or dialects (e.g. Chinese).

- In reality most ideographic scripts are **mixed systems**: ideographic symbols are integrated by morphological and/or phonological information.
Lichtheim (1885) added written language to his and Wernicke’s model.

In a first phase the model represented written language as a dependent and symmetrical function:

in this form, the model could not explain the presence of a spelling deficit in Wernicke’s aphasia.

\[ A = \text{centre of the auditory representations of words} \]
\[ B = \text{centre of the motor representations of words} \]
\[ a = \text{auditory analysis} \]
\[ b = \text{articulatory programming} \]
\[ C = \text{conceptual knowledge} \]
\[ O = \text{centre of the visual engrams (reading)} \]
\[ E = \text{centre of the hand motor engrams (spelling)} \]
In a second phase Lichtheim dropped the connection between the centres B and E: writing remained thus strictly dependent on the integrity of centre A (dependent asymmetrical model):

the model does not account for impaired reading, comprehension and spelling in Broca’s aphasia

A = centre of auditory representations of words
B = centre of auditory representations of words
a = auditory analysis
b = articulatory programming
C = conceptual knowledge
O = visual engrams (reading)
E = hand motor engrams (spelling)
**DEJERINE’S MODEL OF READING & WRITING**  
(1891, 1892)

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**lesion**

<table>
<thead>
<tr>
<th>Alexia with agraphia</th>
<th>angular g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure alexia</td>
<td>OVC left + SCC</td>
</tr>
</tbody>
</table>

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Occipital visual centres (OVC)  
Visual memory centre (VMeC)  
[left angular gyrus]  
Auditory memory centre (AMeC)  
Splenium of corpus callosum (SCC)  
Articulatory-motor centre (AMoC)  
Motor centre of writing (MoCW)
PURE ALEXIA & ALEXIA with AGRAPHIA
(Déjerine, 1892, 1892)

**Pure alexia:**
Disconnection between the visual areas in RH and the visual-verbal centre (angular gyrus) in LH.

**Alexia with agraphia:**
Damage to the visual-verbal centre.

Occipital visual centres (OVC)
Visual memory centre (VMeC) [left angular gyrus]
Auditory memory centre (AMeC)
Splenium of corpus callosum (SCC)
Articulatory-motor centre (AMoC)
Motor centre of writing (MoCW)
DIAGRAM TO READING & SPELLING FOLLOWING DEJERINE (modified)

LEFT HEMISPHERE

spoken word

auditory analysis

auditory memory of words

articulation of words

spoken word

written word

visual analysis

visual memory of words

handwriting of words

written word

RIGHT HEMISPHERE

written word

visual analysis

visual memory of words

articulation of words

handwriting of words

spoken word

auditory analysis

= pure alexia

= alexia and agraphia
LIMITS OF DEJERINE’S MODEL

The model cannot account for some phenomena that can be associated with dyslexic and dysgraphic deficits such as:

- **grammatical class effects** (e.g. nouns vs. grammatical words)
- **imageability effect**
- **semantic paralexias** (e.g. hound ⇒ dog)
- **lexical effects** (Word Frequency, Age of Acquisition etc.)

The model does not account for differences among scripts:

- regular / irregular orthographies

The model does not consider different types of stimuli:

- words / non-words

REGULAR & IRREGULAR ALPHABETIC SYSTEMS

• **Regular alphabetic systems**: there is a correspondence between characters and sounds:
  – by applying G-to-P rules one can read and write without lexical access.

• **Irregular alphabetic systems**: pronunciation or orthography cannot be obtained by applying conversion rules:
  – reading and writing is based on **lexical knowledge** (English, Farsi).

**reading:**  
EA $\Rightarrow$ /iː/ in VEAL /viːl/  
/ɛ/ in HEAD /hɛd/  
/ʌ/ in HEART /hʌrt/  
/ei/ in STEAK /steɪk/

**spelling:**  
/ei/ $\Rightarrow$ BRAIN in /breɪn/  
FRAME in /frem/  
/iə/ $\Rightarrow$ DEER in /diər/  
DEAR in /diər/
READING MODELS:
DUAL-ROUTE MODELS OF READING
Sub-lexical Procedure

• This is based on Grapheme-to-Phoneme conversion rules.

• *It comprises of 3 components:*  
  ◊ isolation of graphemes  
  ◊ conversion into the corresponding phonemes  
  ◊ assembling a phonemic string corresponding to the letter string.

• *It allows reading:*  
  regular words  
  non-lexical orthographic strings (non-words)

• *It does not allow reading:*  
  irregular words
Lexical Procedure

◊ **orthographic input lexicon** (OIL)
◊ **semantic system**
◊ **phonological output lexicon** (POL)

- The **OIL** and **POL** store words known by an individual.

- **It allows:**
  ◊ *faster reading performance* but only for words that are already known to the reader;
  ◊ *only* procedure to read words with irregular orthography

- **It does not allow reading:**
  *(regular) non-words.*
• Above and below the two routes, the model contains two further units:

  ◊ **visual (orthographic) analysis**

  ◊ **phonological output buffer**
ACQUIRED DYSLEXIAS

- Evidence in support of a dual-route model comes from
  - acquired dyslexia
  - normal subjects can read irregular words as well as non-words
# PHONOLOGICAL & SURFACE DYSLEXIA

<table>
<thead>
<tr>
<th></th>
<th>phonological dyslexia</th>
<th>surface dyslexia</th>
</tr>
</thead>
<tbody>
<tr>
<td>damage to the</td>
<td>sub-lexical route</td>
<td>lexical route</td>
</tr>
<tr>
<td>regular words</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>irregular words</td>
<td>yes</td>
<td>no (→ reg.)</td>
</tr>
<tr>
<td>non-words (regular)</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

**lexical effects**

(WF, gramm cl., concr.) *normally present* absent
**DIRECT & DEEP DYSLEXIA**

**Direct dyslexia** (WLP: S, M & S, 1979)

WLP read irregular words, whose meaning she did not understand: this pattern of impairment suggests the existence of a *direct route* connecting the 2 lexicons & bypassing the SS.

**Deep dyslexia**

It is associated with impaired sub-lexical reading (as phonological dyslexia). Patients make also semantic errors.
→ residual reading ability of the RH.
→ instability of the semantic system in absence of phonological control.
LETTER-BY-LETTER DYSLEXIA

This is a severe reading impairment that is not associated with any other language deficit (see pure alexia, Déjerine 1892).

It consists in the inability to read a word using either the lexical or the sublexical route.

In some cases, a patient can name single letters (often using a kinaesthetic strategy) without being able to produce the corresponding sounds, which cannot be bound in a string.

In others, a letter string may be read aloud, but with slow and laborious procedure (backward spelling) (but requires good STM).

Presence of length effect, but not of Word Frequency or grammatical class effect.
Several hypotheses have been put forward to account for *L-by-L dyslexia*:

- Perceptual deficit
- RVF deficit (but L-by-L dyslexia also without RVF deficit)
- Simultagnosia (but L-by-L dyslexia also without SA)
- Orthographic processing deficits

Kinsbourne & Warrington, 1962; Patterson & Kay, 1982; Coslett & Saffran, 1989
NEGLECT DYSLEXIA

This is a reading impairment that is associated with *left unilateral neglect*.

Dyslexia is caused by a representational damage of visual, spatial or body-schema information.

When reading, patients neglect the left side of words and sentences.

- *omissions* (studying ⇒ dying)
- *substitutions* (meadow ⇒ window)

Neglect dyslexia is often associated with neglect dysgraphia thus suggesting a representational cause of the disorders:

- the left side of the orthographic mental representation is neglected.

Patients are often unaware of their impairment (*anosognosia*).
COGNITIVE MODELS OF READING

Conceptual knowledge

Orthographic input lexicon

Phonological output lexicon

Phonemic buffer

Visual analysis

WORD
COGNITIVE MODELS OF READING

Orthographic-to-phonological conversion

Visual analysis

Orthographic input lexicon

Phonological output lexicon

Conceptual knowledge

Phonological buffer

WORD
EVALUATION OF THE READING ABILITIES

Conceptual knowledge

Orthographic input lexicon

Visual analysis

Orthographic-to-phonological conversion

Phonological output lexicon

Phonological buffer

Semantic judgements

Visual lexical decision

Picture and word naming

Reading non-W

Reading & Repetition

/word/

Orthographic-to-phonological conversion

Visual analysis

Orthographic input lexicon

Phonological output lexicon

Phonological buffer

Semantic judgements

Visual lexical decision

Picture and word naming

Reading non-W

Reading & Repetition

/word/
CLINICAL CASE (P.S.)

45 year-old male; *primary progressive aphasia*. Severe nonfluent aphasia with *agrammatic speech output*.

**Reading words and non-words**

<table>
<thead>
<tr>
<th>Performance</th>
<th>N=</th>
<th>% correct</th>
</tr>
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<tbody>
<tr>
<td>- concrete nouns</td>
<td>29</td>
<td>97</td>
</tr>
<tr>
<td>- “irregular” nouns (irreg. stress)</td>
<td>18</td>
<td>89</td>
</tr>
<tr>
<td>- abstract nouns</td>
<td>24</td>
<td>71</td>
</tr>
<tr>
<td>- function words</td>
<td>20</td>
<td>65</td>
</tr>
<tr>
<td>- legal non-words</td>
<td>28</td>
<td>11</td>
</tr>
</tbody>
</table>

**Effects (normal)**

- *Word / non-word difference*: ++
- *imageability*: +
- *Grammatical class*: +

*Diagnosis*: phonological dyslexia
CLINICAL CASE (G.G.)

50 years-old White-collar employee; head trauma 15 months before;
Cerebral CT: left TO intraparenchimal hematoma.

Reading aloud

\[ \begin{array}{lcl}
N= & \% \text{ correct} \\
(1) \text{ concrete nouns} & 29 & 93 \\
(2) \text{ irregular nouns (stress)} & 18 & 88 \\
(3) \text{ Abstract nouns} & 24 & 100 \\
(4) \text{ function words} & 20 & 100 \\
(5) \text{ legal non-words} & 28 & 96 \\
\end{array} \]

Examples of errors

PINT \Rightarrow \text{/pint/ /paint/} \\
COLONEL \Rightarrow \text{/colonel/ /cornel/} \\
YACHT \Rightarrow \text{/yacht/ /jot/}

Diagnosis: surface dyslexia
19 year-old female student; stroke.

Reading aloud

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<td>44</td>
</tr>
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<td>24</td>
<td>17</td>
</tr>
<tr>
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Some errors

helmet ⇒ hat; tiger ⇒ lion, no!; group ⇒ blood;
sting ⇒ shoe; petal ⇒ the flowers, no!;
pole ⇒ igloo; stationmaster ⇒ the train.

Diagnosis: deep dyslexia
SPELLING MODELS
(writing to dictation)
SUBLEXICAL SPELLING

Spoken word

- auditory analysis

Auditory-to-phonological conversion

- Phonological buffer

- phonological-to-orthographic conversion

Graphemic buffer

Written word
LEXICAL SPELLING

spoken word

auditory analysis

auditory input lexicon

cognitive system

orthographic output lexicon

Graphemic buffer

written word
LEXICAL & SUB-LEXICAL SPELLING ROUTES

spoken word

auditory analysis

auditory input lexicon

acoustic - to - phonological conversion

cognitive system

phonemic buffer

orthographic output lexicon

phonological - to - orthographic conversion

graphemic buffer

written word
SPELLING ALONG THE LEXICAL & SUB-LEXICAL ROUTES

X *phonological dysgraphia*
Impaired spelling of non-words

X *surface dysgraphia*
Impaired spelling of irregular words

*spoken word*

*auditory analysis*

*auditory input lexicon*

*acoustic - to - phonological conversion*

*cognitive system*

*orthographic output lexicon*

*phonemic buffer*

*phonological - to - orthographic conversion*

*graphemic buffer*

*written word*
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CLINICAL CASE: G.G.
55 years-old male; left TP hematoma

**Spelling**

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<tr>
<td>Regular words</td>
<td>95</td>
<td>91</td>
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</tr>
<tr>
<td>Irregular words</td>
<td>55</td>
<td>33</td>
<td>60</td>
</tr>
<tr>
<td>Loan words</td>
<td>8</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Non-words</td>
<td>25</td>
<td>21</td>
<td>84</td>
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27 out of 63 possible surface errors (43%):  

*Examples:* CUBO ⇒ QUBO; OLIO ⇒ OGLIO;  
GENIO ⇒ GEGNIO; CUOCO ⇒ QUOCO;  
CUORE ⇒ QUORE

Surface dysgraphia