



An ERP study of noun-adjective agreement in Arabic: The role of animacy and the impact of diglossia

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Max-Planck-Institut
für empirische Ästhetik



الصندوق القطري لرعاية البحث العلمي
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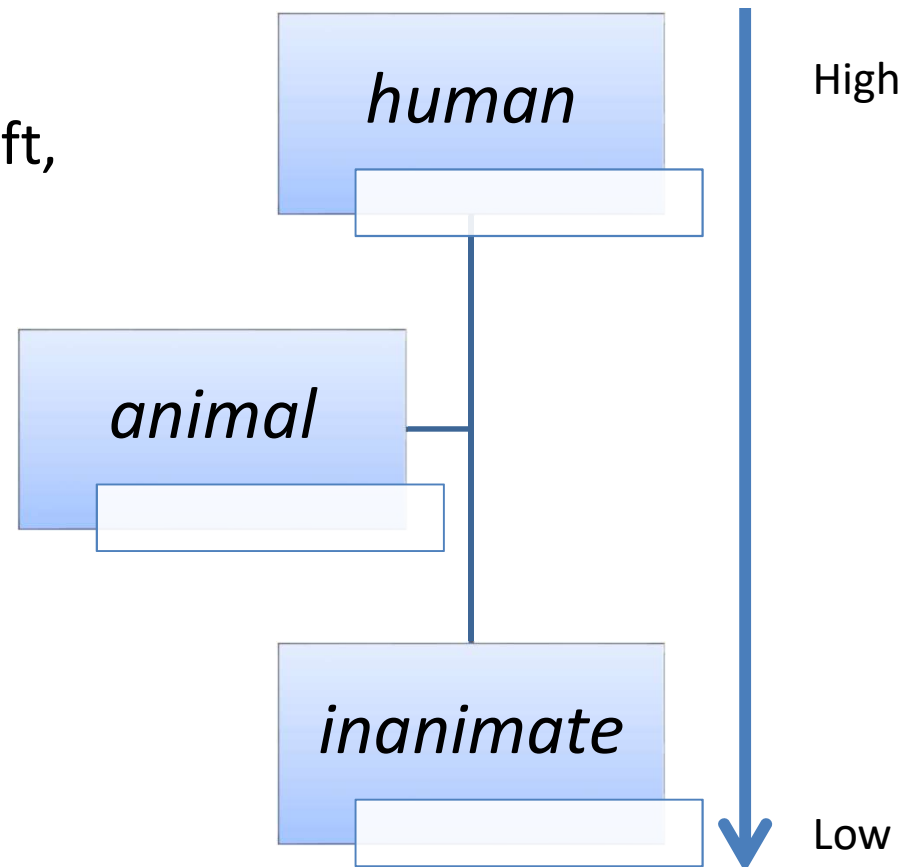
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Current Focus

- **Agreement** in Arabic noun-adjective structures and the interaction of **animacy (humanness)** with morphosyntax.
- We explore:
 - **Neurophysiological correlates/signatures** of this interaction.
 - Potential impact of **diglossia** on (i) language processing and on (ii) the overall architecture of the mental grammar of Arabic speakers.

Animacy

- Animacy hierarchy
(Comrie, 1989; Dahl, 2000; Croft, 1988)
- Animacy distinctions central to human cognition (in general).



Animacy in Cognition

- Their effect reported in (among other areas):
 - **Cognitive neuroscience** (distinct neural structures subserving animate vs. inanimate entities)
 - **Neuropsychology**: dissociations in language pathology (aphasia and Alzheimer's) between different animacy levels.
 - **Language development** (errors or acquisition patterns sensitive to animacy)

See: Grewe et al. 2007, Kriegeskorte et al. 2008; Rakison & Poulin-Dubois, 2001; Caramazza & Shelton, 1998; Saffran & Schwartz, 1994; Hodges, Graham & Patterson, 1995.

Animacy in Grammar

- Languages show syntactic and morphosyntactic *encoding* of animacy distinction (Corbett 2000, Ritter 2014) manifested in aspects such as:
 - thematic role organization
 - word order
 - case assignment
 - and (different types of) agreement

Animacy in Arabic

- Animacy (precisely, humanness) plays an important role in ***agreement*** in Arabic:

Some of the previous talks

Subject ↔ verb

Adjective ↔ noun

Determiner ↔ noun

Relative pronoun ↔ noun

etc.

Animacy and agreement in StA

- In StA plural N-Adj structures:
- *Masculine human* plurals trigger full agreement (in gender and number):
 - If **M.PL** noun, then **M.PL** adjective, pronoun etc.
- *Masculine non-human* (broken) plurals trigger full disagreement:
 - If **M.PL** noun, then **F.SG** adjective, pronoun etc.
- *Feminine non-human* plurals trigger partial disagreement.

Examples...

- This mismatch would be ungrammatical for H Ns.

(1) rižaal kibaar
man.**M.PL** big.**M.PL**
“big men”

* kabiir-a
big-**F.SG**

Ungrammatical agreement

- This mismatch would be ungrammatical for H Ns.
- Full agreement would be ungrammatical in NH Ns.

(1) rižaal kibaar
man.**M.PL** big.**M.PL**
“big men”

* kabiir-a
big-**F.SG**

(2) kilaab kabiir-a
dog.**M.PL** big-**F.SG**
“big dogs”

* kibaar
big.**M.PL**

- The phenomenon of ‘deflected agreement’
- Most common in Arabic (Ryding 2005).
- Occasional in Biblical Hebrew (?)

Interestingly ...

- While obligatory in StA,

(1) rižaal kibaar
men.M.PL big.M.PL/nice-M.PL
“big men”

Interestingly ...

- While obligatory in StA,
- *Deflected Agreement* is either not allowed in SpA:

(1) rižaal kibaar
men.M.PL big.M.PL
“big men”

(2) člaab *kbiir-a
dog.M.PL big-F.SG
“big dogs” (Qatari Arabic)

Interestingly ...

- While obligatory in StA,
- *Deflected Agreement* is either not allowed in SpA:

(1) rižaal kibaar
men.**M.PL** big.**M.PL**
“big men”

(2) člaab *kbiir-a kbaar
dog.**M.PL** big-**F.SG** big.**M.PL**
“big dogs” (Qatari Arabic)

Interestingly ...

- And if attested, it is optional

(1) rižaal kibaar
men.**M.PL** big.**M.PL**
“big men”

(2) člaab kbiir-a kbaar
dog.**M.PL** big-**F.SG** big.**M.PL**
“big dogs” (Qatari Arabic)

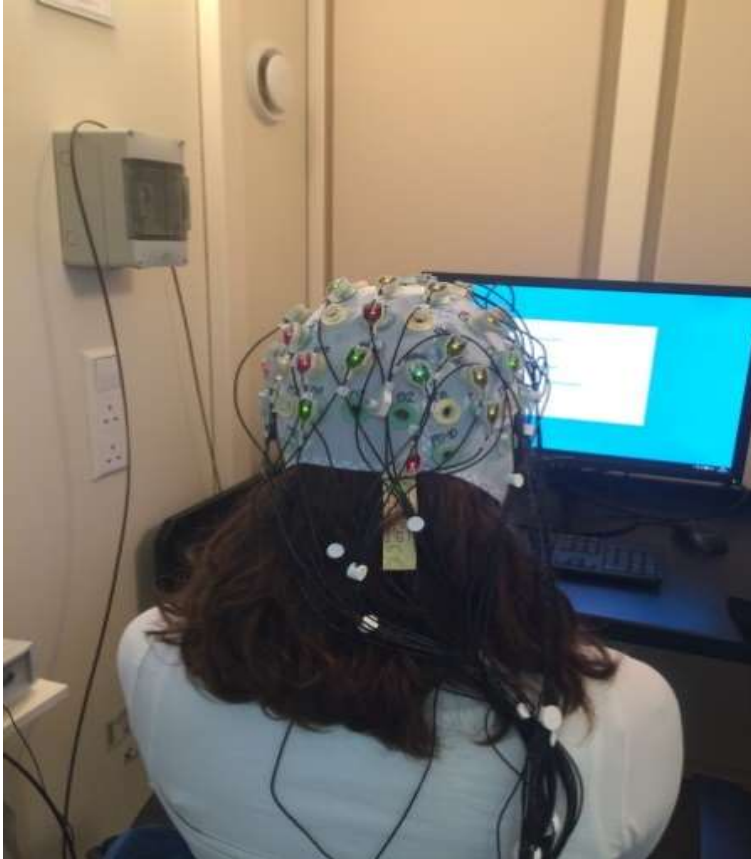
Questions

- How does the processing system deal with the StA double-mismatch in NH cases?
 - The role of animacy/humanness?
- Do(es) the pattern(s) attested in SpA influence processing the corresponding structures in StA?
 - The impact of diglossia?

Paradigm and Methodology

- Rapid serial visual presentation
- Grammaticality judgements
- Simultaneous electroencephalography (EEG) recording

EEG



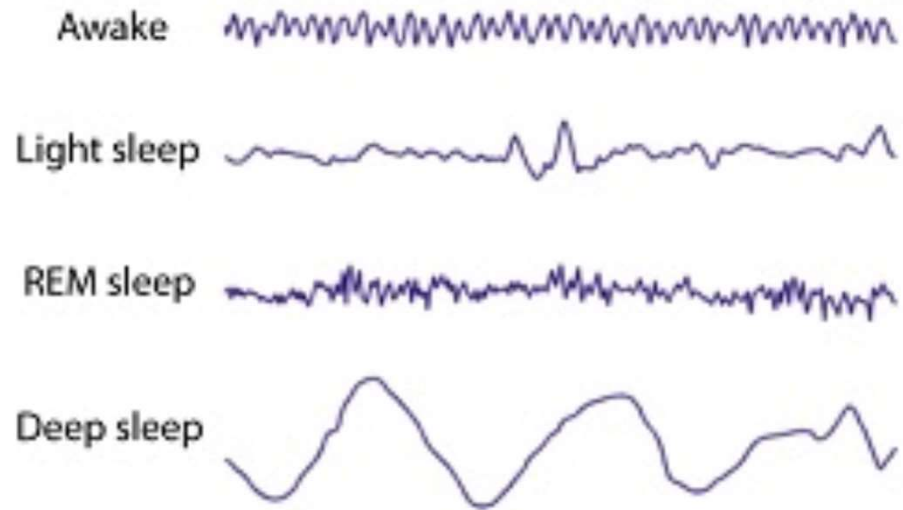
QU Lab

- Non-invasive technology to study the neural correlates of language processes.
- Relatively cheap (although time-consuming).
- Provides high temporal resolution (less precise spatial resolution).

Types of EEG Waveforms

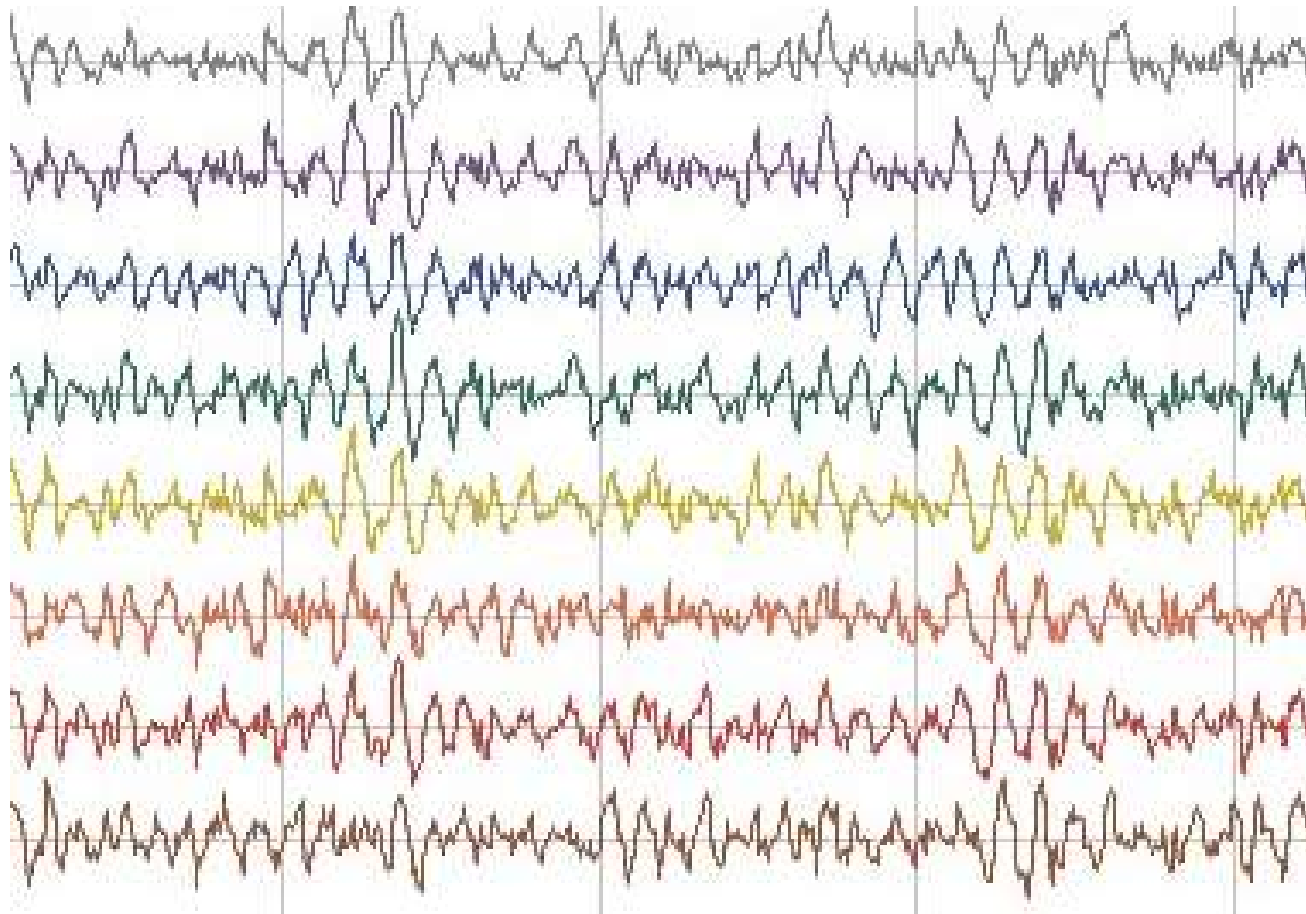


When we read or hear language



A few seconds of EEG traces showing different EEG waveforms associated with different brain states.

EEG Data



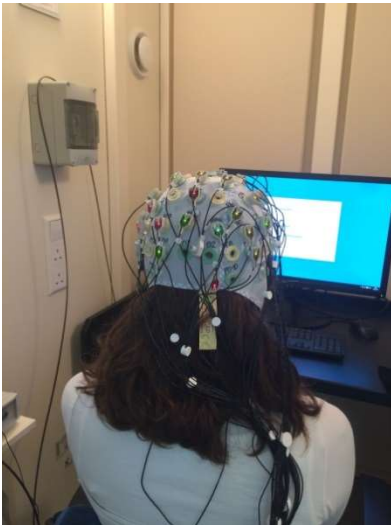
Not usable
in this form

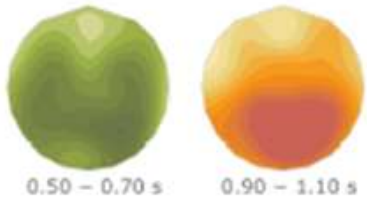
It undergoes
a process of
cleaning and
analysis

Raw EEG data recorded from 8 electrodes/sites

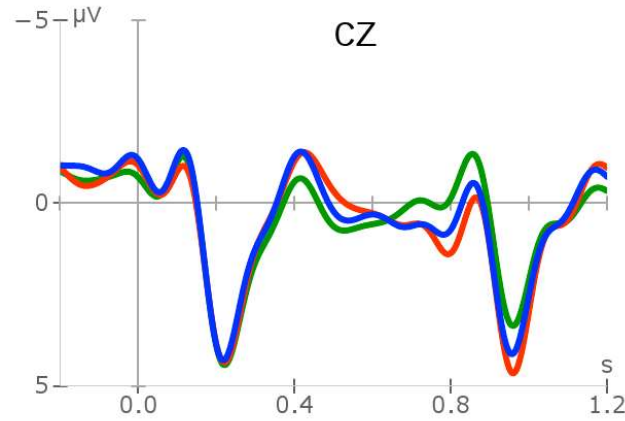
The process of EEG data acquisition and analysis

Participant sitting comfortably in a shielded booth, wearing an EEG cap and reading/listening to language stimuli

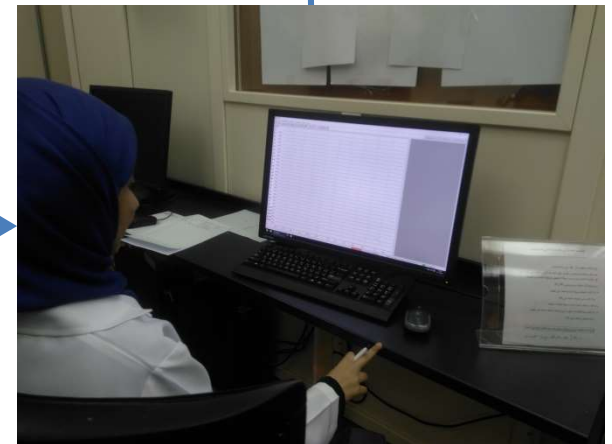
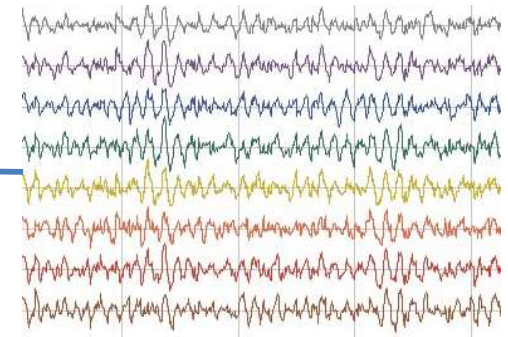




Broad scalp topography can be generated



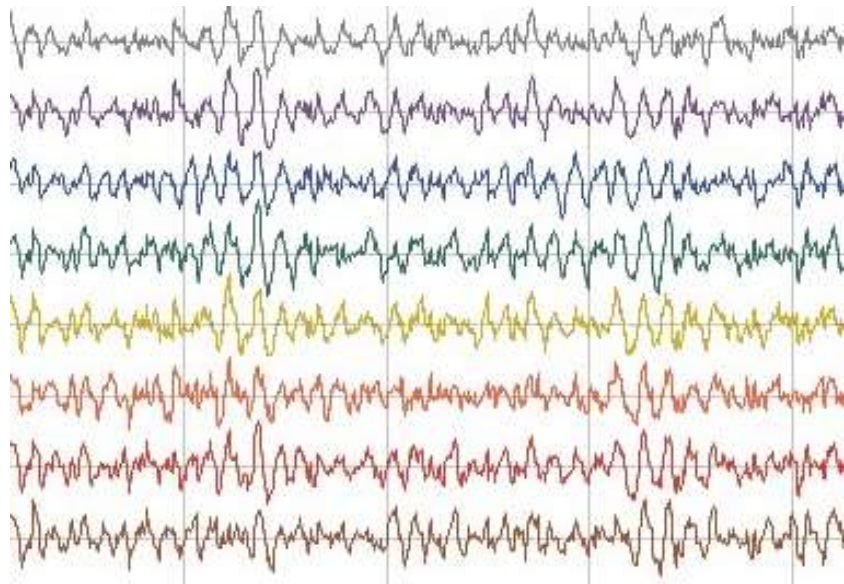
Data cleaned from artefacts and then averaged and ERP components can be seen



EEG signal amplified and sent to and recorded on a computer

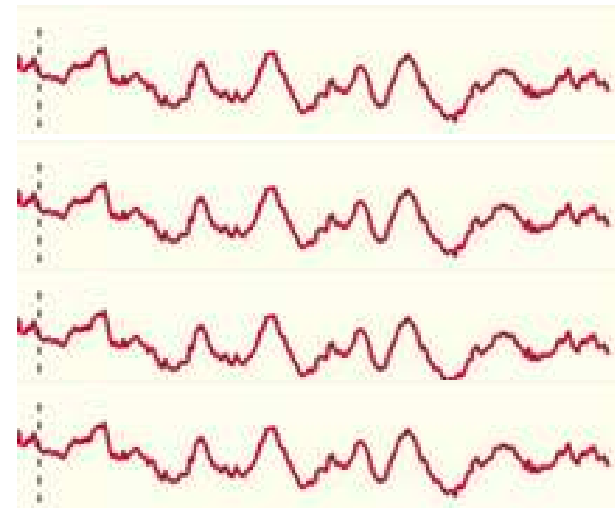
EEG vs. Event Related Potentials

EEG



Continuous EEG waves

ERPs



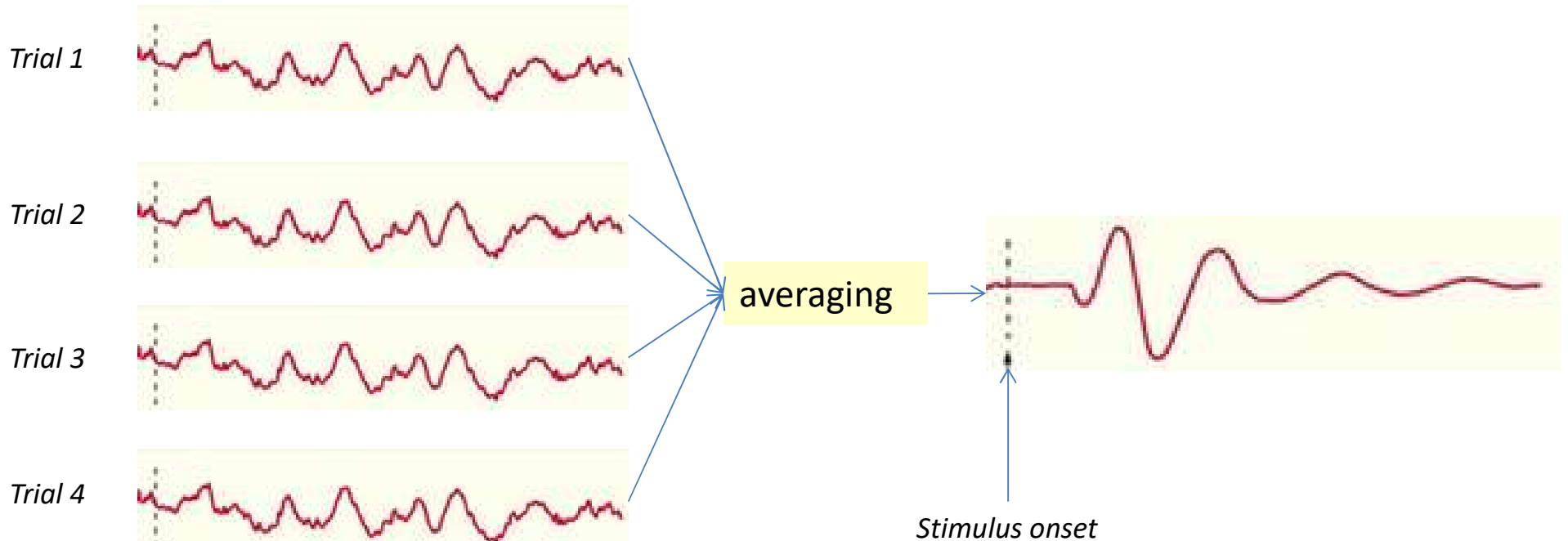
Stimulus onset

EEG waves time-locked to a given stimulus (and event)

ERPs = brain responses measured as the direct result of a given event (sensory, cognitive, or motor).

Averaging

A segment is taken from many trials (and also over many participants).



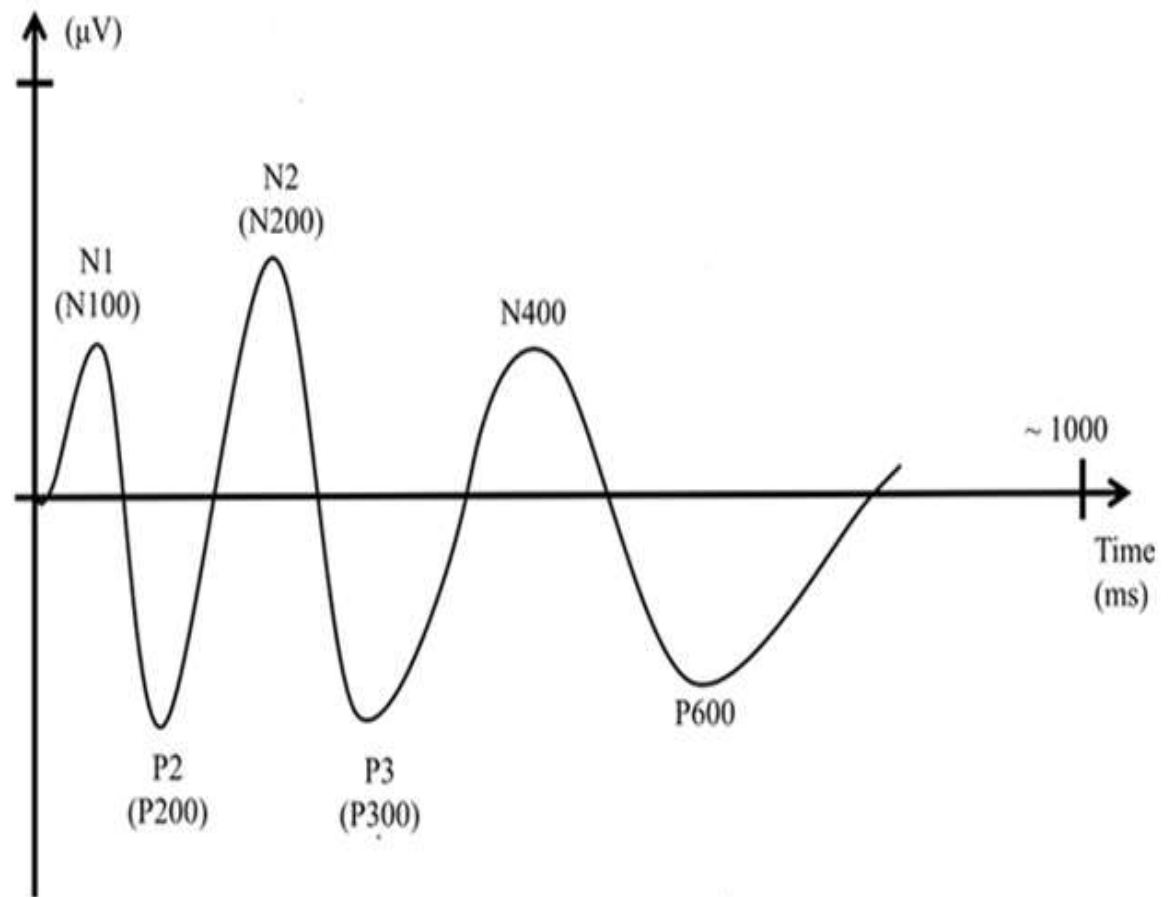
Stimulus onset

Trials are time-locked to (aligned with) a given stimulus onset (e.g., verb, adjective, etc..)

Averaging gets rid of noise (continuous brain activity) and leaves only the ERPs which reflect the processing of the given stimulus

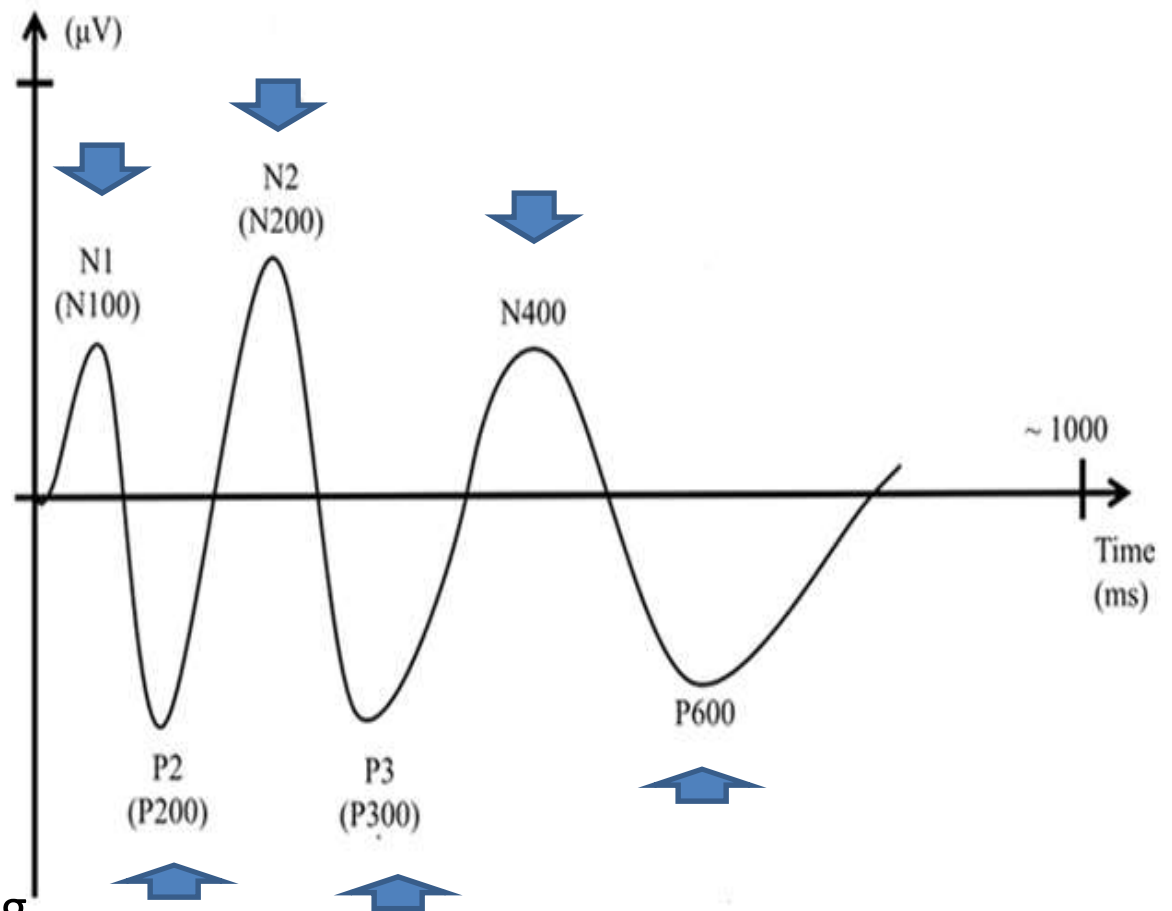
ERP Effects

- **latencies** (horizontal axis: time from stimulus in ms.)
- **Polarity:**
 - positive potential
 - negative potential
- **Amplitude** (vertical axis unit): scalp potential in microvolts: negative upward; positive downward)



Functional Interpretation

- N1 and P2: pre-attentive perceptual processing (physical properties of stimulus)
- N2: stimulus detection
- P3: stimulus categorization and probability (memory updating, as in oddball paradigm)
- N400: semantic (conceptual) processing
- P600: syntactic processing



Now...

What ERPs are taken to be relevant to
language?

Relevant ERP components

- **N400**: negative-going ERP peaking ~ 400 ms after the onset of the critical item .
 - Commonly associated with semantic processes.
- P600: positive-going ERP peaking ~ 600 ms after the onset of the critical item.
 - Commonly associated with syntactic processing/repair.
- LAN: negative-going ERP peaking between 300 to 500 ms after the onset of the critical item.
 - Generally associated with morphosyntactic processes (such as verb agreement).

N400

Kutas & Hillyard (1980)

— XXXXX IT WAS HIS FIRST DAY AT WORK.
- - - - - XXXXX HE SPREAD THE WARM BREAD WITH SOCKS.

Reading Senseless Sentences: Brain Potentials Reflect Semantic Incongruity

Abstract. In a sentence reading task, words that occurred out of context were associated with specific types of event-related brain potentials. Words that were physically aberrant (larger than normal) elicited a late positive series of potentials, whereas semantically inappropriate words elicited a late negative wave (N400). The N400 wave may be an electrophysiological sign of the "reprocessing" of semantically anomalous information.

SCIENCE, VOL. 207, 11 JANUARY 1980

MARTA KUTAS
STEVEN A. HILLYARD



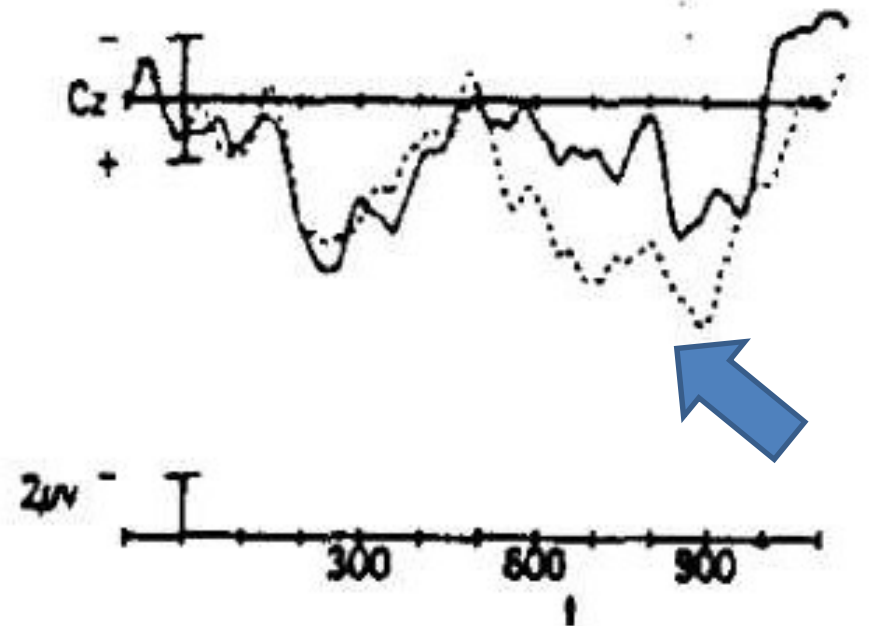
Relevant ERP components

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- LAN: negative-going ERP peaking between 300 to 500 ms after the onset of the critical item.
 - Generally associated with morphosyntactic processes (such as verb agreement).

P600

Osterhout & Holcomb (1992)

Syntactic Anomaly



alp electrodes while sub-
ch were inconsistent with
) quite distinct from the
e words (N400). Further-
ble elicited an N400-like
ceptable. These findings
anomaly engendered by
ctically ambiguous string
600 and N400 effects are
spectively). © 1992 Academic
UAGE 31, 785-806 (1992)

— The broker persuaded to sell the stock was ...

..... The broker hoped to sell the stock was ...

Relevant ERP components

- N₄₀₀: negative-going ERP peaking ~ 400 ms after the onset of the critical item .
 - Commonly associated with semantic processes..
- P₆₀₀: positive-going ERP peaking ~ 600 ms after the onset of the critical item.
 - Commonly associated with syntactic processing/repair.
- **LAN**: negative-going ERP peaking between 300 to 500 ms after the onset of the critical item.
 - Generally associated with morphosyntactic processes (such as subject-verb agreement).

LAN

Osterhout & Mobley (1995)

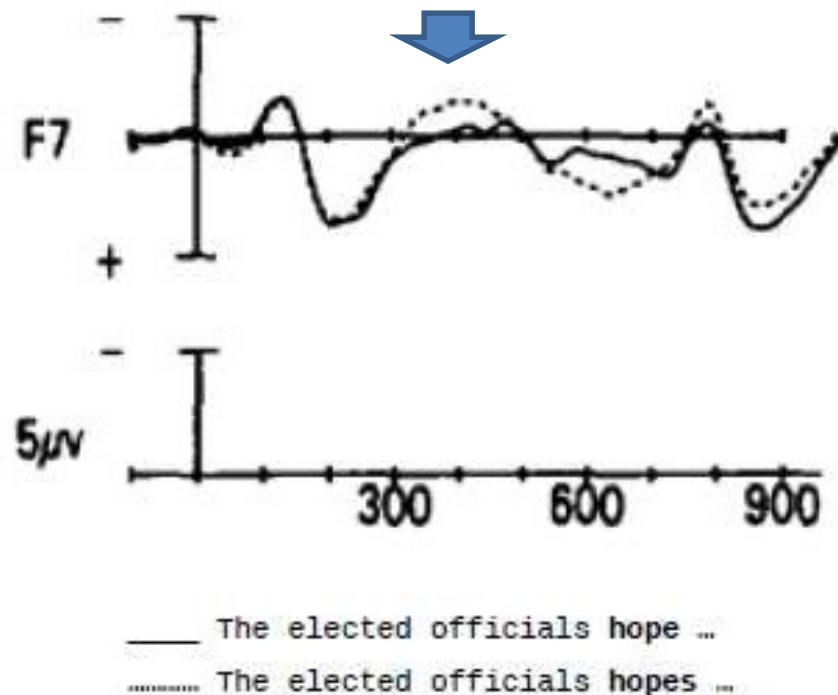
Effects Elicited by Failure to Agree

BY LINDA A. MOBLEY

University of Washington

Recorded from 13 scalp electrodes while subjects read sentences with number or gender agreement. Subjects judged the sentences and passively read sentences in Experiment 3. The number, reflexive-antecedent number, and reflexive-antecedent gender violations elicited a broadly distributed positive-going wave (P600). Subfrontal negativity. In Experiment 2, personal subject noun elicited a P600, but only when subjects read semantically anomalous words elicited an enhanced P600. Number disagreement elicited a P600 and semantic reflexive-antecedent agreement violations did not elicit a P600. The authors speculate that agreement between sentence content and semantic or discourse factors. © 1995 Academic Press

JOURNAL OF MEMORY AND LANGUAGE 34, 739-773 (1995)



Back to our study...

Methodology

- Participants:
33 right-handed native speakers of Qatari Arabic.
- EEG recording:
Data recorded at 25 scalp electrode sites; 250 Hz.
- Reference:
Left-mastoid, re-referenced to linked mastoids offline
- Ground electrode:
AFZ; Offline filter: 0.3 – 20 Hz band-pass

Methodology

- Sentences: *Noun – Adjective – Verb – PP*



Measures taken at the adjective

- Presentation: Rapid serial visual presentation of stimuli

Methodology

- Tasks:

- **Acceptability judgement:**

- *Is the sentence acceptable?*



(Yes – No)

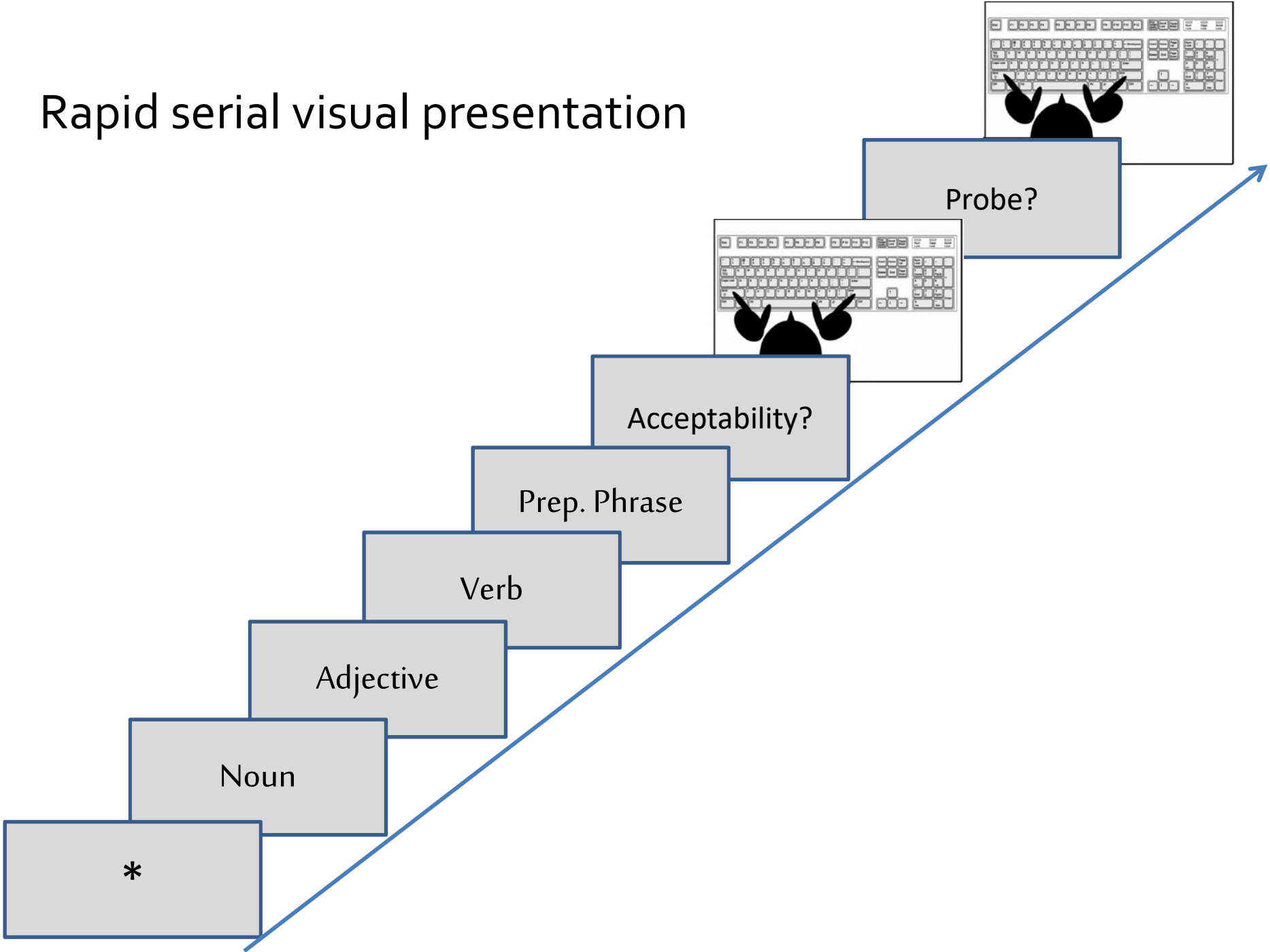
- Followed by **probe** detection:

- *Did you see the word X in the previous sentence?*

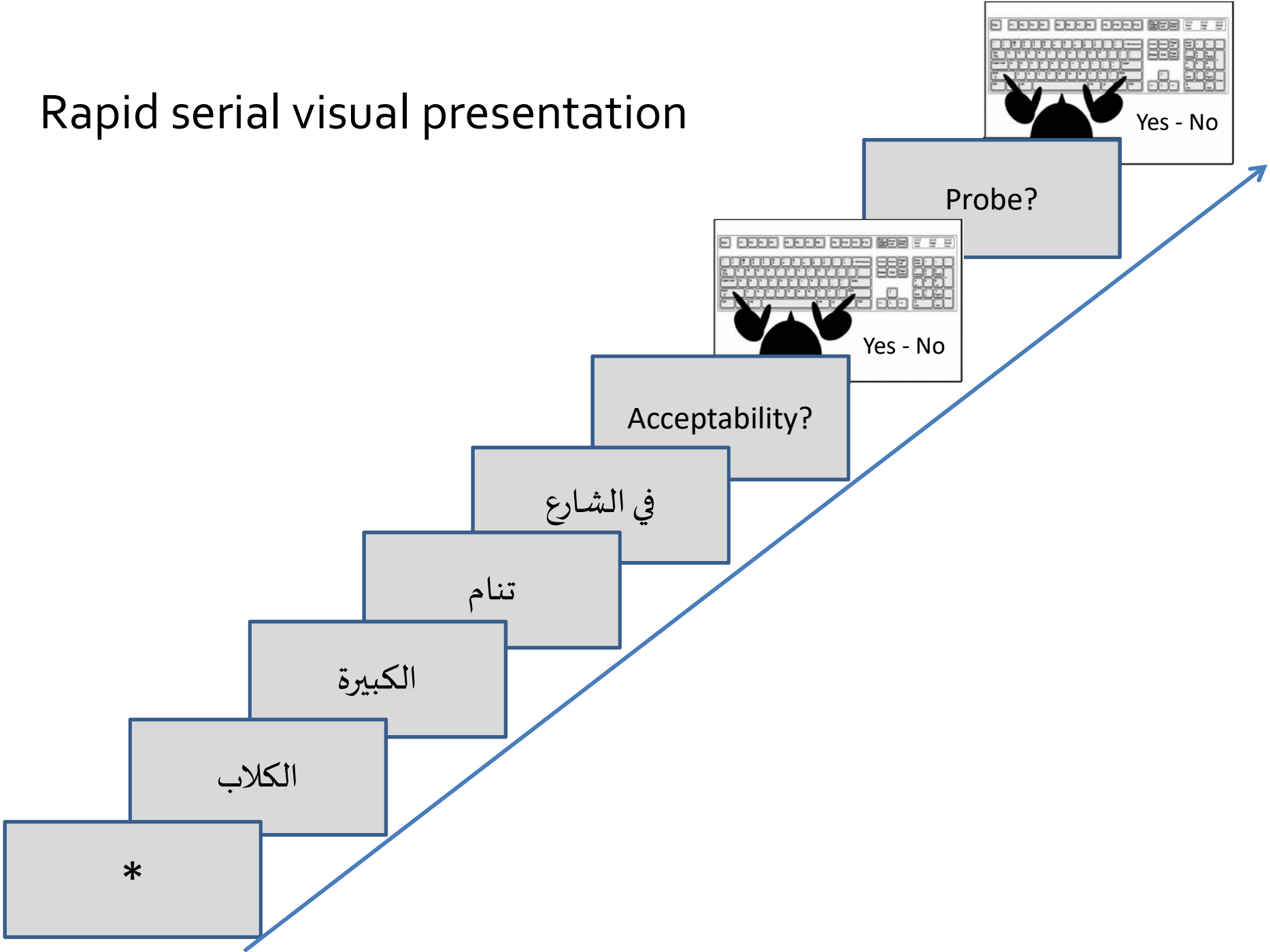
(Yes – No)



Rapid serial visual presentation



Rapid serial visual presentation



Manipulations

Conditions

HA	بالمكان	أعجبوا	الكبار	الرجال	Human Acceptable
	bi l-makaan by DEF.-place	ʔuʕʒib-uu were-impressed	l-kibaar DEF.-big.M.PL	l-rižaal DEF.-man.M.PL	
HV*	بالمكان	أعجبوا	الكبيرة*	الرجال	Human Violation
	bi l-makaan by DEF.-place	ʔuʕʒib-uu were-impressed	l-kabiir-a DEF.-big-F.SG	l-rižaal DEF.-man.M.PL	
"The big men were impressed by the place"					
NA	في الشارع	نامت	الكبيرة	الكلاب	Nonhuman Acceptable
	fii l-šaariʕ in DEF.-street	naam-at slept	l-kabiir-a DEF.-big-F.SG	l-kilaab DEF.-dog.M.PL	
NV*	في الشارع	نامت	الكبار*	الكلاب	Nonhuman Violation
	fii l-šaariʕ in DEF.-street	naam-at slept-F.SG	l-kibaar DEF.-big.M.PL	l-kilaab DEF.-dog.M.PL	
"The big dogs slept in the street"					

Hypotheses

Hypotheses

1. **Same** brain response patterns signaling agreement violations as opposed to those signaling acceptable patterns (possibly, negativity – positivity complexes: LAN – P600 or N400 – P600 or later positivity → Humanness/animacy effect.
2. **Grammaticality judgments**: Violations should be systematically rejected.
3. **SpA effect**: If SpA system is activated, we expect different ERP signatures of HV vs. NV.
→ Diglossia impact (?)

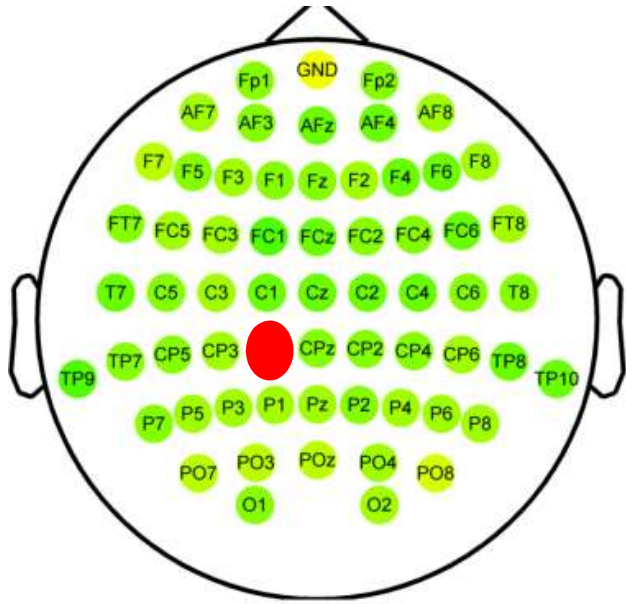
Results

Results – Overall

- HV*s (Condition 2: **men big-F.SG**) rated **ungrammatical** and led to significant **negativity** in the central-parietal areas of the brain.
- NV*s (Condition 4: **dogs big.M.PL**), also rated **unacceptable**, but they did **not** trigger the same neural negativity as HV*.
- Unlike the ERPs, GJ results show a general difference between V and A conditions (i.e., regardless of whether the noun involved is human or non-human).
 - i.e., there is no effect of humanness. Violations are overall ‘judged’ as being violations.

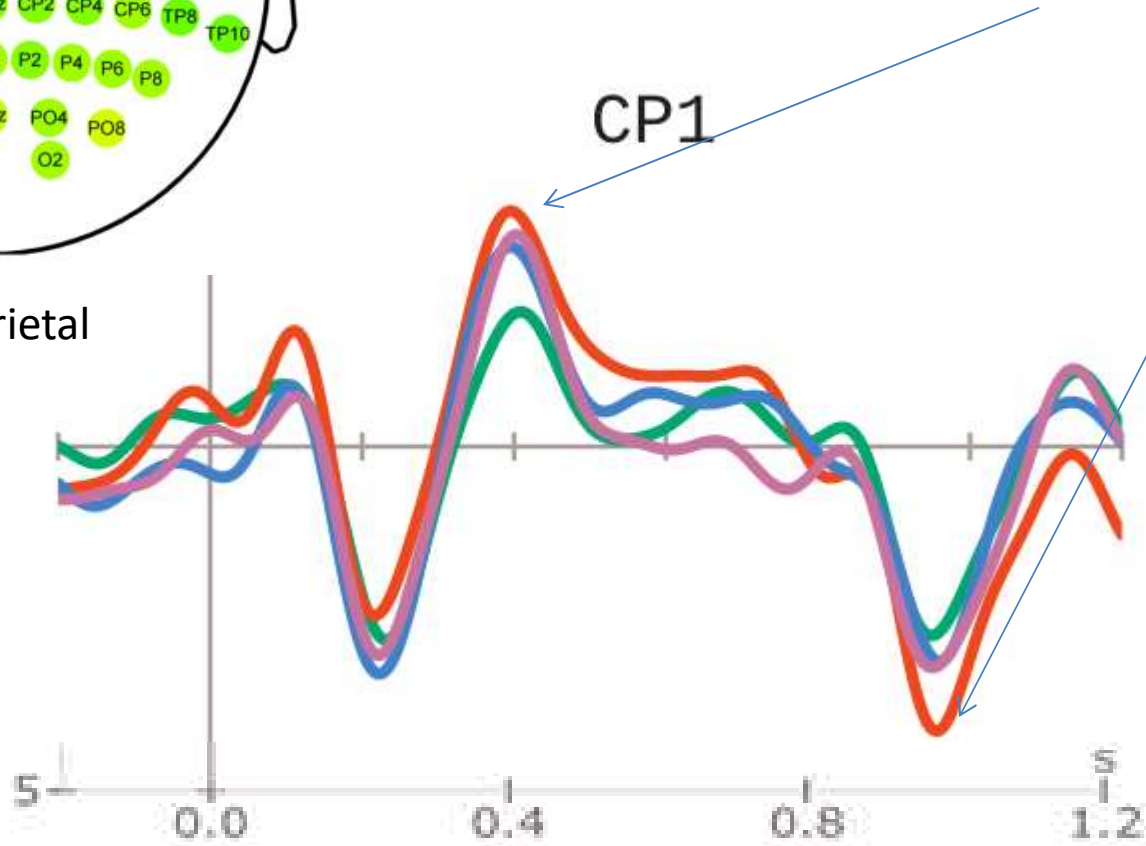
Let's look at specific ROIs

Results



— HV: Negativity (N400), later positivity

Central-parietal



N = 33

— HA

— HV

— NA

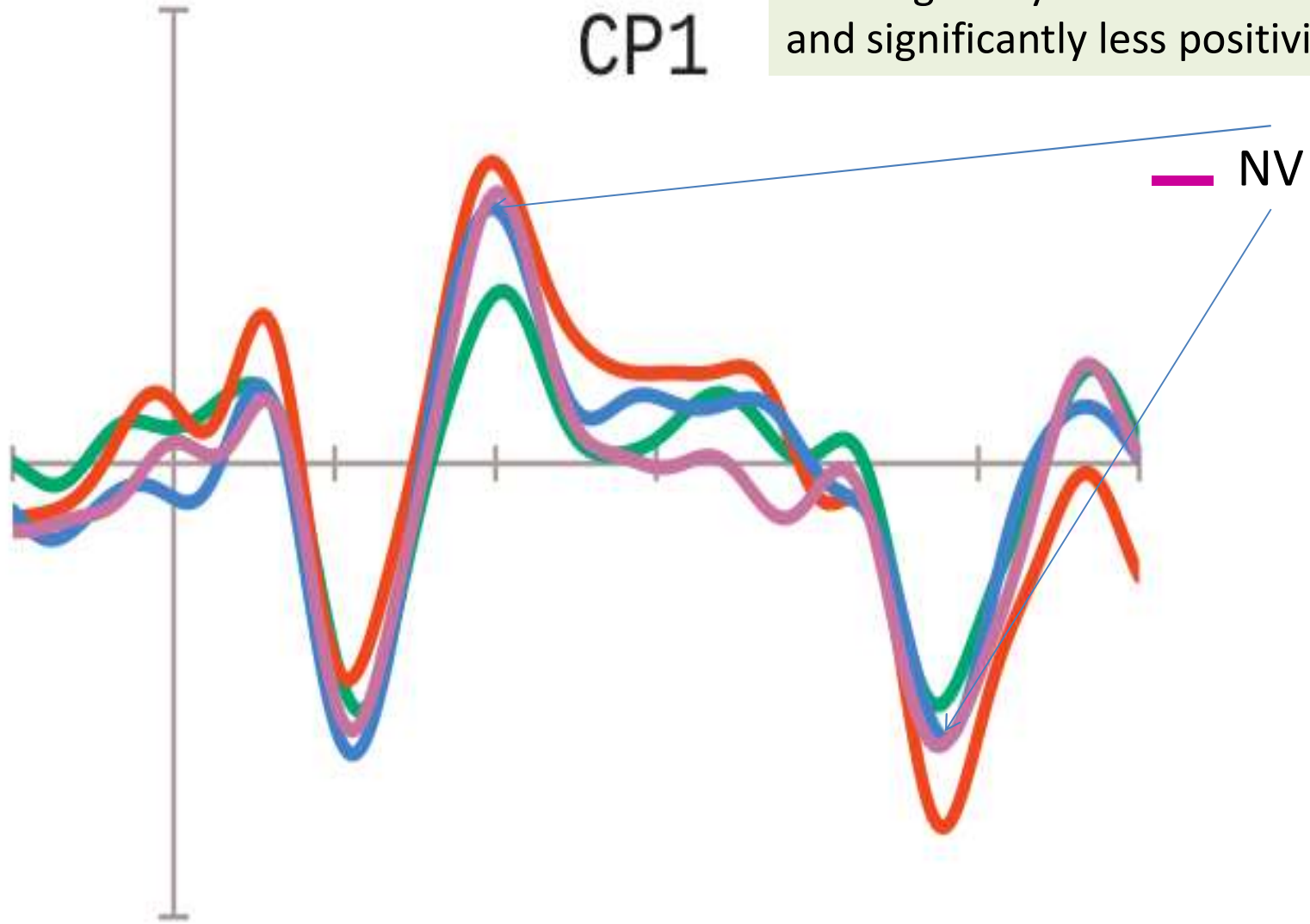
— NV

Note that it **overlaps** with its acceptable counterpart (the blue line) at both stages

Compared to NV

which shows significantly less negativity and significantly less positivity

CP1



N = 33

HA

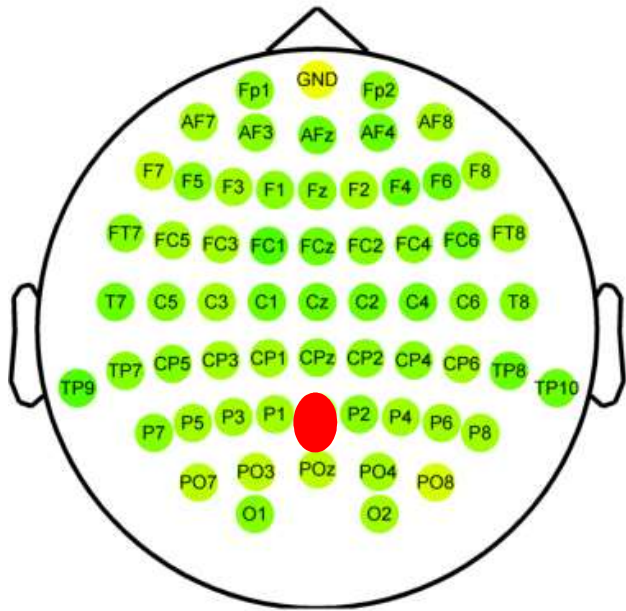
HV

NA

NV

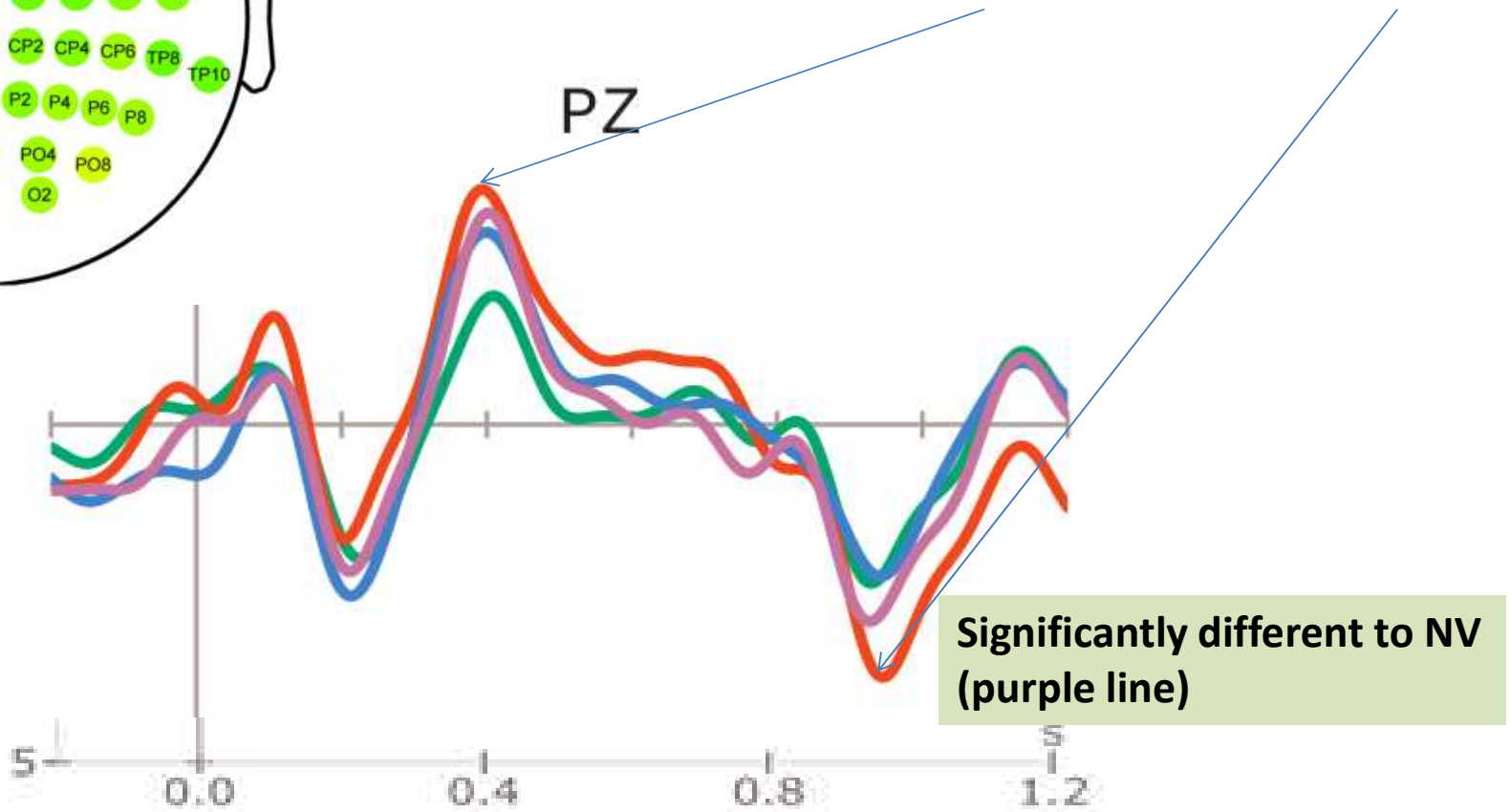
A peak at another point

Results



Parietal

— HV: Negativity (N400), later positivity



N = 33

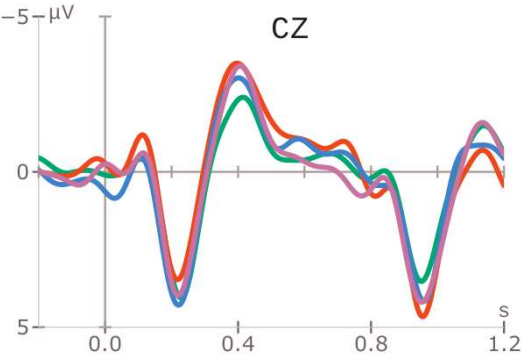
— HA

— HV

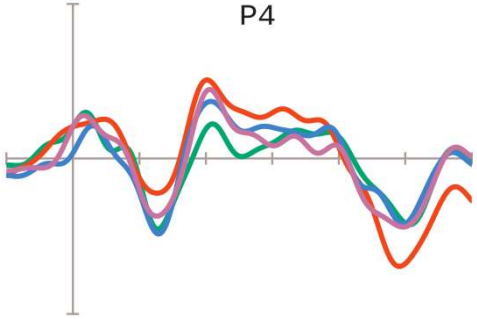
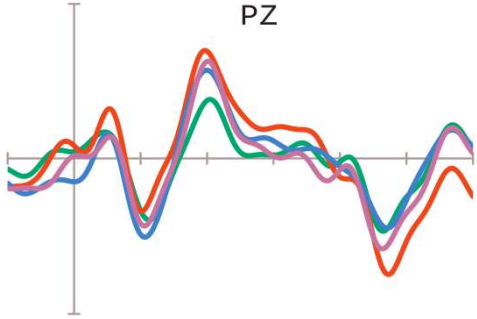
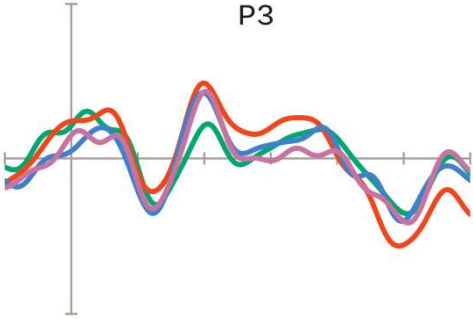
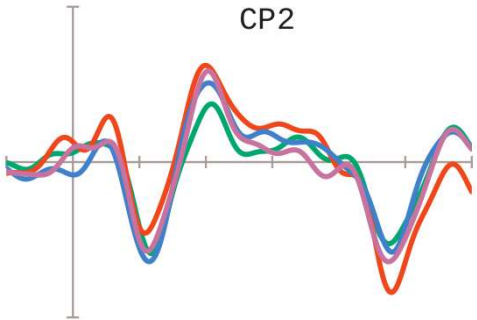
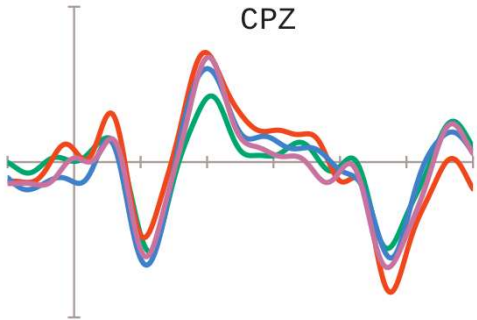
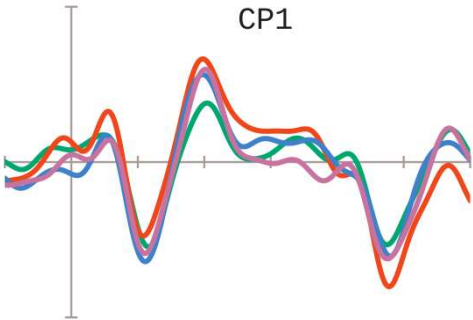
— NA

— NV

Different ROIs
(electrodes) in the
centro-parietal region



A consistent pattern!



N = 33 — HA — HV — NA — NV

Topography of the effects

Results: ERP

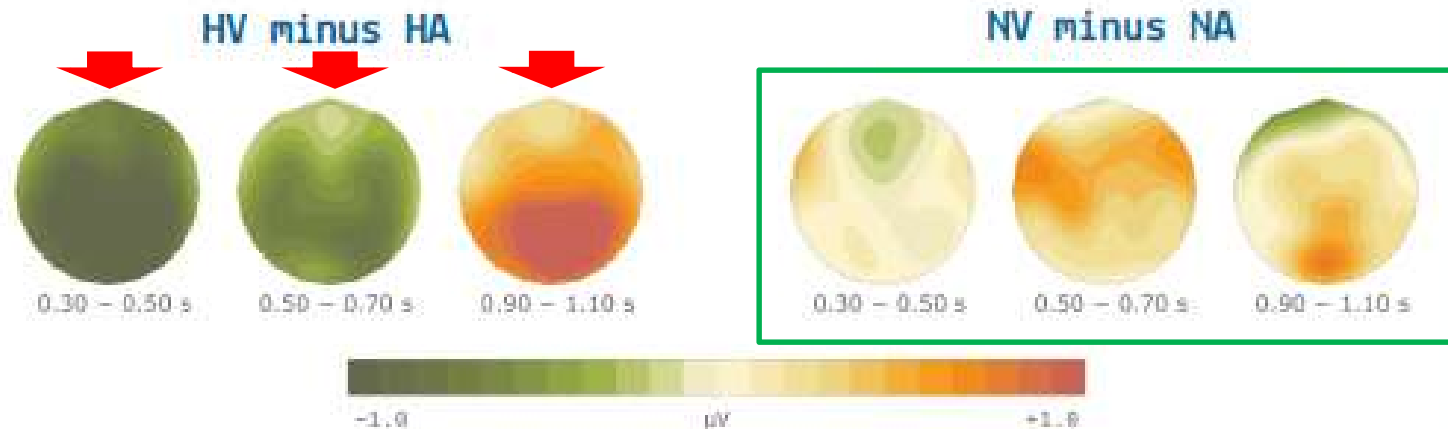
Measures taken at the adjective

Comparing HV and NV: *man big-F.SG* and *dog big.M.PL*

The **HV** condition elicited a centro-parietal negativity (300 – 500 ms; 500 – 700 ms)

Followed by a late-positivity (900 – 1100 ms)

Topography of Effects at the Adjective



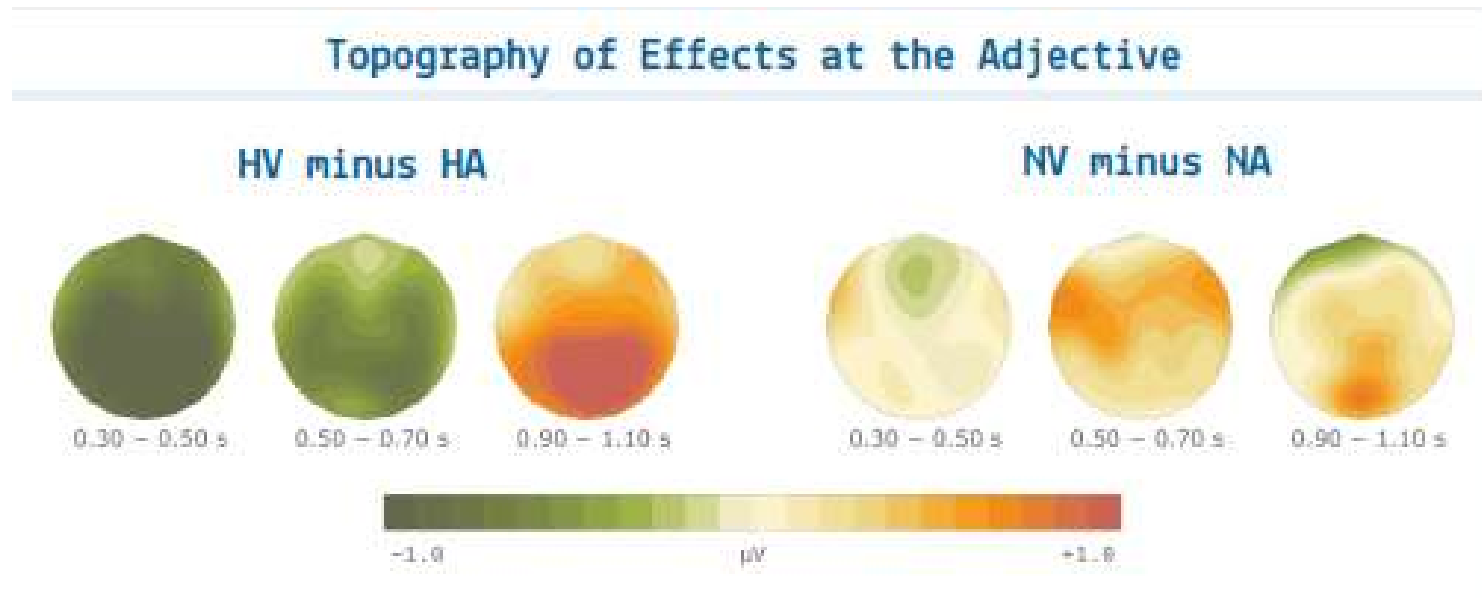
as opposed to its **A** counterpart.

No comparable effects for **NV** condition its acceptable counterpart.

Results: ERP

- HV and NH trigger different brain responses.

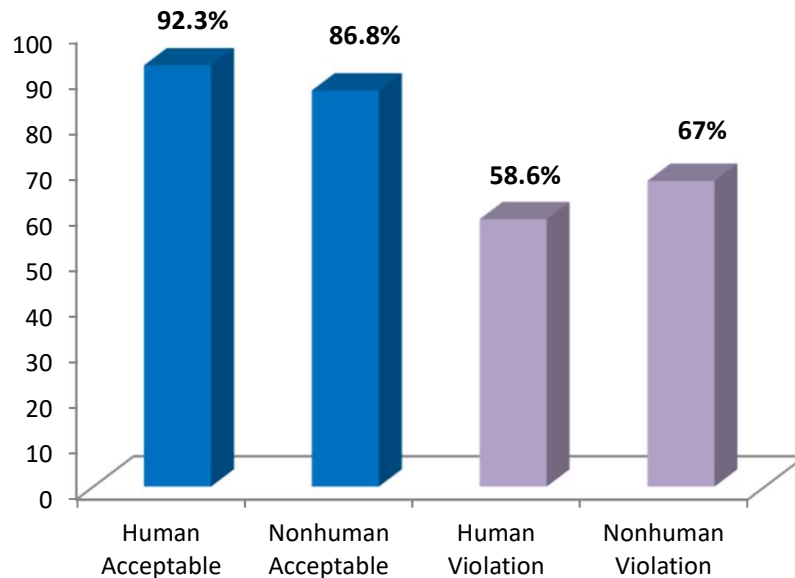
So, we have a “Humanness” (animacy) effect.



What about Grammaticality
Judgments?

Results: Acceptability

- A general effect of V vs. A conditions ($p < 0.001$)
- There was no effect of humanness ($p = 0.4$).



!!

Grammatical mattered

Humanness did not

Deflected agreement generally rated ill-formed for [+human]

Full agreement generally rated ill-formed for [- human]

Summary of Results

ERP results	Behavioral results
show a difference between V and A conditions <u>only for [+Human] nouns</u>	show a difference between V and A conditions, <u>regardless of humanness</u>
→ Effect of humanness	→ No effect of humanness
Only Human violations are 'processed' as being violations (recall NV = NA)	All violations are 'judged' as being violations
→ Influence of SpA grammar?	→ Metalinguistic knowledge?

Summary of Results

ERP results	Behavioral results
show a difference between V and A conditions <u>only for</u> <u>[+Human] nouns</u>	show a difference between V and A conditions, <u>regardless of humanness</u>

Summary of Results

- Agreement violations involving human broken plural (Condition HV*):
 - rated ungrammatical
 - triggered significant negativity in the central-parietal areas.
- By contrast, violations involving non-human broken plurals (Condition NV*):
 - rated unacceptable
 - but did not trigger the same neural negativity associated with grammatical violations.

Discussion & Interpretation

Discussion

- Results suggest that even though deflected agreement is obligatory in StA, the fact that it is not so in SpA influences how StA is processed.
- This may explain why non-human violations (NH*) show the same ERP patterns as their acceptable (A) counterparts.

Discussion

- The results clearly show that humanness (and animacy) interacts with morphosyntax both:
 - at the **early** stages of processing (early negativity: 400 ms)
 - and at the **later** integration stage (late positivity: later than 600 ms).

Why is this differential processing
between HV* and NV*?

Diglossic Grammar?

- Competing grammars/rules from SpA?
- Mitigating violations in StA, when they correspond to non-violations in SpA.
- Architecture of Arabic speakers' grammar:
 - Speakers may possess 'hybrid' systems (whose features are yet to be identified at various levels of structure and processing: syntax, phonology, etc.)
 - How different from-similar to bilinguals' grammars?

Language Processing Questions

- Same results as Barber & Carreiras (2005) for N-Adj agreement in Spanish (N400 type of effect).
- Det-N disagreement yields additional LAN (not observed in our results)
 - Maybe specific syntactic domains are associated with specific ERP signatures.

For the linguists...

- Grammaticality judgements and/or brain data clearly did not converge.
- Metalinguistic analysis and explicit knowledge vs. natural/online analysis and implicit knowledge?
- Which way to go, when they diverge?
- Examples of data elicitation that may yield slightly unreliable intuitions.

Conclusions

- The results confirm the processor is sensitive to (HV treated differently to NV).
- Indirect evidence for the effect of diglossia in online language processing and raises questions:
 - (i) the nature of diglossic grammar
 - (ii) the subtle but non-significant distinction between metalinguistic knowledge (reflected in grammaticality judgments) and implicit linguistic knowledge (reflected by brain responses).

Merci...