Neural Bases of the World’s Language

Course website:
www.psych.nyu.edu/pylkkanen/J-term2017-NeuralBasesWorldLanguages/

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Outline

• Brain correlates of words
• Specific morphological case: Past tense
• Arabic morphology
Nuts and bolts of language

- Language has a list of stored elements (=lexicon) and a generative mechanism that builds complex structures from the stored elements.

- Core question: What elements are stored and what are generated?
neuromagnetic investigation is fascinating
Lots of generation, little storage

Lexical entries:
- neuro
- magnet
- investigate
- fascinate
- -ic
- -ion
- is
- -ing
Lots of storage, little generation

- Neuromagnetic investigation is fascinating

- Lexical entries:
  - neuromagnetic
  - magnetic
  - magnet
  - investigation
  - investigate
  - fascinating
  - fascinate etc...
Morphology

- The study of the internal structure of words.

What are the basic computational units of language?

Do words such as

*magnetic* and *magnetism*

contain the same computational unit: *magnet*, or are these just two words that are similar in sound and in meaning?

Answer from Linguistics:

- They uncontroversially contain the same unit.

Psychology/Psycholinguistics:

- This question was a subject of intense debate for a long time.
- For example, it was argued that what looks to be morpheme identity is just similarity at the extreme (Seidenberg & Gonnerman, 2000; Gonnerman and Plaut, 2000).
- But the field has now come more or less to a consensus that all morphologically complex words decompose into their pieces during processing.
How can we find out whether morphemes are the basic building blocks of language?

- It is uncontroversial that morphemes are the basic building blocks of language *in some sense*, since, for example, we have tacit knowledge about the properties of morphemes that allows us to create new complex words.

  - *Sally is very blick today.*
  - *Did her _____ make you happy?*
    - As soon as you know that *blick* is an adjective, you can derive *blickness*.

  - *Kim wugged the computer today.*
  - *So the computer must be pretty easily________*
    - As soon as you know that *wug* is a verb, you can derive *wuggable*.

- But could it still be the case that once we’ve learned a complex word, we memorize it as a whole and don’t bother to split it up into its pieces anymore?
In language processing, do we decompose complex words like neuromagnetism into their constituent morphemes, or do we access them as whole?
Decomposition theory

magnet

ism

ic

ize

Storage theory

magnetize

magnolia

magnetic

magnet

magnetism

magnificent

Etc...
Predictions

Decomposition theory

magnet
magnet

magnet ism

magnet ize

magnet ize
Predictions

Decomposition theory

All of these words contain the same morpheme \textit{magnet}.

→ All of these words relate to each other via identity.

→ Any prime-target combination of these words should elicit repetition priming.
Predictions

All of these words are similar in sound.

→ They should compete with each other in recognition.

Some of these words are also similar in meaning.

→ They should semantically prime each other.

None of these words relate to each other via identity.

→ Any priming effect between magnet and magnetism, for example, should be explainable in terms of sound and meaning similarity alone.
Do morphologically related words elicit repetition priming effects or cumulative similarity effects?

- Rastle et a. (2000) tested for the priming effects of
  - Meaning similarity: cello - VIOLIN
    <unrel> - VIOLIN
  - Form/sound similarity: typhoid - TYPHOON
    <unrel> - TYPHOON
  - Meaning + form similarity: screech - SCREAM
    <unrel> - SCREAM
  - Morphological relatedness: adapter - ADAPTABLE
    <unrel> - ADAPTABLE
  - Identity: church - CHURCH
    <unrel> - CHURCH

- Lowercase visual prime followed by uppercase visual target.
- Lexical decisions to target only.
- Priming assessed with respect to unrelated controls.
<table>
<thead>
<tr>
<th>Condition</th>
<th>No. Letters</th>
<th>No. Syllables</th>
<th>Frequency</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ M+S+O (departure-DEPART)</td>
<td>5.17</td>
<td>1.38</td>
<td>24.38</td>
<td>4.79</td>
</tr>
<tr>
<td>+ M− S+O (apartment-APART)</td>
<td>5.12</td>
<td>1.54</td>
<td>34.92</td>
<td>4.62</td>
</tr>
<tr>
<td>− M+S− O (cello-VIOLIN)</td>
<td>5.12</td>
<td>1.42</td>
<td>30.58</td>
<td>6.42</td>
</tr>
<tr>
<td>− M− S+O (electrode-ELECT)</td>
<td>4.50</td>
<td>1.33</td>
<td>30.62</td>
<td>7.50</td>
</tr>
<tr>
<td>ID (church-CHURCH)</td>
<td>4.79</td>
<td>1.54</td>
<td>39.29</td>
<td>4.71</td>
</tr>
</tbody>
</table>

Note: M, morphological; S, semantic; O, orthographic.
Additional factor that was manipulated:

Stimulus Onset Asynchrony (SOA)
- The interval between the onset of the prime and the onset of the target.

- Priming effects differ in how fast they develop and how long they last.
- Rastle et al. used 3 different SOA’s:
  - 43 msec
  - 73 msec
  - 230 msec
**Results** *(Rastle et al. 2000)*

How much faster or slower were subjects’ lexical decisions to the related than to the unrelated conditions?
Positive numbers = priming. Negative numbers = inhibition.

![Graph showing priming effects](image)

- **church-CHURCH**
  - Positive priming all around.
- **screech-SCREAM**
  - Slowly developing priming effect.
- **cello-VIOLIN**
  - Slowly developing priming effect.
- **typhoid-TYPOHOON**
  - No reliable effects.
Conclusions

- The effect of morphological relatedness is
  - Indistinguishable from the effect of identity.
  - Unexplainable in terms of combined form and meaning similarity.

- This follows straightforwardly from the decomposition theory but not from the storage theory.
Can we find evidence for decomposition in the brain?

- We saw that for simple words, the latency of the M350 tracks frequency (Embick et al. 2001)

- For complex words, would the M350 track the frequency of the whole word or the frequencies of the constituent parts?
  - If it tracks the constituent parts, evidence that complex words are indeed represented as complex.
Fiorentino & Poeppel (2007)

- Lexical decision
  - compound words (*flagship*)
  - single words (*crescent*)
  - pseudoword foils (*crowskep*)

- 60 compound word
- 60 single word pairs

- The whole word frequency of the compound was always matched to that of the single word, but the constituent frequency was not
### Fiorentino & Poeppel (2007)

<table>
<thead>
<tr>
<th>Perspective on Internal Structure</th>
<th>Whole-word representation</th>
<th>Morphologically Structured Entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>flagship</td>
<td>crescent</td>
</tr>
<tr>
<td>Log Frequency</td>
<td>.68</td>
<td>.69</td>
</tr>
<tr>
<td>Length</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Syllabicitiy</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Neurolinguistic evidence that processing *flagship* involves accessing *flag* and *ship*.

The M350 reflects the frequencies of compound constituents, not the whole word.

But when, and where, does the decomposition happen?

Presumably before the M350 since at that stage the brain is already sensitive to the frequencies of the parts.

<table>
<thead>
<tr>
<th>Word category</th>
<th>Example</th>
<th>Lexical Decision Time</th>
<th>M350 latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound</td>
<td>flagship</td>
<td>672</td>
<td>333</td>
</tr>
<tr>
<td>Single word</td>
<td>crescent</td>
<td>743</td>
<td>361</td>
</tr>
</tbody>
</table>

*Fiorentino & Poeppel (2007)*
Figure 6. Three components in the magnetoencephalographic (MEG) response to visually presented word stimuli are typically observed. (A) Contour maps at response peak (the light grey areas represent the outgoing portions of the magnetic field contour, and the dark grey areas represent the ingoing portions of the magnetic field contour). The first distribution, around 170 ms post-onset, is associated with visual word form processing. The response has been argued from dipole modelling to originate in the occipito-temporal cortex, perhaps in the fusiform gyrus. The component around 250 ms post-onset may reflect some aspects of phonological or ortho-phonological processing. The third component, peaking between 300–400 ms has been previously implicated as involved in lexical access. This was the first component sensitive to the stimulus manipulation in the current study. (B) Butterfly plot of all channels over left hemisphere illustrating peaks in the evoked field.
Behavioral evidence for across the board

pre-semantic decomposition from masked priming

- The prime is sandwiched between a forward pattern mask and the target stimulus, which acts as a backward mask:

  E.g.,:  
  mask (500 ms)  
  prime (40-50 ms)  
  target (500 ms)  

  horse
  HOUSE

- At such short SOAs, subjects are not consciously aware of the prime.
  - Nevertheless, form-based and repetition priming can be obtained.
  - No semantic priming (SOA too short).

- Masked priming demo:
  http://www.u.arizona.edu/~kforster/priming/
Behavioral evidence for across the board pre-semantic decomposition from masked priming

- Davis, Rastle, & New (2004):

  In a masked priming paradigm:
  - morphology: CLEANER - clean priming
  - apparent morphology: CORNER - corn equivalent priming
  - no morphology: BROTHEL - broth no priming

- All apparently morphologically complex words are decomposed in early stages of visual word perception.

- What are the brain correlates of such early decomposition?
What are the earliest effects of morphological complexity in MEG? (Zweig & Pykkänen, 2008, LCP)

- Lexical decisions on
  - bimorphemic (teacher)
  - monomorphemic (switch)
  - orthographic controls (winter)

- Larger M170 amplitudes for bimorphemic words:

- This initial result was bilateral. Subsequent research has mostly focused on left lateral M170 responses, showing evidence for decomposition even for pseudo-complex forms like corner. Thus we know that semantically blind decomposition occurs at least in the left M170 generator.
Follow up thoughts!

- Zweig & Pylkkänen: *winter* does not decompose, suggesting that the presence of the pseudo affix –er does not trigger decomposition if the rest of the word is not also a morpheme (which *wint* is not).
Summary

Behavior:
• Words containing the same morpheme show repetition as opposed to similarity effects. This is evidence that the morphemes exist (as opposed to just whole words).

Brain:
• At the M170 level, all forms that look morphologically complex are decomposed into parts.
  • Fusiform gyrus, left dominant.

• At the M350 level, strong evidence that the meanings of the pieces have been accessed.
  • Left posterior temporal cortex.
Summary

**M100**
100-150ms

Effects of **low-level visual features** such as size and luminance.

**Form-based**
“Visual feature analysis”

**M170**
150-200ms

**Letter-string effects**
“Visual word form area”

**decomposition**
(anything that looks complex decomposes)

**M350**
300-400ms

**Lexical effects:**
Frequency

(Embick et al., 2000, *CBR*)

Morpheme repetition
(Pylkkänen et al., 2002; Stockall & Marantz, 2006, *Mental Lexicon*)

Morpheme frequency
(Fiorentino & Poeppel, 2007, *LCP*
Pylkkänen et al., 2004, *Cognition*)

“Morpheme access”
THE PAST TENSE DEBATE
Irregular past tense inflection

- *give - gave, teach - taught*

- The meaning of *give* is contained in *gave* since *gave* describes giving in the past. But the sound of *give* is not contained in *gave*.

- Are *give* and *gave* two lexical entries that are similar to each other or is there some morpheme that they both contain?
The past tense debate

<table>
<thead>
<tr>
<th>Transparent</th>
<th>Opaque</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sound of stem is completely contained in the sound representation of the affixed form</em></td>
<td><em>Sound of stem not contained in the sound representation of the affixed form</em></td>
</tr>
</tbody>
</table>
| walk - walked  
talk - talked  
dance - danced | sing – sang  
bring - brought  
go-went  
(*suppletion*) |

regular  
irregular

*suppletion*: is the replacement of one stem with another, resulting in an allomorph of a morpheme which has no phonological similarity to the other allomorphs.
A necessary concept: allomorphy

- Two sound representations are linked to the same meaning and context decides which sound representation is used.
- The two allomorphs of the indefinite article in English:
  - **Before a consonant:** *a* car
  - **Before a vowel:** *an* idea
The past tense debate

- Are regulars and irregulars represented similarly or differently in the mind/brain?
- This question was popularized in the late nineties by Steven Pinker.
Three theories

- Dual mechanism theory (Pinker’s “Words and Rules” theory)
  - Regular (transparent) forms are generated by rule, irregulars are stored.

- Single mechanism storage theory
  - Both regulars and irregulars are stored.

- Single mechanism composition theory
  - All forms involve composition.
  - How could that work???
    - Irregulars involve root allomorphy combined with either a null or an overt past tense morpheme.

\[
\begin{array}{ccc}
\text{sang} & \emptyset & \text{kep} \quad -t
\end{array}
\]
Relationship between the stem and the past tense form in the three theories

- **Dual mechanism theory:**
  - \textit{walk} - \textit{walked} \quad \textit{sing} - \textit{sang}
  - \rightarrow \textit{stem identity} \quad \rightarrow \textit{neighbors}

- **Single mechanism storage theory:**
  - \textit{walk} - \textit{walked} \quad \textit{sing} - \textit{sang}
  - \rightarrow \textit{neighbors} \quad \rightarrow \textit{neighbors}

- **Single mechanism composition theory:**
  - \textit{walk} - \textit{walked} \quad \textit{sing} - \textit{sang}(\emptyset)
  - \rightarrow \textit{stem identity} \quad \rightarrow \textit{stem identity}
Differences between regulars and irregulars

1. Brain damage can affect regulars and irregulars differently.
Aphasic data

Inferior frontal damage -- problems with
   \textit{regulars}

Temporal lobe damage -- problems with
   \textit{irregulars}
Explaining the aphasic data
Dual mechanism theories

- Left inferior frontal lobe supports rules.
  Regulars are derived by rule.
- Temporal lobe houses the lexicon.
  Irregulars are stored in the lexicon.
Explaining the aphasic data

Single mechanism storage theories

- In this theory, the aphasic data would somehow need to follow from the distinct levels of phonological relatedness between irregulars and their stems, on the one hand, and regulars and their stems on the other.
Explaining the aphasic data
Single mechanism composition theories

- Difference would need to lie in a problem with allomorphy.
- Tyler et al. (2004):
  - **Processing regulars** involves phonological parsing of a stem and an affix. This is supported by inferior frontal regions.
  - **Irregulars** involve listing of the irregular form (although it is linked to the same stem morpheme as the present tense form). Problems with irregulars arise from lexical access problems.
Aphasic upshot

- Dual mechanism theories tell a neat(ish) story.
Long lag priming

- When prime and target are separated by intervening words, only repetition priming effects are observed.
**REPETITION**

**PRIME**

- teach
- spin
- ocean
- hand

**TARGET**

- teach

**PHONONOLOGICAL**

**PRIME**

- teach
- spin
- ocean
- hand

**TARGET**

- tea

**SEMANTIC**

**PRIME**

- teach
- spin
- ocean
- hand

**TARGET**

- learn

**PRIMING?**

- YES

- NO

Time - - >
Regularity and irregularity in long lag priming
(Marslen-Wilson & Tyler, 1998)

- Repetition effect both for regulars and irregulars!

**Fig. 4 Delayed repetition priming.** Listeners made lexical decisions to primed and unprimed targets, and the difference (in ms) is plotted for each condition. No priming was found at these long lags for purely semantically related targets, but significant and equally strong priming was found for targets preceded by both regular and irregular morphologically related primes.
Similarities between regulars and irregulars

1. Long lag priming.
   - Both regulars and irregulars pattern with repetition priming.
   - This can only be explained by the single mechanism composition theory.
M350 priming (Stockall & Marantz, 2006)

- If the M350 reflects access to morphological roots,
  - Dual mechanism theory predicts cumulative similarity effects for irregulars (give - gave) and repetition priming for regulars (walk - walked)
  - Single mechanism storage theory predicts cumulative similarity effects for both irregulars and regulars.
  - Single mechanism composition theory predicts repetition priming for both for irregulars and regulars.

Result:
- **jump - jumped** (positive priming in M350 latency)
- **give - gave** (positive priming in M350 latency)
- **teach - taught** (positive priming in M350 latency)
- **boil - broil** (no priming)
M350 priming (Stockall & Marantz, 2006)

- In M350 priming, give – gave behaves as if the prime and target contained the same morpheme, just like jump – jumped.
What about M170 decomposition? Does the M170 “see” two pieces in gave?

- Fruchter, Stockall & Marantz (2013):
  - Masked priming in MEG.
  - **Prediction:** If masked priming effects reflect form-based decomposition, then they should be observed in the M170 in MEG.
  - **Result:** Yes, irregulars do show a masked priming effect in the M170.
Three theories

- Dual mechanism theory (Pinker’s “Words and Rules” theory)
  - Cannot explain the long lag priming, M350 priming

- Single mechanism storage theory
  - Cannot explain long lag priming or M350 data

- Single mechanism composition theory
  - The winner (at least for now...).
Arabic Morphology
Morphology

Types of morphological patterns

Concatenative morphology
- Two morphemes are ordered one after another i.e. affixation and compounding

Nonconcatenative morphology
- Also called discontinuous/nonlinear morphology

Arabic
How are words formed in Arabic?

كتب

“Wrote”

K t b

CVCVCV

Root

Template

Vocalic tier
Types of Arabic Morphemes

- Arabic morphemes fall into three categories:
  
  1. **Templatic morphemes**
  Templatic morphemes are interleaved to form words. Morphemes come in three types that are equally needed to create a word stem: roots, patterns and vocalisms.

  2. **Affixational morphemes**
  Affixational morphemes are concatenated to form words. Affixes can be classified into prefixes, suffixes and circumfixes, which precede, follow or surround the word stem, respectively.

  3. **Non-templatic word stems (NTWSs)**
  NTWSs are word stems that are not constructed from a root/pattern/vocalism combination.
Templatic morphemes

Roots, Patterns and Vocalism

1. Root morpheme:
It is a sequence of three, four, or five consonants (termed radicals) that signifies some abstract meaning shared by all its derivations. For example, the words: katab “he wrote”, kaatib “writer” and maktuwb ‘written’ all share the root ktb (writing related)

2. Pattern morpheme:
It is an abstract template in which roots and vocalisms are inserted. CVCVC, CVCCVC, CVVVCV..etc

3. Vocalism
It specifies which short vowels to use with a pattern.
Affixal morphemes

Arabic affixes can be:

1. **prefixes** such as sa+ (+) ‘will/[future]’, sayaktub “He will write”

2. **suffixes** such as +uwna (+) ‘[masculine plural, yaktubuwna]’ “they are writing”

3. **circumfixes** such as ta++na ( ++ ) ‘[subject 2nd person feminine plural, taktubna]’ “They are writing”

Note: multiple affixes can appear in a word.
Non-templatic word stems (NTWSs)

• NTWS are word stems that are not derivable from templatic morphemes. They tend to be foreign names and borrowed terms.

• For example,
  washintun ‘Washington’. Word stems can still take affixational morphemes, e.g., wa alwashintuniyun ‘and the Washingtonians’.
What’s unique about Arabic?

• Unlike the familiar concatenative morphology of the Indo-European languages, Semitic morphology shows a wide variety of purely morphological alternations \textit{internal} to the stem.

• For example, consider the forms here In Arabic

a. kataba ‘he wrote’
b. kattaba ‘he caused to write’
c. kaatiba ‘he corresponded’
d. takaatabuu ‘they kept up a correspondence’
e. ktataba ‘he wrote, copied’
f. kitaabun ‘book (nom.)’
g. kuttaabun ‘Koran school (nom.)’
h. kitaabatun ‘act of writing (nom.)’
i. maktabun ‘office (nom.)’
General observations

Arabic morphological system

- Vowel change/differences in voclism
- Consonantal roots
- Semantic of the roots/templates...
- patterns
What do we need to know to solve the puzzle/ to do a morphological analysis?

• Are roots independent morphological units?

• Are patterns/templates morphological units?

• How to explain the systematic and irregular meanings associated with each pattern?
Arabic lexicon

• Are morphemes, the smallest units of form and meaning, represented as independent units in the mental lexicon, or is the mental lexicon mainly a source of full forms?

• In the context of Semitic languages, these questions are equivalent to asking:

  whether the mental lexicon is organized in terms of roots and word patterns, or in terms of full forms or CVCVC-stems?
The notion of roots!

- Arguments supporting the notion that the root as a single/genuine unit?

  ➢ A language game of Bedouin Hijazi Arabic

  In this game, you can manipulate the consonantal roots (freely permuted in any order), though the nonroot consonants remain unchanged!. For example, the possible permutations of “difaʕna” 'we pushed' from the root /dfʕ/ appear here:

  a. daʕafna
  b. fiɗafna
  c. ʕadafna
  d. faʕadna
  e. ʕafadna

  ➢ Data from behavioural studies
  ➢ Data from aphasic patients
  ➢ Data from brain imaging techniques
Vocalism

• Certain verbal categories such as aspect and voice are marked on the various templates not by the disarrangement of consonantism but rather by altering the quality of the vowels of the stem in a systematic way.

• Examples:

*Kataba* “he wrote”  
*kutiba* “it was written”  
*lafaba* “he played”  
*lufiba* “it was played”  
*jamaľa* “he collected”  
*jumiʕa* “it was collected”
Patterns/ Templates

• Patterns are “Forms” of morphosyntactic categories associated with a particular phonological shape (CV “template”) and specific meanings?

• Examples of systematic meaning of the template CVCCVC

a. Ahmad ʕallam-3, MAS, SNG Fatma 1-siwaaga
   Ahmad taught Fatma DEF-driving
   ‘Ahmad taught Fatma how to drive’

b. Ahmad naḍdsaf-3, MAS, SNG 1-beet
   Ahmad cleaned DEF-house
   ‘Ahmad cleaned the house’

c. Ahmad kassar-3, MAS, SNG 1-baab
   Ahmad broke DEF-door
   ‘Ahmad broke the door’
Patterns/ Templates

- Examples of irregularities

Ahmed xayyam-3, Mas, Sng
Ahmed camped out
‘Ahmed camped out’
Theories of Arabic/ Semitic Morphology

1. Word/ lexeme/ stem- based approach

The basic unit of morphology is the stem ‘word’, so roots and templates are not genuine morphological units

(e.g., Bat-El, 1993; Farwaneh, 2007; Ratcliffe, 1997 Ussishkin, 2000, 2005, 2003)

2. Root -based approach

Words are decomposed into a root, a template (maybe) & affixes (if any), and all these units are morphemes

(e.g., Prunet et al, 2000; Idrissi et al, 2008; Boudelaa et al., 2010; Faust and Hever, 2010)
Word or stem-based approach

- The starting point of morphological structure is lexemes, which are meaningful but need not to be simplex, and roots may be part of morphological structure, but they play a less central role!

- It dispenses with roots and patterns!

- It views the Arabic lexicon as being built around processes that take the stem as a basic unit.

- Words are derived from other stem words. For Example: kaatataba is derived from kataba
Word or stem-based approach

• Thus, in this framework, the root and word pattern are dispensed with on the grounds that they play no role either in deriving surface word forms or in conveying semantic and grammatical information.

• How would you parse the imperfective active verb [yuʕallim] “he teaches” under this approach?

• Hints: ʕlm= root for “knowledge”, yu= prefix
• Therefore, an imperfective active verb form like [yuʕallim] he teaches is not parsed into: the prefix ya~, the root {ʕlm} and the word pattern {faʕil}, but into the prefix ya and the stem [ʕallim].
• This stem is then used as the basic building block to derive other forms
Root/ Morpheme -based approach

• Under this approach, Arabic morphology operates with three morphemes:

1. A consonantal root conveying the core semantic meaning,
2. A vocalic melody conveying morpho-syntactic meaning such as active-passive
3. A CV-Skeleton that contributes morpho-syntactic information and determining the phonological structure of the surface form.
According to this model, a word like “laʕab”, ‘he played’ consists of what?

It is comprised of:

1. the root /lʕb/
2. the vocalic melody a
3. the CV-Skeleton CVCVC.
What are the implications?!

• The two views have implications for the way Arabic words are accessed and stored in the mental lexicon!

• For the patterns of deficits seen following brain injury

• For the way in which language processing is neurally instantiated/represented in the brain.

• Insight into the organization of the lexicon!
Data from aphasiac patients

The Mental Representation of Semitic Words

Jean-François Prunet
Renée Béland
Ali Idrissi

This article is concerned with external evidence bearing on the nature of the units stored in the mental lexicons of speakers of Semitic languages. On the basis of aphasic metathesis errors we collected in a single case study, we suggest that roots can be accessed as independent morphological units. We review documented language games and slips of the tongue that lead to the same conclusion. We also discuss evidence for the morphemic status of templates from aphasic errors, language games, and slips of the tongue. We conclude that the available external evidence is best accounted for within a morpheme-based theory of morphology that forms words by combining roots and templates.

Keywords: roots, templates, Semitic, metathesis, morphology, aphasia
The mental representation of Semitic words (Prunet et al)

- **Subject:**
  ZT, Arabic-French bilingual, suffered a stroke at the age of 32 CT scan shows damage to left perisylvian area

- **Tests:**
  ZT was tested in both languages in:
  - Reading aloud
  - Picture naming
  - Repetition
  - Writing to dictation

- **General result:**
  ZT displayed same deficit in both languages
One type of error in Arabic, *NOT* in French: consonant metathesis!

In Arabic, ZT randomly reorders root consonants only.

**Noteworthy:**

Even if the linear order of consonants is affected, patterns and vowels usually remain intact in all tasks.
Examples of consonant metathesis in Arabic

<table>
<thead>
<tr>
<th>Target</th>
<th>Output</th>
<th>Target gloss</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>ſušb</td>
<td>šuʃb</td>
<td>‘grass’</td>
<td>reading aloud</td>
</tr>
<tr>
<td>fašil</td>
<td>šafil</td>
<td>‘failed’</td>
<td>reading aloud</td>
</tr>
<tr>
<td>ma-ţhuud</td>
<td>ma-ţduuh</td>
<td>‘effort’</td>
<td>repetition</td>
</tr>
<tr>
<td>faašil</td>
<td>šaafil</td>
<td>‘failing’</td>
<td>repetition</td>
</tr>
<tr>
<td>bahṛ</td>
<td>hbr (حیبر)</td>
<td>‘sea’</td>
<td>writing to dictation</td>
</tr>
<tr>
<td>mi-nţaq-a</td>
<td>m-ţnq-t (مطنقة)</td>
<td>‘region’</td>
<td>writing to dictation</td>
</tr>
<tr>
<td>naxl</td>
<td>xanl</td>
<td>‘palm trees’</td>
<td>picture naming (written)</td>
</tr>
<tr>
<td>șahaa?if</td>
<td>șafaa?ih</td>
<td>‘newspapers’</td>
<td>picture naming (oral)</td>
</tr>
</tbody>
</table>
Within the root based model

• ZT’s errors are compatible with root based model!

• Arabic roots contain only consonants, it follows that only nonaffixal consonants will be affected by metatheses operating on the root tier
Metathesis in French!

• **ZT’s errors in French involve:**
  1. Multiple reversals of consonants
  2. Vowels
  3. Syllables

• **Strikingly interesting:**

• A significant quantitative difference:

  (119 in Arabic and 12 in French)
Prunet et al (2000) presented evidence from the metathesis errors for the existence of the consonantal root as a lexical unit in Arabic.

Their finding thus supports the root based model.
Subliminal Speech Priming on Emirati Arabic Verbs: an MEG investigation
Background

• Subliminal speech priming technique
  – Kouider and Dupoux (2005)
  – Its elements and structure
**Background**

**Subliminal Speech Priming**  
Kouider and Dupoux (2005): an *auditory* parallel of visual masked priming (Forster and Davis, 1984)
Background

Subliminal Speech Priming
  o Kouider and Dupoux (2005): auditory parallel of visual masked priming (Forster and Davis, 1984)

• Elements of a subliminal speech priming trial:
  1. A forward mask (attenuated, compressed and reversed)
  2. Prime (attenuated and compressed)
  3. Target
  4. Backward masks (attenuated, compressed and reversed)

• They occur in two different tiers
• Duration of prime compression is a crucial aspect of this technique (35% of its original duration).
Background

- Trial structure of subliminal speech priming (Kouider and Dupoux, 2005)

- Click here to listen to an example from Shcluter’s paper (2013)
Compression Rate

- Detect the identity priming effect (the most basic effect predicted if the technique is working)

<table>
<thead>
<tr>
<th>Desired Compression goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real-word repetition</td>
</tr>
<tr>
<td>Non-word repetition</td>
</tr>
</tbody>
</table>
Subliminal speech priming

- Kouider and Dupoux (2005)
- Schluter (2013):
  - Mental representation of roots in Moroccan Arabic
  - Results:
    - Strong effect for the morphological condition
    - An effect for the identity condition
    - No phonological effect
- Ussiskhn et al. (In press)
  - Lexical access in Maltese
  - Results:
    - Morphological effect
    - Identity effect
- Daltozz et al (2011): they reduced the sound intensity level, rather than compressing the primes
  - Results:
    - Semantic priming effect
**Experimental design**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Prime</th>
<th>Word-Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantically related</td>
<td>nazzal</td>
<td>raxxaš</td>
</tr>
<tr>
<td></td>
<td>‘he brought down’</td>
<td>‘he made cheap’</td>
</tr>
<tr>
<td>Morphologically related</td>
<td>rexaš</td>
<td>raxxaš</td>
</tr>
<tr>
<td></td>
<td>‘it became cheap’</td>
<td>‘he made cheap’</td>
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<tr>
<td>Identity/ Repetition</td>
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<td>raxxaš</td>
</tr>
<tr>
<td></td>
<td>‘he made cheap’</td>
<td>‘he made cheap’</td>
</tr>
<tr>
<td>Control/ unrelated</td>
<td>setar</td>
<td>raxxaš</td>
</tr>
<tr>
<td></td>
<td>‘he unrevealed it’</td>
<td>‘he made cheap’</td>
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An illustration of the Experimental Design ‘word-targets’

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<tr>
<td>Semantically related</td>
<td>Šawwar</td>
<td>banner</td>
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<tr>
<td></td>
<td>‘he hurt s.o.’</td>
<td></td>
</tr>
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<td>Šimax</td>
<td>banner</td>
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<tr>
<td></td>
<td>‘he scratched sth.’</td>
<td></td>
</tr>
<tr>
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<td>banner</td>
<td>banner</td>
</tr>
<tr>
<td>Control/ unrelated</td>
<td>Šaraf</td>
<td>banner</td>
</tr>
<tr>
<td></td>
<td>‘he knew’</td>
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An illustration of the Experimental Design ‘nonword-targets’
Hypotheses & Predictions

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<tr>
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<td>banner</td>
<td>banner</td>
</tr>
<tr>
<td>‘he knew’</td>
<td></td>
<td></td>
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An illustration of the Experimental Design ‘nonword-targets’

E.g., Frost et al., 1997; 2000; 2005; Deutsch et al, 1998; Boudelaa & Marslen-Wilson, 2004
Methodology

Stimuli:

– 54 target words X 4 counterbalanced conditions
– 54 phonologically legal nonwords are created as fillers
– Stimuli are mostly based on a list of verbs taken from N.T.C.'s Gulf Arabic-English Dictionary (Qafisheh, 1997)
– A semantic relatedness survey was conducted on 28 subjects, using ‘Qualtrics Survey’ provided by NYU
– Stimuli were recorded by a female native speaker of Emirati Arabic from the city of Al Ain.
– Stimulus editing/extracting was performed in Praat where the recordings are transcribed in order to extract the tokens
– Volume was normalized across recordings
Methodology

Task

• The experiment uses a lexical decision task where subjects are instructed to press a button when they recognize real-word stimuli and press a different button in response to nonword stimuli.

Measure of awareness

• Subjects are asked to perform a lexical decision task on primes.
• The goal of this task is to measure accuracy so that, based on the results, we discard subjects’ data if they are able to identify primes (more than 70% accuracy).

Practice Sessions

• Subjects receive two practice sessions (one for the main experiment and one for the awareness test) where 12 training trials are presented.
Methodology

Participants:

• 26 healthy, right handed, native speakers of Emirati Arabic subjects participated in this experiment, but only 21 were included in our results.

Procedures:

• Prior to recording, the head shape of each participant is digitized, to allow source localization
• Subjects practice the task inside the MEG room
• The entire recording took about 40 minutes.
• Stimuli were presented using Presentation software
Single trial structure

- Click [here](#) to listen to this stimulus item

øllam ‘he taught  darras ‘he taught

<table>
<thead>
<tr>
<th>FwdMask</th>
<th>Prime</th>
<th>BkwdMask1</th>
<th>BkwdMask2</th>
<th>BkwdMask3</th>
<th>BkwdMask4</th>
<th>BkwdMask5</th>
</tr>
</thead>
</table>

- Time: 220 ms  220 ms  600 ms  220 ms  220 ms
1. Control vs. Identity
2. Control vs. Morphological
3. Control vs. Semantic
4. Semantic vs. Morphological
5. Nonword_Control vs. Nonword_Identity
Full Brain Results

Condition 1: Control Condition 2: Identity

Condition 1: Control Condition 2: Morph

Condition 1: Control Condition 2: Semantic
Full Brain Results

Condition 1: Sem Condition 2: Morph

Condition 1: NW_Control Condition 2: NW_Ident
Behavioral Results

Error rate

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Identity</th>
<th>Morphologically-related</th>
<th>Semantically-related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error rate</td>
<td>31%</td>
<td>30%</td>
<td>31%</td>
<td>32%</td>
</tr>
</tbody>
</table>

Accuracy on the main experiment

- 5 subjects were excluded for performing less than 70% accuracy rate

Awareness Test

- The highest rate for the subject who was able to identify the primes is 42% accuracy rate
- All subjects were not able to say whether the primes were word or non-word
Behavioral Results

Reaction times (RT) in all the conditions for **word targets**
Behavioral data

Reaction times (RT) in all the conditions for non-word targets
Summary of the Results

• Permutation and window tests
  – Priming effect in the auditory regions for the identity condition
  – No significant priming effect for the morphological condition
  – No significant priming effect for the semantic condition

BUT: There is a tendency towards effects for these conditions (they did not survive FDR correction)

• The behavioural data showed priming effects for all three conditions

• No priming effect for the repetition/identity condition for non-word targets
Follow up Experiments

- The unexpected results of this experiment = the prime compression rate?

- **Behavioural experiments**
  
  - **Goal**: to determine the best compression rate of primes for Emirati Arabic words.

  - **Two versions**:
    1. Fixed compression time of 240 ms (slightly longer than the previous one, average was 220 ms)
    2. Compression time of primes from 35% to 30% (shorter than the previous one)

  - **Prediction**: a priming effect for at least the identity condition in one or both experiments
Methodology

- **Stimuli**
  - Same as in the first experiment

- **Participants**
  - 30% Exp: 33 female native speakers of Emirati Arabic
    - 26 were only included on our results
  - 240 Exp: 35 female native speakers of Emirati Arabic
    - 28 were only included on our results

- **Task:**
  - An auditory lexical decision task using subliminal speech priming technique
Methodology

• **Awareness Test:**
  - A post-test on the prime awareness

• **Procedures:**
  - The experiment was presented using DMDX (Forster & Forster, 2003)
  - Each trial consisted of a fixation cross, followed by the auditory stimulus
  - Subjects were tested at the UAEU lab
Results

- **Accuracy rate**
  - Seven subjects achieved less than 70% accuracy rate in both versions. Thus, we excluded them from further analysis.
  - The average accuracy rate in both versions for all subjects was about 80%.

- **Error rate**

<table>
<thead>
<tr>
<th>Exp</th>
<th>Control</th>
<th>Identity</th>
<th>Morphological</th>
<th>Semantic</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>14%</td>
<td>11%</td>
<td>9%</td>
<td>12%</td>
</tr>
<tr>
<td>240%</td>
<td>12%</td>
<td>10%</td>
<td>10%</td>
<td>12%</td>
</tr>
</tbody>
</table>

- **Awareness test**
  - The average accuracy rate for the 30% Experiment was 33%
  - The average accuracy rate for the 240 Experiment is 30%
  - None of the subjects on both experiments were able to achieve more than 70% accuracy rate. Therefore, all subjects were included.
Results: 30% Experiment

Means of RT of all conditions (word targets) for the 30% Experiment
Results: 240 Experiment

Means of RT of all conditions (word targets) for the 240 Experiment
Summary of the Results

• **30% Experiment:**
  – No priming effects at all!
  – The primes are too short to be recognized at all.

• **240 Experiment:**
  • A priming effect for the identity condition
  • A strong priming effect for the morphologically related prime-target pairs
  • No semantic effect
  • No priming effect for identical non-word prime-target pairs
Discussion

1. Subliminal speech priming technique:
   • Compression rate of primes
   • Fixed compression rate vs. reduction to a certain percentage
     – Variability in the compression rate?

2. Status of the consonant roots in Arabic:
   • Subjects were able to detect the morphological relations between two words sharing the same root, indicating that roots are morphological unit in Arabic
   • Morph effect was bigger than identity effect (240 ms Exp)