Modelling the Effects of Formal Literacy Training on Language Mediated Visual Attention

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⁴ Department of Psychology, Lancaster University, Lancaster, U.K.
Within the field...
Within the field...

1) What is the nature of the information involved in language processing?
Within the field...

1) What is the nature of the information involved in language processing?

2) What are the processes that operate on that information?
Language Processing in Context

Behaviour | Cognitive State

Linguistic | Non-Linguistic
Language Processing in Context

- Behaviour
- Cognitive State

Processes?

Information?

Linguistic (Speech Signal)

Non-Linguistic (Visual Environment)
The Visual World Paradigm

(Cooper, 1974; Tanenhaus et al, 1995)
The Visual World Paradigm

*(Cooper, 1974; Tanenhaus et al, 1995)*
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“/b/ /i/ /k/ /ə/ /r/”
The Visual World Paradigm
(Cooper, 1974; Tanenhaus et al, 1995)

"/b/ /i/ /k/ /ə/ /r/"

Eye Gaze

Speech

Visual Display

Huettig & McQueen (2007)
The Visual World Paradigm

(Cooper, 1974; Tanenhaus et al, 1995)

“/b/ /i/ /k/ /ə/ /r/ “

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Phonological Competitor

"/b/ /i/ /k/ /ə/ /r/"

Eye Gaze

Speech

Visual Display

Phonological

Allopenna et al, 1998; Magnuson et al, 2007

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Eye Gaze

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Phonological

Allopenna et al, 1998; Magnuson et al, 2007

Visual

Dahan & Tanenhaus, 2005; Huettig & Altmann, 2007

Phonological Competitor

Visual Competitor

Huettig & McQueen (2007)
The Visual World Paradigm

(Cooper, 1974; Tanenhaus et al, 1995)

Phonological
Allopenna et al, 1998; Magnuson et al, 2007

Visual
Dahan & Tanenhaus, 2005; Huettig & Altmann, 2007

Semantic
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“/b/ /i/ /k/ /ə/ /r/”

Eye Gaze

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Phonological
Allopenna et al, 1998; Magnuson et al, 2007

Visual
Dahan & Tanenhaus, 2005; Huettig & Altmann, 2007

Semantic
Huettig & Altmann, 2005; Yee & Sedivy, 2006
Individual Differences

Huettig, Singh & Mishra (2011)
Individual Differences

Huettig, Singh & Mishra (2011)

High Literates

- Phonological Competitor
- Semantic Competitor
- Unrelated Distractor

Low Literates

- Change in p (fixation)
- Time from target word onset (ms)
Individual Differences

Huettig, Singh & Mishra (2011)

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**Figure:**

- **High Literates**
  - Phonological Competitor
  - Semantic Competitor
  - Unrelated Distractor

- **Low Literates**
  - Phonological Competitor
  - Semantic Competitor
  - Unrelated Distractor

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<td>Divergence</td>
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**Graphs:**
- **High Literates**
  - Phonological Competitor
  - Semantic Competitor
  - Unrelated Distractor
- **Low Literates**
  - Change in p (fixation)
  - Time from target word onset (ms)
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Huettig, Singh & Mishra (2011)

**High Literates**

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- Semantic Competitor
- Unrelated Distractor

**Low Literates**

**Phonological Effects**

- **Divergence**
  - High Literates: 200-299ms
  - Low Literates: No effect

- **Group Comparisons**
  - Difference observed 300 – 599ms
  - High literates > Low literates

**Semantic Effects**

- **Divergence**
  - High Literates: 400-499ms

- **Group Comparison**
  - Difference observed 400 – 800ms
  - High literates > Low literates
Individual Differences

Huettig, Singh & Mishra (2011)

What Differs?

High Literates

Low Literates
Individual Differences

Huettig, Singh & Mishra (2011)

High Literates

Low Literates

What Differs?

Eye Gaze

Speech

Visual Display
Individual Differences

Huettig, Singh & Mishra (2011)

High Literates

Low Literates

What Differs?

Eye Gaze

Speech

Visual Display
Effects of Literacy on Phonological Processing

Illiterates display:

- Poor phonological segmentation (Bowey, 2005)
- Poor phoneme awareness (Morais, 1979)
- Poor pseudoword repetition (Reis & Castro-Caldes, 1997)

Better metaphonological abilities:
- Syllable detection (Morais et al, 1989)
- Rhyme awareness (Morais et al, 1995)
- Phonological length (Kolinsky et al 1987)
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Theoretical Models

- **Literacy improves phonological processing**
  - Castles & Coltheart, 2004; Morais, Cary, Algeria & Bertelson, 1979
  - Although direction of causality disputed (Muter, Hulme, Snowling & Stevenson, 2004)

- **How?**
  - **Online**: Speech processing activates corresponding orthographic code
    - Ziegler and Ferrand, 1998
  - **Offline**: Exposure to orthography modifies phonological system
    - Muneaux & Ziegler, 2004; Taft 2006

- **Grain Size Theory** (Ziegler & Goswami, 2005)
  - Exposure to written words results in a change in the granularity of the processing of words
  - Illiterates more likely to process sound of a word without a componential, phonological decoding
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Research Question

Can differences in the granularity of speech processing offer explanation for differences observed between **High** and **Low literates** in Language Mediated Visual Attention
Computational Modelling

- Demands explicit description of ...
  - Information
  - Processes

- Previous success modelling the Visual World Paradigm
Computational Modelling

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  – Information
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Computational Modelling

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• Previous success modelling the Visual World Paradigm

• Competition at multiple levels of representation
  - Allopenna, 1998;
  - Huettig & McQueen, 2007

Auditory Stimulus
Visual Display
Eye Gaze
Computational Modelling

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- Parallel activation
  - Kukona & Tabor, 2011
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Eye Gaze

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- Cascaded activation across modalities
  - Spivey, 2007
  - Huettig & McQueen, 2007
Model Architecture:

- Recurrent Neural Network
- Groups of discrete non-linear processing units
- Weighted connections between units
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Auditory Stimulus

Visual Display
Network

Parsimonious architecture:

- Vision Layer
- Eye Layer
- Integrative Layer (400 units)
- Auditory Layer
- Semantic Layer
Network

- Vision Layer (80 units)
- Eye Layer
- Integrative Layer
- Semantic Layer
- Auditory Layer
Network
Network

Eye Layer
(4 units)

Integrative Layer

Semantic Layer
(160 units)

/b/  /i/  /k/  /ə/  /r/  ...

Network
Network

Integrative Layer

Loc. 1 → Loc. 2
Loc. 3 → Loc. 4

/b/ /i/ /k/ /ə/ /r/ ...

Semantic Layer
Network
Artificial Corpus

Fundamentalist Approach

Ensures all aspects of the representations are controlled

(Plaut, 2002)
Artificial Corpus

200 items, each with unique:

auditory,

visual

and semantic representations.
## Models

<table>
<thead>
<tr>
<th>Auditory</th>
<th>Coarse</th>
<th>Moderate</th>
<th>Fine</th>
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<tbody>
<tr>
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<tr>
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<td>Fine</td>
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<td><strong>Phoneme Level</strong></td>
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<td>10 features per phoneme</td>
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<td></td>
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</tr>
<tr>
<td><strong>Moderate</strong></td>
<td><strong>Coarse Sublexical</strong></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2 components per word</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>All components unique</td>
<td></td>
<td></td>
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<td></td>
<td>30 features per component</td>
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<td>1 component per word</td>
<td>2 components per word</td>
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<td>60 features per component</td>
<td>30 features per component</td>
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<tr>
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<td>“bkr”</td>
<td>“bl” “kr”</td>
<td>“/b/ /i/ /k/ /ə/ /r/”</td>
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All components unique
**Artificial corpus:** 200 items, each with unique *auditory, visual* and *semantic* representations
Artificial corpus: 200 items, each with unique **auditory**, **visual** and **semantic** representations

### Model

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### Representations

**Artificial corpus:** 200 items, each with unique **auditory**, **visual** and **semantic** representations

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<td>20 unit binary feature vector</td>
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<td>Initial 2 phonemes shared with target: <code>[b] /i/ /k/ /ə/ /r/</code></td>
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![Signal Overlap Diagram]

- **Signal Overlap**
  - **Linguistic Component**
  - **Bars:**
    - Coarse: 0.75
    - Moderate: 0.5
    - Fine: 0.25
### Competitors

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<td>2/3 of features in initial component shared with target</td>
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- " /b/ /i/ /k/ /ə/ /r/ "

**Linguistic Component**

- **Signal Overlap**
  - **Linguistic Component**

![Graph](https://via.placeholder.com/150)
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<td>Distance between competitor signal and target on average $\frac{1}{2}$ that of distance between distractor and target</td>
<td></td>
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<tr>
<td><strong>Semantic</strong></td>
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</tr>
<tr>
<td>1/3 of all features shared with target</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2/3 of features in initial component shared with target</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Initial 2 phonemes shared with target</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>/b/ /i/ /k/ /ə/ /r/</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
<td></td>
</tr>
</tbody>
</table>

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<tr>
<th><strong>Auditory</strong></th>
<th><strong>Signal Overlap</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td>Linguistic Component</td>
</tr>
<tr>
<td><img src="image2.png" alt="Graph" /></td>
<td>Linguistic Component</td>
</tr>
<tr>
<td><img src="image3.png" alt="Graph" /></td>
<td>Linguistic Component</td>
</tr>
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</table>
## Auditory Representation Overlap

<table>
<thead>
<tr>
<th>Grain Size</th>
<th>Category</th>
<th>Signal Overlap (𝑥̅, σ)</th>
<th></th>
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<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Onset</td>
<td>Rhyme</td>
<td>Word</td>
<td></td>
</tr>
<tr>
<td>Fine</td>
<td>Competitor</td>
<td>.18 (.07)</td>
<td>.50 (.13)</td>
<td>.34 (.07)</td>
<td></td>
</tr>
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<td></td>
<td>Unrelated</td>
<td>.50 (.12)</td>
<td>.50 (.12)</td>
<td>.50 (.09)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Competitor</td>
<td>.17 (.08)</td>
<td>.50 (.11)</td>
<td>.34 (.07)</td>
<td></td>
</tr>
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</tbody>
</table>
Error based learning algorithm used to adjust connection weights
Vision -> Semantics:
Moderate = 97%
Other = 98%
**Vision -> Semantics:**
Moderate = 97%
Other = 98%

**Auditory -> Semantics:**
All = 100%
**Vision -> Semantics:**
Moderate = 97%
Other = 98%

**Semantics -> Location:**
All = 99%

**Auditory -> Semantics:**
All = 100%
Training

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Moderate = 97%
Other = 98%

**Auditory -> Semantics:**
All = 100%

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All = 99%

**Auditory -> Location:**
Moderate = 98%
Other = 96%
Previous Simulations

Fine grain (Phoneme Level) model:
- Replicates behaviour of literates
Previous Simulations

Fine grain (Phoneme Level) model:
- Replicates behaviour of literates
  - **Visual** Competitor Effects

---

**Dahan & Tanenhaus, 2005**

**Huettig & Altman, 2007**
Previous Simulations

Fine grain (Phoneme Level) model:

- Replicates behaviour of literates
  - **Visual** Competitor Effects
  - **Semantic** Competitor Effects

---

**Yee & Sedivy, 2006**

**Huettig & Altmann, 2005**
Previous Simulations

Fine grain (Phoneme Level) model:
- Replicates behaviour of literates
  - **Visual** Competitor Effects
  - **Semantic** Competitor Effects
  - **Multimodal** Effects

![Empirical Data and Simulation](image-url)
Huettig, Singh & Mishra (2011)
Experiment 1

“... magar”
Testing

Huettig, Singh & Mishra (2011) Exp. 1
Huettig, Singh & Mishra (2011) Exp. 1
Huettig, Singh & Mishra (2011) Exp. 1
Testing

Huettig, Singh & Mishra (2011) Exp. 1

Integrative Layer

Semantic Layer
Testing

Huettig, Singh & Mishra (2011) Exp. 1
Huettig, Singh & Mishra (2011) Exp. 1
Huettig, Singh & Mishra (2011) Exp. 1
Huettig, Singh & Mishra (2011) Exp. 1

Integrative Layer

Semantic Layer

Time (ts)
Results

For each category of model:

• 5 x instantiations
  – new corpus
  – new random seed

• 40 stimuli sets x 24 arrangements
  – 960 test trials

• Mean difference, from word onset, of proportional eye unit activation for given item

Ratios:
\[
p\left(\text{fixating item type } A\right) \\
p\left(\text{fixating item type } A \text{ or } B\right)
\]
Results

For each category of model:

- 5 x instantiations
  - new corpus
  - new random seed

- 40 stimuli sets x 24 arrangements
  - 960 test trials

- Mean difference, from word onset, of proportional eye unit activation for given item

Ratios: \[
\frac{p(\text{fixating item type } A)}{p(\text{fixating item type } A \text{ or } B)}
\]
Results

For each category of model:

- 5 x instantiations
  - new corpus
  - new random seed

- 40 stimuli sets x 24 arrangements
  - 960 test trials

• Charts: Mean difference, from word onset, of proportional eye unit activation for given item

• Analysis:

  \[
  \text{Ratio: } \frac{p(\text{fixating item type A})}{p(\text{fixating item type A or B})}
  \]
Results

Huettig, Singh & Mishra (2011):

Simulations:

- Fine
- Moderate
- Coarse
Huettig, Singh & Mishra (2011): Results

Simulations:

High Literates

Low Literates
Huettig, Singh & Mishra (2011):

**High Literates**

- Phonological Competitor
- Semantic Competitor
- Unrelated Distractor

**Low Literates**

Simulations:

**Fine**

- Fine_Aud
- Fine_Sem
- Fine_Control

**Moderate**

- Moderate_Aud
- Moderate_Sem
- Moderate_Control

**Coarse**
Huettig, Singh & Mishra (2011): Simulations:

**High Literates**

- Phonological Competitor
- Semantic Competitor
- Unrelated Distractor

**Low Literates**

- Change in p(fixation)
- Time from target word onset (ms)

**Fine**

- Change in p(fixation)
- Time from display onset (ts)

- Fine_Aud
- Fine_Sem
- Fine_Control

**Moderate**

- Change in p(fixation)
- Time from display onset (ts)

- Moderate_Aud
- Moderate_Sem
- Moderate_Control

**Coarse**

- Change in p(fixation)
- Time from display onset (ts)

- Coarse_Aud
- Coarse_Sem
- Coarse_Control
Results

Change in p(fixation) vs. Time from display onset (ts)

- Fine_Aud
- Fine_Sem
- Fine_Control
- Moderate_Aud
- Moderate_Sem
- Moderate_Control
- Coarse_Aud
- Coarse_Sem
- Coarse_Control
Results

Change in p(fixation) vs. Time from display onset (ts)

- Preview (ts 0 – 7)
- Early (ts 8 – 18)
- Late (ts 19 – 29)
Auditory Competitor vs Distractor

2-way ANOVA on Auditory competitor-distractor ratios

Model = between-subject factor
Time = within-subject factor
Main effect of **time** \( [F(2,234) = 38.155, p<0.001] \)

Difference between **preview** and **early** \( [F(1,238) = 39.387, p<0.001] \)

Difference between **preview** and **late** \( [F(1,238) = 29.202, p<0.001] \)
Main effect of **model**

\[ F(2,117) = 4.467, p=0.14 \]

**Fine and Moderate** > **Coarse**

**Auditory Competitor vs Distractor**
Interaction between model and time

\[ F(4, 234) = 3.582, p = 0.23 \]

Quadratic contrast effect for time was significant in the interaction

\[ F(2, 117) = 5.074, p = 0.008 \]

\( \Rightarrow \) Models more differentiated in early window than preview or late
Auditory Competitor vs Distractor

Change in p(fixation)

Time from display onset (ts)

Preview: Coarse = Moderate = Fine

Fine_Aud, Fine_Control, Moderate_Aud, Moderate_Control, Coarse_Aud, Coarse_Control
Auditory Competitor vs Distractor

Early:
- Coarse < Fine  \[F(1,78) = 14.373, p<0.001\]
- Coarse < Moderate  \[F(1,78)=9.544, p= 0.003\]
- Moderate = Fine
### Auditory Competitor vs Distractor

**Late:**
- Coarse < Fine  \[F(1,78) = 4.286, p=0.042\]
- Coarse < Moderate  \[F(1,78) = 7.153, p=0.009\]
- Moderate = Fine

*Change in p(fixation)*

*Time from display onset (ts)*
2-way ANOVA on Semantic competitor-distractor ratios

Model = between-subject factor
Time  = within-subject factor

Change in p(fixation) vs Time from display onset (ts)
Semantic Competitor vs Distractor

Main effect of time

- Preview < Early: $F(1,238) = 59.607, p<0.001$
- Preview < Late: $F(1,238) = 243.403, p<0.001$
- Early < Late: $F(1,238) = 80.562, p<0.001$

$F(2,234) = 230.642, p<0.001$
Semantic Competitor vs Distractor

No main effect of **model**
No interaction between **model** and **time**

Change in p(fixation)

Time from display onset (ts)
Replicating Huettig, Singh & Mishra (2011)

<table>
<thead>
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**Semantic Effects**

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**Divergence**

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Models more differentiated in early time steps rather than late or preview

Fine and Moderate > Coarse
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Differences in the granularity of speech processing can lead to modulation of the phonological effect

⇒ Results of Huettig, Singh and Mishra (2011) consistent with the argument that formal literacy training leads to increased granularity in speech processing

However,

1) Very Coarse grain structure required to eliminate phonological effect

2) Additional mechanism required to explain reduced semantic effect in Low Literates
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A Graded Effect of Granularity?

- Qualitative features hint at graded effect
  - Difference between Moderate and Fine models for ts 13-16 (p<0.05)

- Larger corpus/test set
  - Unlikely to eliminate effect

⇒ Low literates rely on very coarse grained structure
  - Performance on meta-phonemic tasks worse than literates
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Huettig, Singh & Mishra (2011)
Experiment 2

Experiment 2: Displays contained Phonological Competitor and 3 Unrelated Distractors
Huettig, Singh & Mishra (2011)

Experiment 2

Experiment 2: Displays contained **Phonological Competitor** and 3 Unrelated Distractors

**Empirical Data**

**High Literates**

**Low Literates**
Huettig, Singh & Mishra (2011)  
Experiment 2

Experiment 2: Displays contained **Phonological** Competitor and 3 Unrelated Distractors

**Empirical Data**

A. **High Literates**

- Graph showing change in p(fixation) over time from target word onset (ms)

B. **Low Literates**

- Graph showing change in p(fixation) over time from target word onset (ms)

**Simulation**

- Graph with lines representing different conditions (Fine_Aud, Moderate_Aud, Coarse_Aud)
Discussion

• Increased grain size **does not** modulate **semantic** effect
  
  – Additional mechanism required
    
    • Qualitative difference (Huettig, Singh & Mishra, 2011)
  
  – Reduction in **General Processing Speed** (Salthouse, 1996)
    
    • Potentially explains both effects
    
    • Simulating less efficient internal processing
      
      Adding noise to network:
      
      – Will reduce semantic effect, yet may not eliminate phonological effect
Discussion

- Increased grain size **does not** modulate **semantic** effect
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Adding noise to network:
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    • Potentially explains both effects
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      Adding noise to network:
        — Will reduce semantic effect, yet may not eliminate phonological effect

![Graph showing semantic effects for different grain sizes]
Future Directions

• Mani & Huettig (submitted)
  – Pre-literate behaviour ≈ Low literate behaviour

• Read et al (1986)
  – Chinese Literates ≈ Illiterates
  – Basic alphabetic knowledge dramatically increases performance on phoneme awareness tasks
  – Reduced activation of phonological network (Brennan et al, 2012)
Future Directions

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- Read et al (1986)
  - Chinese Literates ≈ Illiterates
  - Basic alphabetic knowledge dramatically increases performance on phoneme awareness tasks
  - Reduced activation of phonological network (Brennan et al, 2012)
How does literacy alter grain size?

- **Online:** Ziegler and Ferrand, 1998
  - Speech processing activates corresponding orthographic code

- **Offline:** Muneaux & Ziegler, 2004; Taft 2006
  - Exposure to orthography modifies phonological system
## Auditory Representation Overlap

<table>
<thead>
<tr>
<th>Grain Size</th>
<th>Category</th>
<th>Signal Overlap ($\bar{x}$, $\sigma$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>.51 (.10)</td>
</tr>
<tr>
<td>Task</td>
<td>Vision Description</td>
<td>Auditory Description</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Form to Semantics</td>
<td>4 visual representations randomly selected from corpus, 1 assigned as target</td>
<td>Random time invariant noise provided as input</td>
</tr>
<tr>
<td>Speech to Semantics</td>
<td>Random time invariant noise provided as input across all 4 input slots</td>
<td>Speech signal of target provided as a staggered input</td>
</tr>
<tr>
<td>Speech to Location</td>
<td>4 visual representations randomly selected from corpus, 1 assigned as target</td>
<td>Speech signal of target provided as a staggered input</td>
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<td>Semantics to Location</td>
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## Embedded Competitors

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<tr>
<th>Modality</th>
<th>Item</th>
<th>Constraint</th>
<th>Signal Overlap ($\bar{\alpha}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Near</td>
<td>4 of 8 functional properties shared with target</td>
<td>97.5%</td>
</tr>
<tr>
<td></td>
<td>Unrelated</td>
<td>Max. 1 functional property shared with target</td>
<td>95%</td>
</tr>
<tr>
<td>Vision</td>
<td>Competitor</td>
<td>For 10 visual features $P$(feature overlap with target) = 1; for remaining features $P$(feature overlap with target) = 0.5</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>Unrelated</td>
<td>$P$(feature overlap with target) = 0.5</td>
<td>50%</td>
</tr>
</tbody>
</table>
Simulating Phonological Effects

Allopenna et al, 1998:

- Display Contains:
  - **Target** (e.g. beaker)
  - Cohort Competitor (e.g. beetle)
  - Rhyme Competitor (e.g. speaker)
  - Distractor (e.g. carriage)

Empirical Data

Simulation
Simulating Visual Effects

**Dahan & Tanenhaus, 2005**

Display:
- **Target** (e.g. beaker)
- **Visual Competitor** (e.g. bobbin)
- **2 x Distractor** (e.g. carriage)

**Empirical Data**

**Simulation**

---

**Huettig & Altmann, 2007**

Display:
- **Visual Competitor** (e.g. bobbin)
- **3 x Distractor** (e.g. carriage)

**Empirical Data**

**Simulation**
Simulating Semantic Effects

**Sedivy & Yee, 2006**

Display:
- Target (e.g. beaker)
- Semantic Competitor (e.g. fork)
- 2 x Distractor (e.g. carriage)

**Empirical Data**

**Simulation**

**Huettig & Altmann, 2005**

Display:
- Semantic Competitor (e.g. fork)
- 3 x Distractor (e.g. carriage)

**Empirical Data**

**Simulation**
Simulating Interaction

Huettig & McQueen, 2007: Long Display Preview (approx. 7 words)

Display:
- Onset Competitor (e.g. beaver)
- Visual Competitor (e.g. bobbin)
- Semantic Competitor (e.g. fork)
- Distractor (e.g. carriage)

Empirical Data

Simulation

\[ p(\text{fixation}) \]

\[ p(\text{vis fix}) \]
\[ p(\text{sem fix}) \]
\[ p(\text{phon fix}) \]
\[ p(\text{dist fix}) \]
Simulating Interaction

Huettig & McQueen, 2007: Short Display Preview (200ms)

Display:
- Onset Competitor (e.g. beaver)
- Visual Competitor (e.g. bobbin)
- Semantic Competitor (e.g. fork)
- Distractor (e.g. carriage)

Empirical Data

Simulations

Short Preview

No Preview
Questions

• Phonological competitor still fixated above distractor at end of trial
  – threshold on activation required to initiate saccade
  – additional training
  – additional competition in eye layer (winner takes all)
<table>
<thead>
<tr>
<th>Model</th>
<th>Fine</th>
<th>Moderate</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic</td>
<td>12 -&gt; end (p&lt;0.05)</td>
<td></td>
<td></td>
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<tr>
<td>Auditory</td>
<td>11-&gt;end (p&lt;0.001)</td>
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