The visual word form area: expertise for reading in the fusiform gyrus

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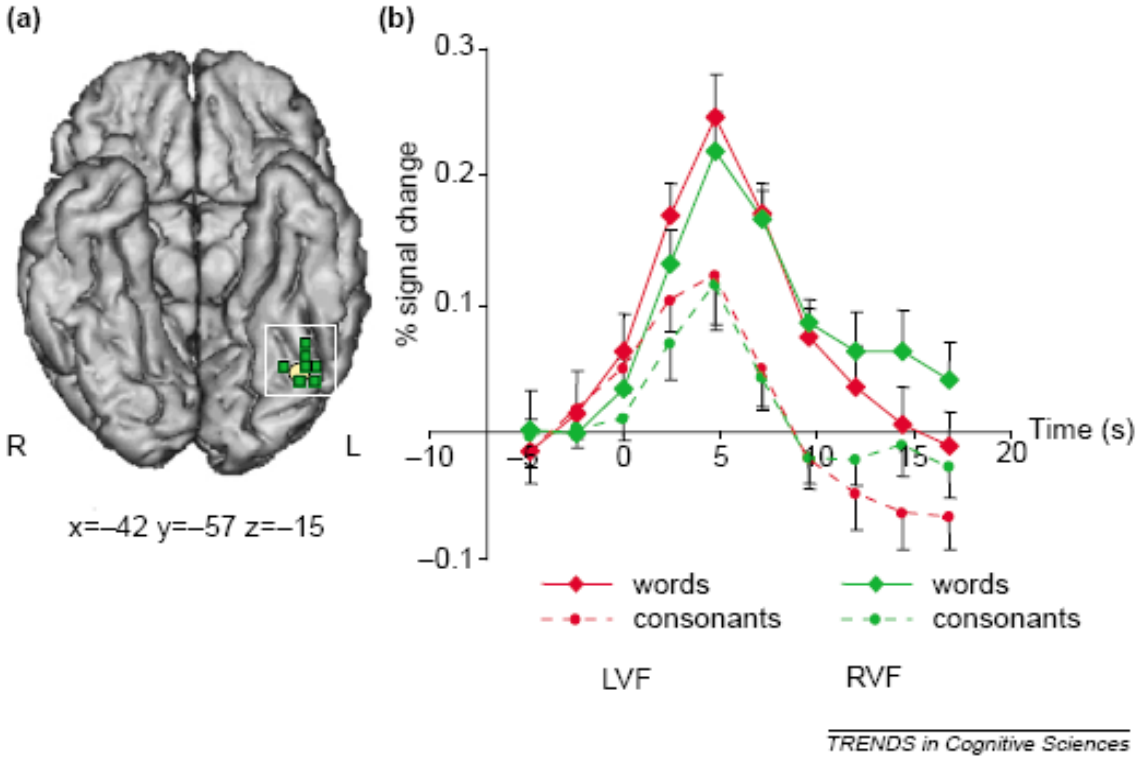


Fig. 1. (a) Peak of the Visual Word Form Area (VWFA) identified in individual subjects (green squares) and in group analyses (yellow circle) projected onto the inferior surface of a normalized brain. L indicates left hemisphere, R right. (b) Percentage change in BOLD signal for words and consonant strings versus checkerboards in the left and right hemifields at the peak of the group VWFA, averaged across subjects (bars represent the intersubject standard error).

Die VWFA (visuelle Wort-Form Area)

- Einige Jahre nachdem Kinder gelernt haben, Buchstaben in Wörter zu dekodieren, bildet sich eine perzeptuelle Expertise, durch die Gruppen von Buchstaben mühelos in Wörter integriert werden.
- McCandliss et al. (2003) postulieren eine Verbindung zwischen dieser Expertise und einer Region im linken Gyrus fusiformis, der VWFA.
- Lesen und Schreiben als Kulturtechniken existieren erst seit ca. 5400 Jahren. Wie soll sich in so kurzer Zeit ein eigenes funktionelles “Modul” für Lesen gebildet haben?
- McCandliss et al. nehmen einen Entwicklungsprozess im Individuum an, bei dem die perzeptuelle Erfahrung mit geschriebenen Wörtern als Katalysator einer zunehmende Spezialisierung von Systemen zur visuellen Objekterkennung im inferioren Temporallappen fungiert.

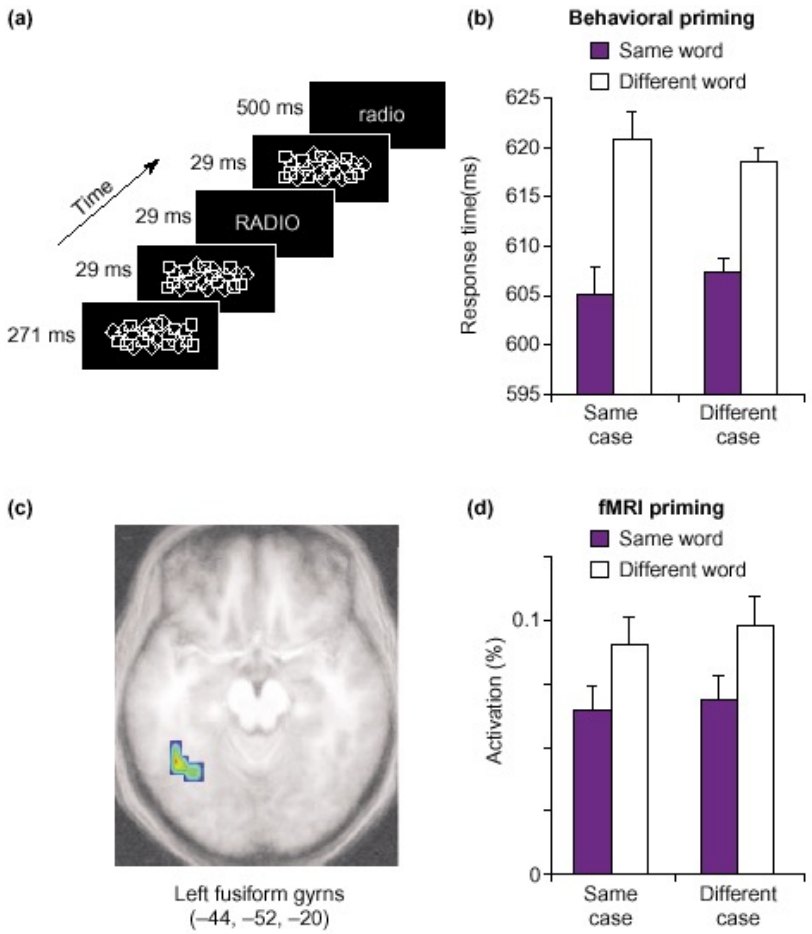
Perzeptuelle Expertise beim Lesen

- Trotz enormer Variationen in Größe, *Schriftart*, **Font** oder retinaler Position kann das visuelle System innerhalb von weniger als 250 ms die relevante Information aus einem geschriebenen Wort extrahieren.
- Die Lesegeschwindigkeit in Wörtern mit 3-6 Buchstaben Länge ist bemerkenswert unabhängig von der Wortlänge, was auf parallele Verarbeitung der Buchstaben hinweist (Nazir et al., 1998).
- Der Wortüberlegenheitseffekt (word superiority effect) zeigt, dass ein Targetbuchstabe innerhalb eines Wortes besser verarbeitet wird als innerhalb einer sinnlosen Buchstabenkette (Reicher, 1969).
- Diese perzeptuellen Effekte persistieren über eine Reihe von “nicht-essentiellen” Änderungen des Stimulus (z.B. in Font oder Grösse). Hier wird offenbar abstrakte, invariante Information über die Struktur visueller Wörter (visuelle Wort-Formen) extrahiert und in ein für das Lesen essentielles “perzeptuelles Objekt” integriert (Rayner & Pollatsek, 1989).

VWFA

- Areale im Gyrus fusiformis können durch visuelle Objekte, Gesichter, oder Wörter aktiviert werden.

VWFA (linke Hemisphäre)



From Dehaene et al, 2001, Nature Neuroscience

Fig. 2. Evidence for subliminal activation of a case-invariant representation of words in the left fusiform gyrus. (a) A subliminal priming paradigm allowed the presentation of a short masked prime followed by a word target. Subjects were engaged in a semantic classification task on target words and were not unaware of the presence of primes. (b) The behavioral results indicated a reduction of response time when the same word was repeated as prime and as target, irrespective of case change. (c) The cerebral bases of this repetition priming were identified by searching the whole brain for regions of reduced activation on repeated-word trials. This revealed the visual word form area in the left fusiform gyrus. (d) The activation profile of this area, relative to control trials with masks only, parallels response times in showing reduced activation on repeated trials irrespective of case change. This suggests that this area holds a case-invariant neural code for visual words and that this code can be activated automatically without awareness.

VWFA und Dyslexie

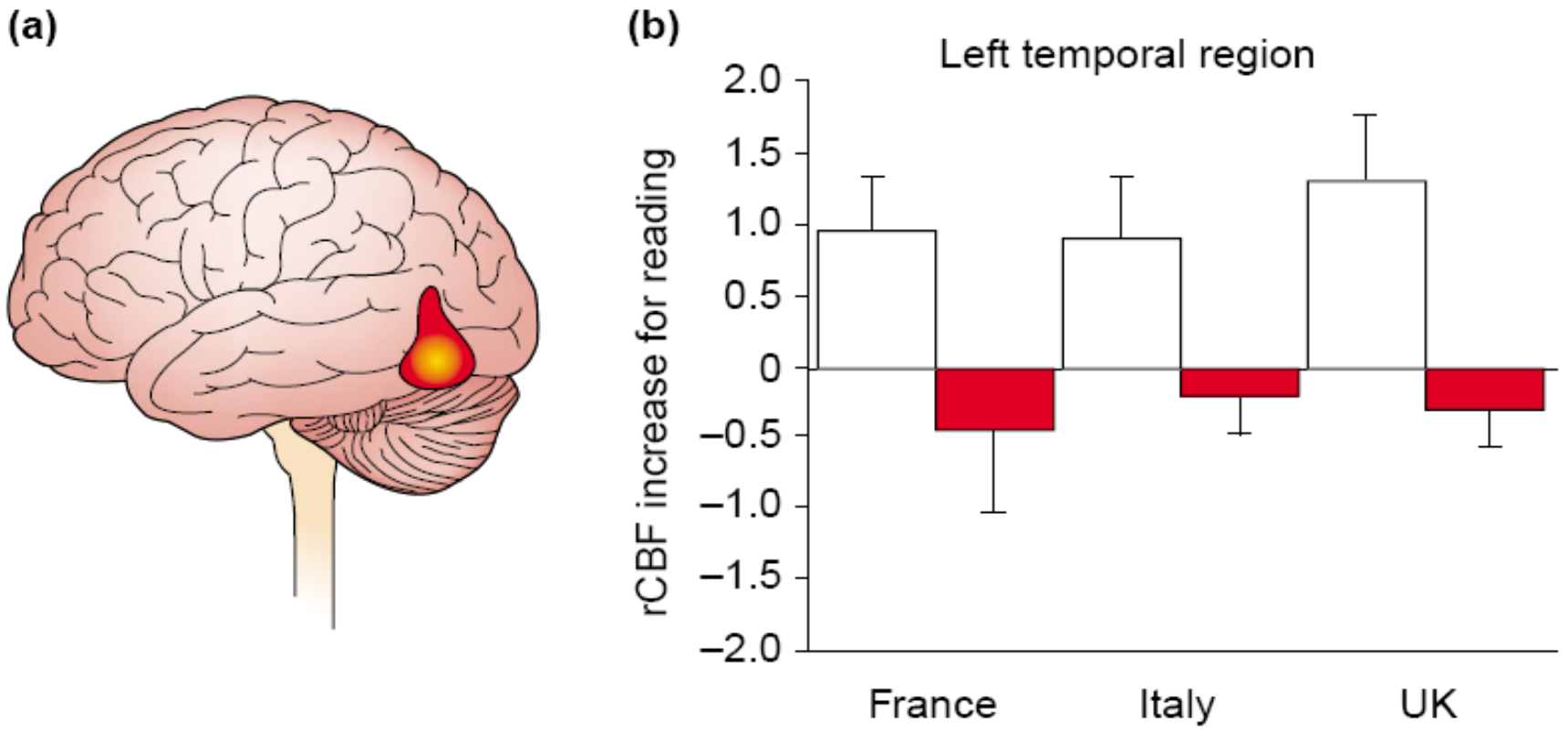


Fig. I. (a) Area consistently more active for normal readers versus dyslexic adults during reading tasks, with a peak difference located near the VWFA ($x = -52$, $y = -60$, $z = -14$). Activations displayed for this analysis are restricted to areas that consistently demonstrated group differences between normal and dyslexic adults under conditions that included both explicit and implicit reading tasks, and subject populations reading French, Italian, and English. (b) Bar graphs illustrate the PET measures of increased relative cerebral blood flow in this region for each language. Error bars indicate 1 standard error. Normal adult readers showed an increase in rCBF (white bars), whereas dyslexic readers (red bars) consistently failed to show this response. Redrawn with permission from Ref. [44].

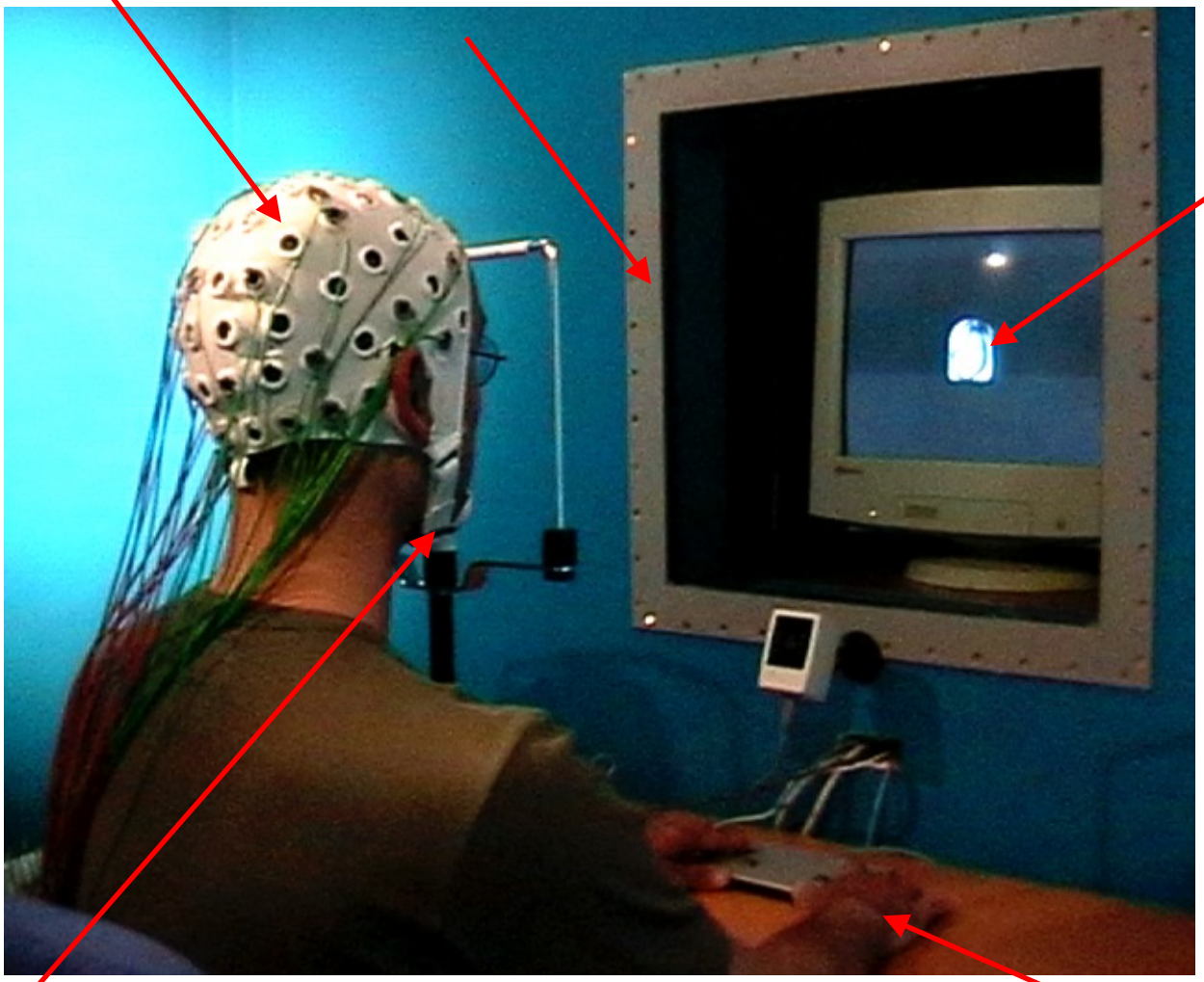
Zusammenfassung

- Areale im Gyrus fusiformis sind spezialisiert für das Erkennen komplexer visueller Stimuli (Gesichter, Objekte, Wörter).
- Die für diese Stimuli relevanten Prozesse variieren möglicherweise auf den Dimensionen “holistische vs. merkmalsorientierte Verarbeitung” (Farah, 1991), und die für die Erkennung relevanten Repräsentationen sind in unterschiedlichem Maße “bildhaft vs. abstrakt”
- Hemisphärenspezialisierungen in der fusiformen Region zeigen sich in einer rechtshemisphärischen Spezialisierung für Gesichter (holistische Verarbeitung, bildhafte Repräsentationen) bzw. in einer linkshemisphärischen Spezialisierung für Wörter (merkmalsorientierte Verarbeitung, abstrakte Repräsentationen)

Head cap with inserted Ag/AgCl electrodes

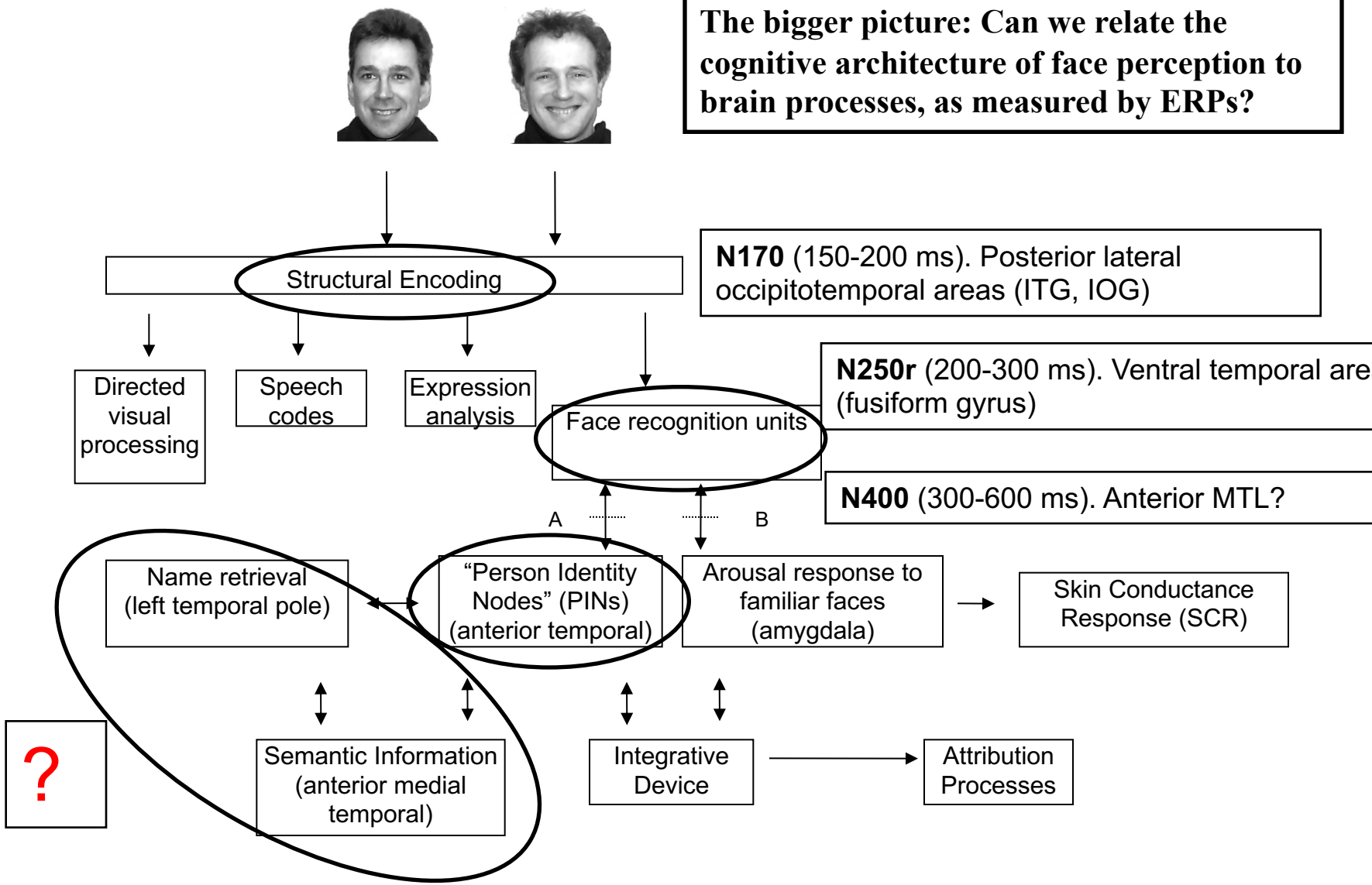
Electromagnetically shielded recording chamber

Visual stimulus presentation



Fixed chin rest

Keypress response pad



Source: S.R. Schweinberger & A.M. Burton (2003). Covert recognition and the neural system for face processing. **Cortex, 39**, 9-30.

Brain Regions that Mediate Face Recognition

I. 1960s: Patients with unilateral brain lesions

- RH > LH (e.g., Milner, 1968)

II. 1970s: Divided visual field presentation technique

- RH > LH (Rizzolatti et al., 1971)

III. 1970-1980s: Post-Mortem analyses of brain-injured patients with prosopagnosia (inability to recognize familiar faces)

- Occipitotemporal areas of both hemispheres, RH > LH

IV. Late 1990s - : Functional brain imaging in neurologically healthy individuals (e.g., fMRI, PET)

- Occipitotemporal areas of both hemispheres, RH > LH
- "Fusiform face area" (FFA, Kanwisher et al., 1997)

ERP Studies of Face Recognition

I. RH superiority

- RH > LH (Barrett et al., 1988, Schweinberger & Sommer, 1991)

II. Face-specific ERPs

- VPP (Jeffreys, 1989), N170 (Bentin et al., 1996)

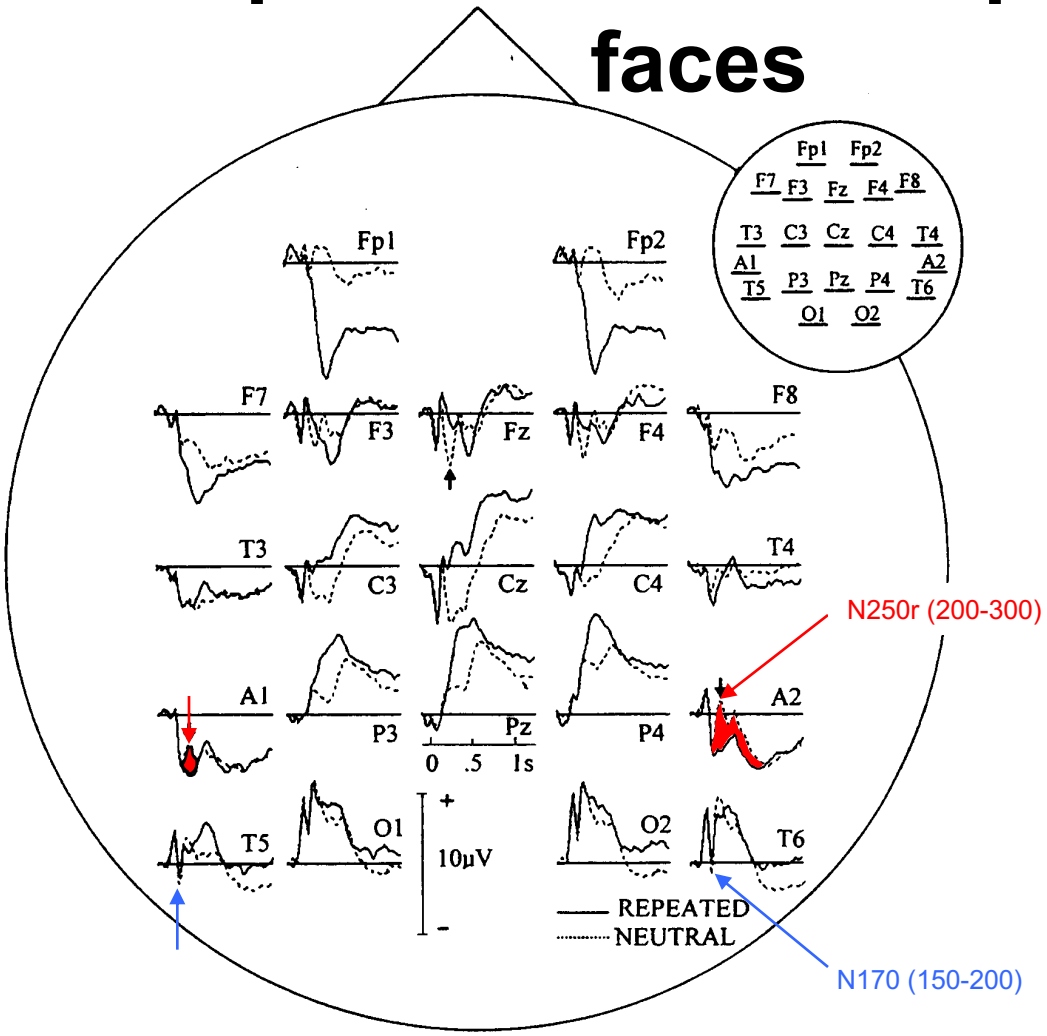
III. N170

- Larger for faces than for other visual stimuli
- Independent of face familiarity, face priming
- Source: Posterior lateral inferior temporal gyrus
- Probably neither related to individual face recognition nor to FFA

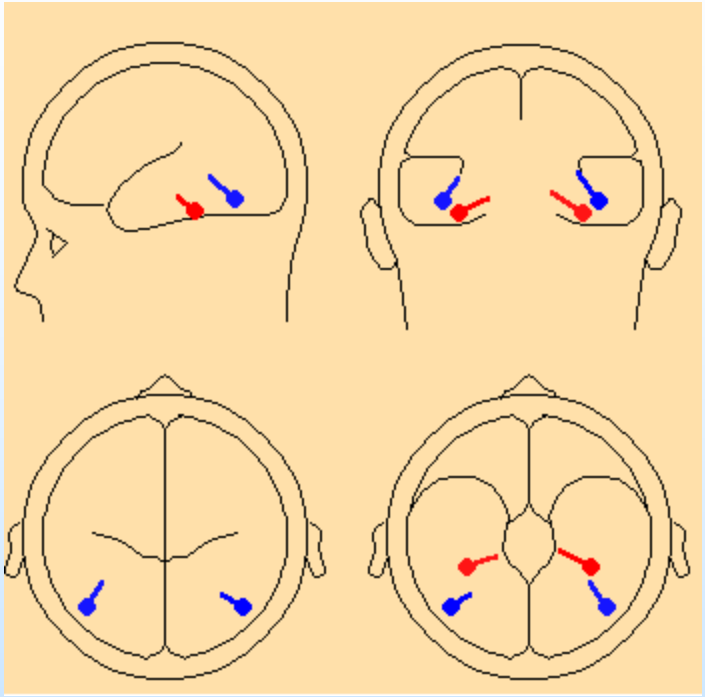
IV. N250/N250r

- Larger for familiar than for unfamiliar faces (Schweinberger et al., 1995)
- Large repetition priming effects
- Source: fusiform
- ERP correlate of individual face recognition (Eimer et al., 2012)

ERPs to repeated and non-repeated famous faces

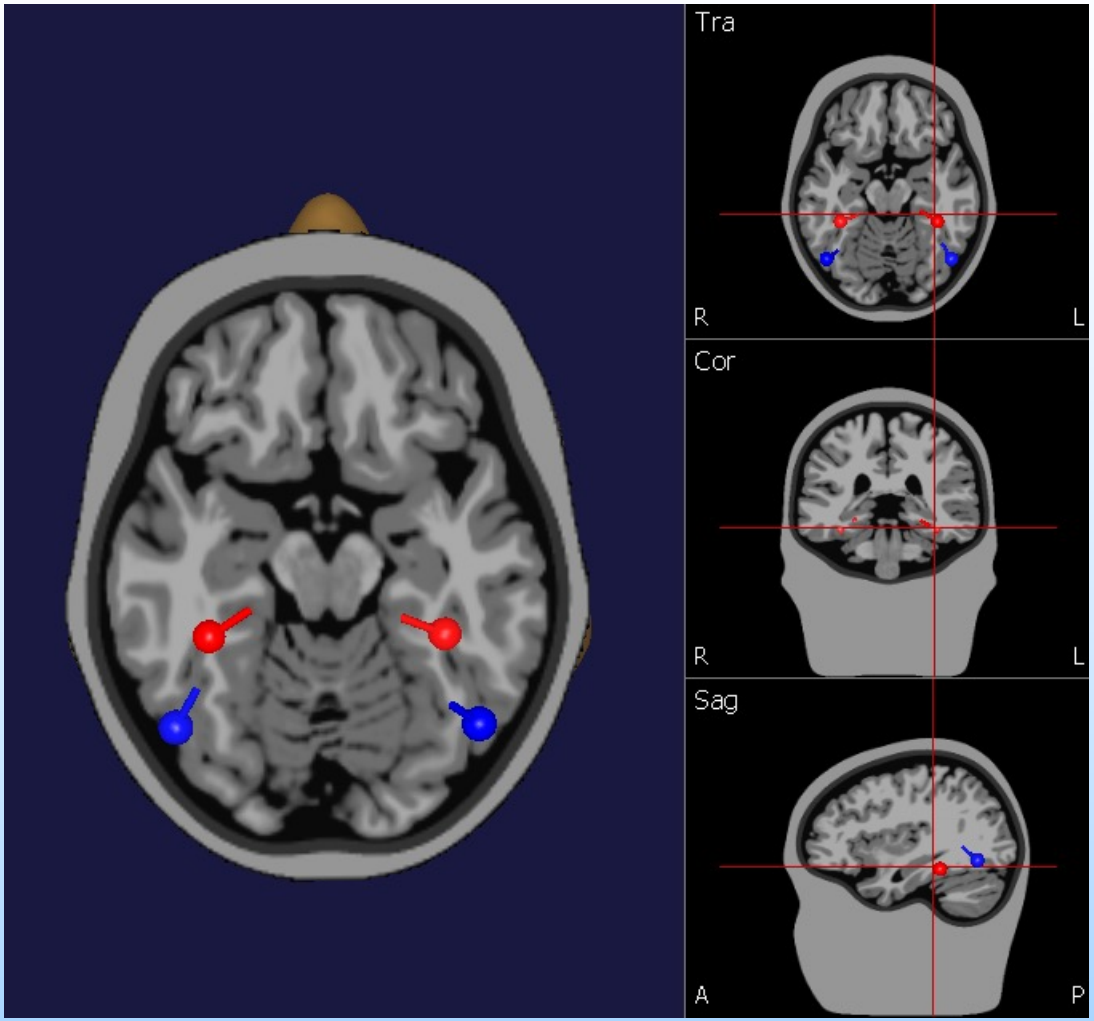


BESA Dipole Fit for N170 (blue) and N250r (red)



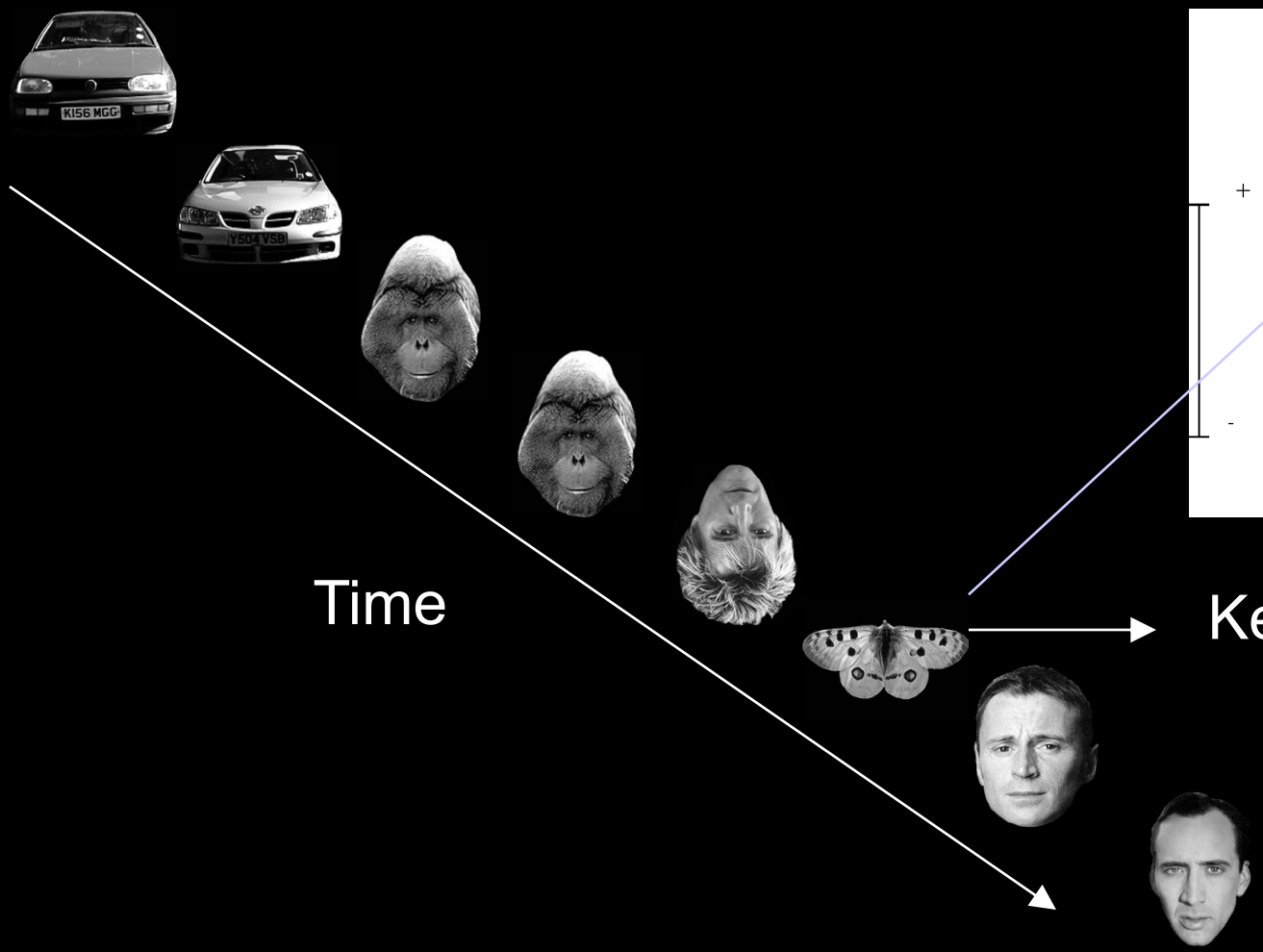
N170: 160-190 ms window
N250r: 260-290 ms window
No constraints except for symmetric dipoles
R.V. < 3% for both fits

Dipoles projected on to standard brain

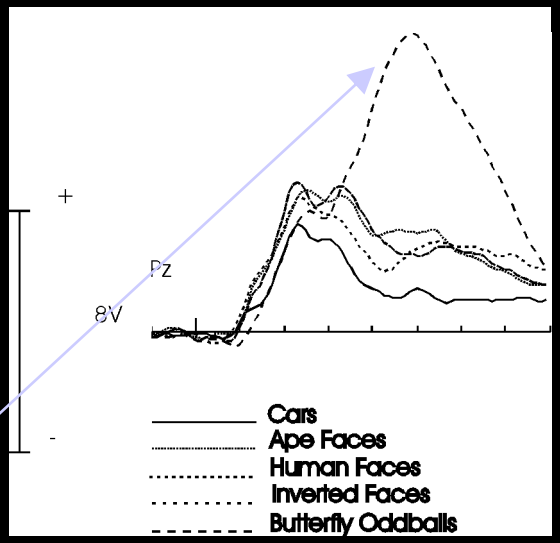


Are the N170 and/or N250r ERPs face-specific?

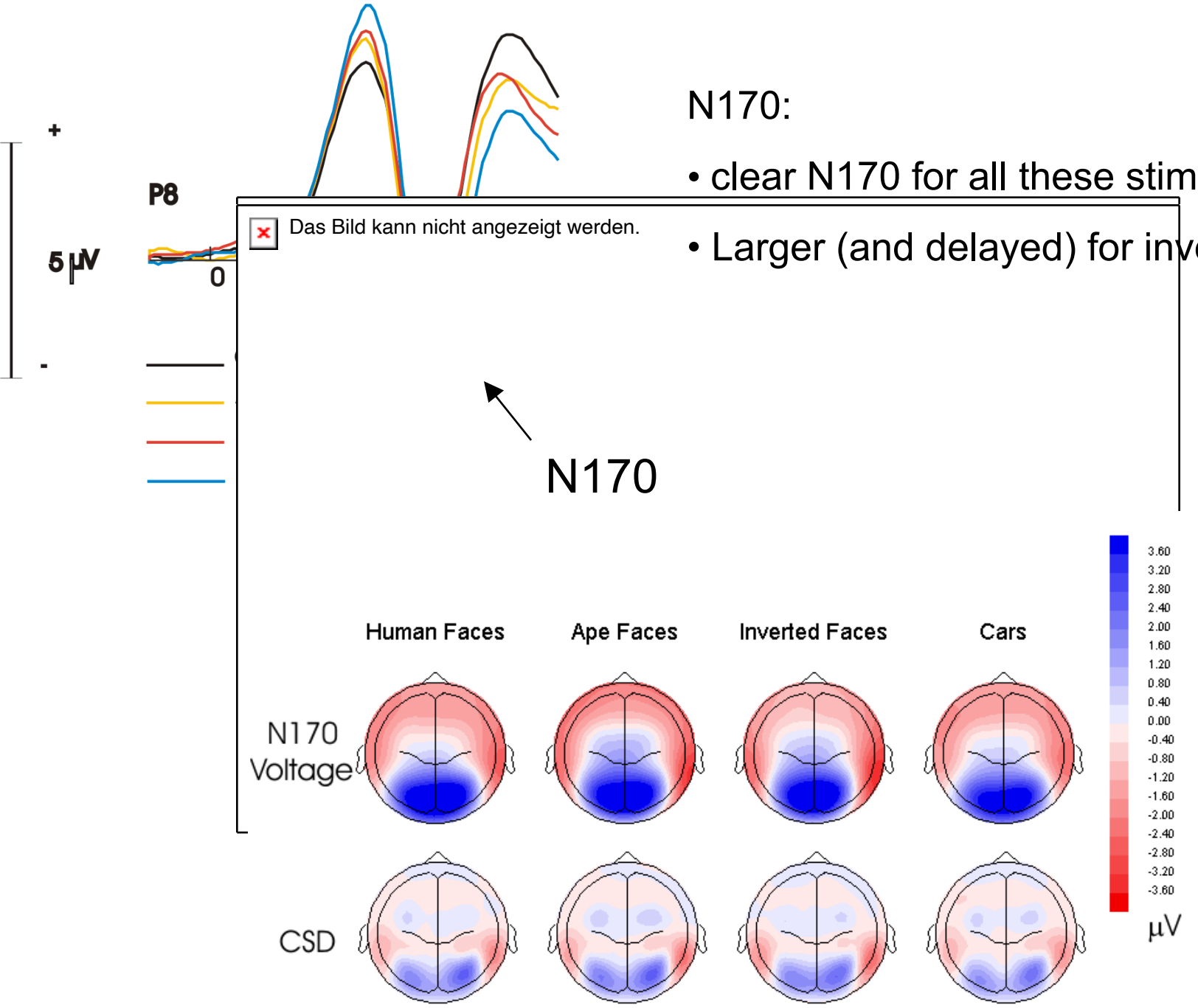
Task: Respond to Butterfly Targets



P300 “Target Effect” to Butterflies

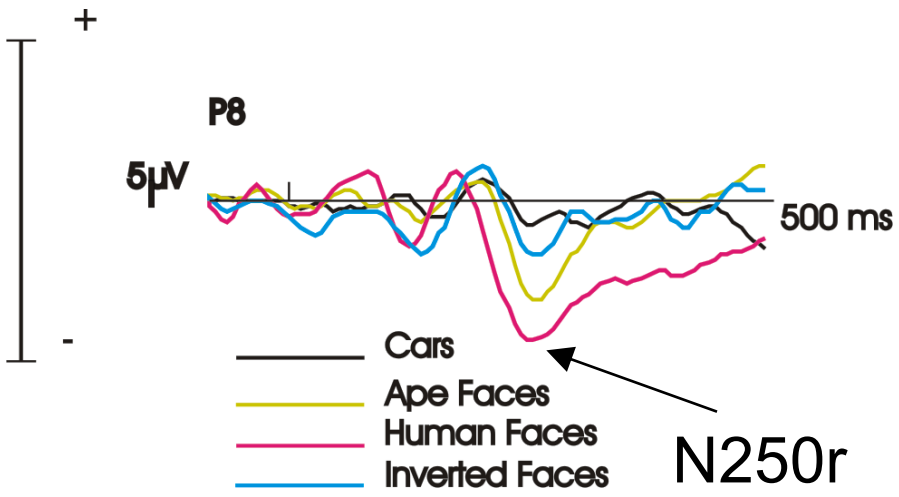


Keypress Response



N170:

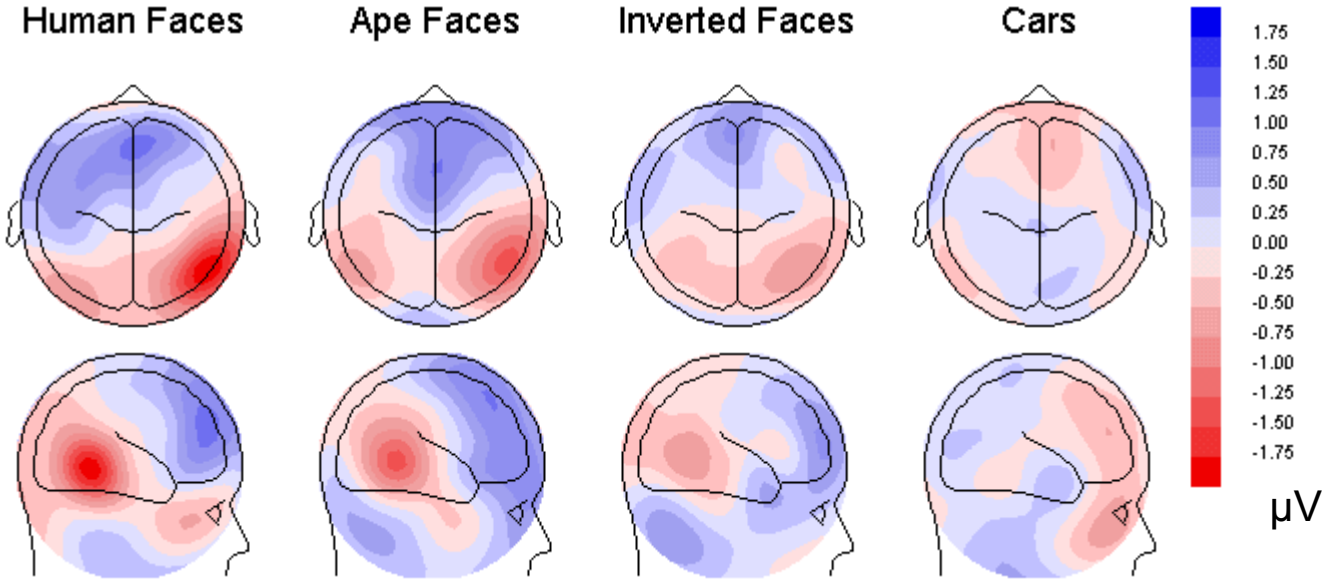
- clear N170 for all these stimuli!
- Larger (and delayed) for inverted faces



N250r:

- human faces > ape faces
- no N250r for inverted faces and cars

N250r (260-310 ms)
(Difference repeated minus nonrepeated)



64 channels, voltage maps, spherical spline interpolation

Conclusion

- N250r is a “face-selective” ERP
- sensitive to repetition
- probably generated in fusiform gyrus
- may relate to individual face recognition

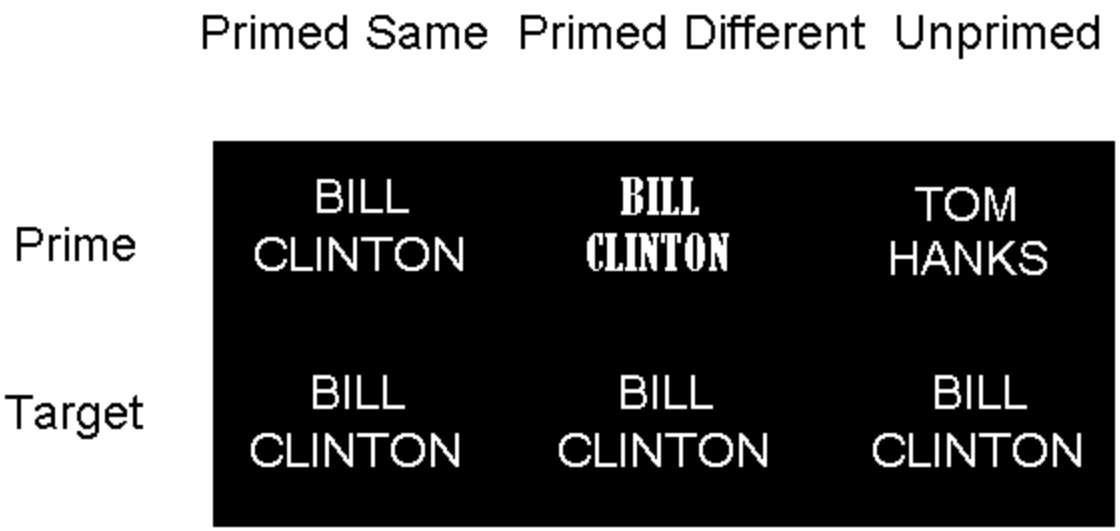
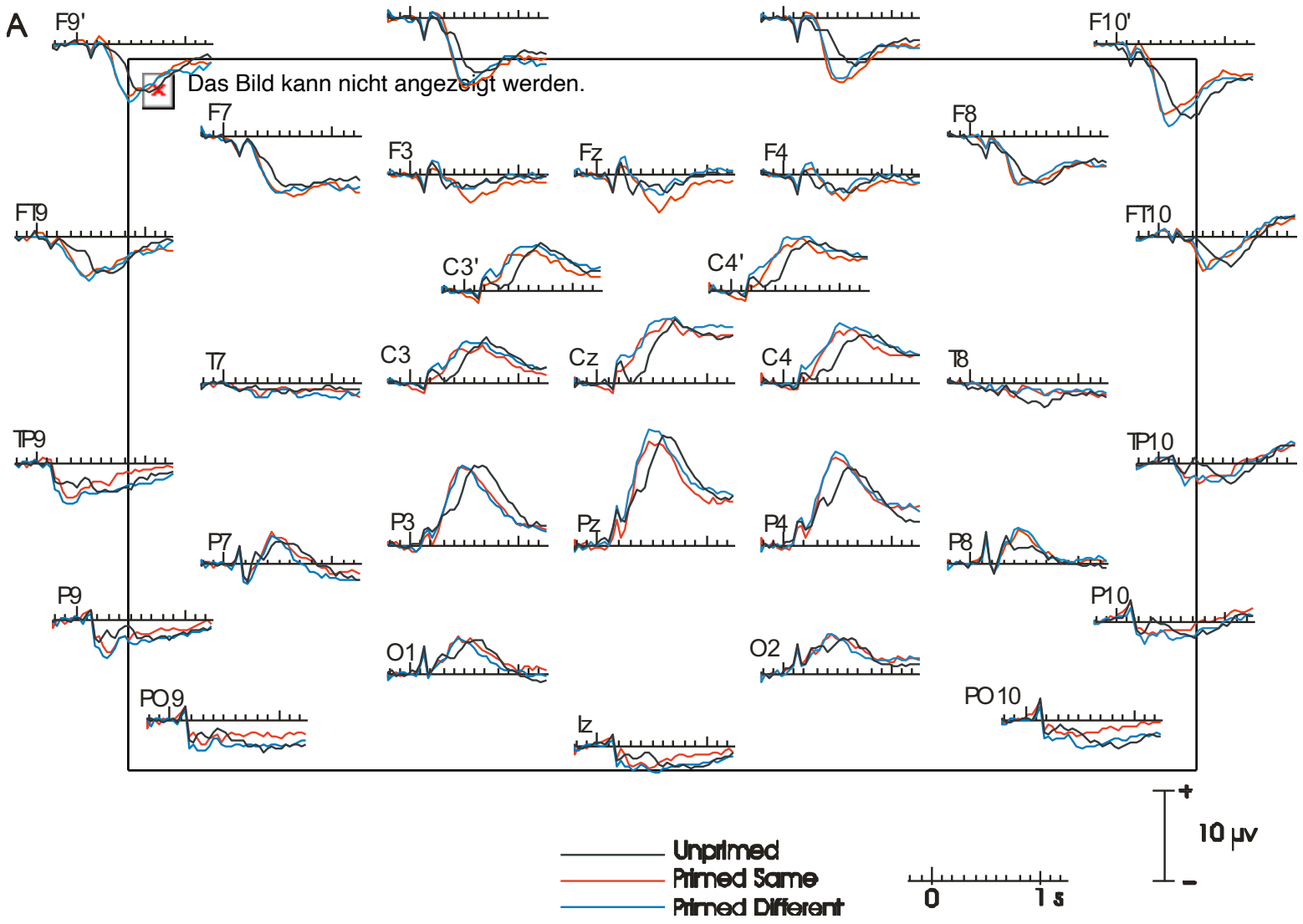


Figure 1. Examples of the prime and target names in Experiment 1. Bottom row: target names. Top row: prime names for the primed same, primed different, and unprimed conditions, respectively.

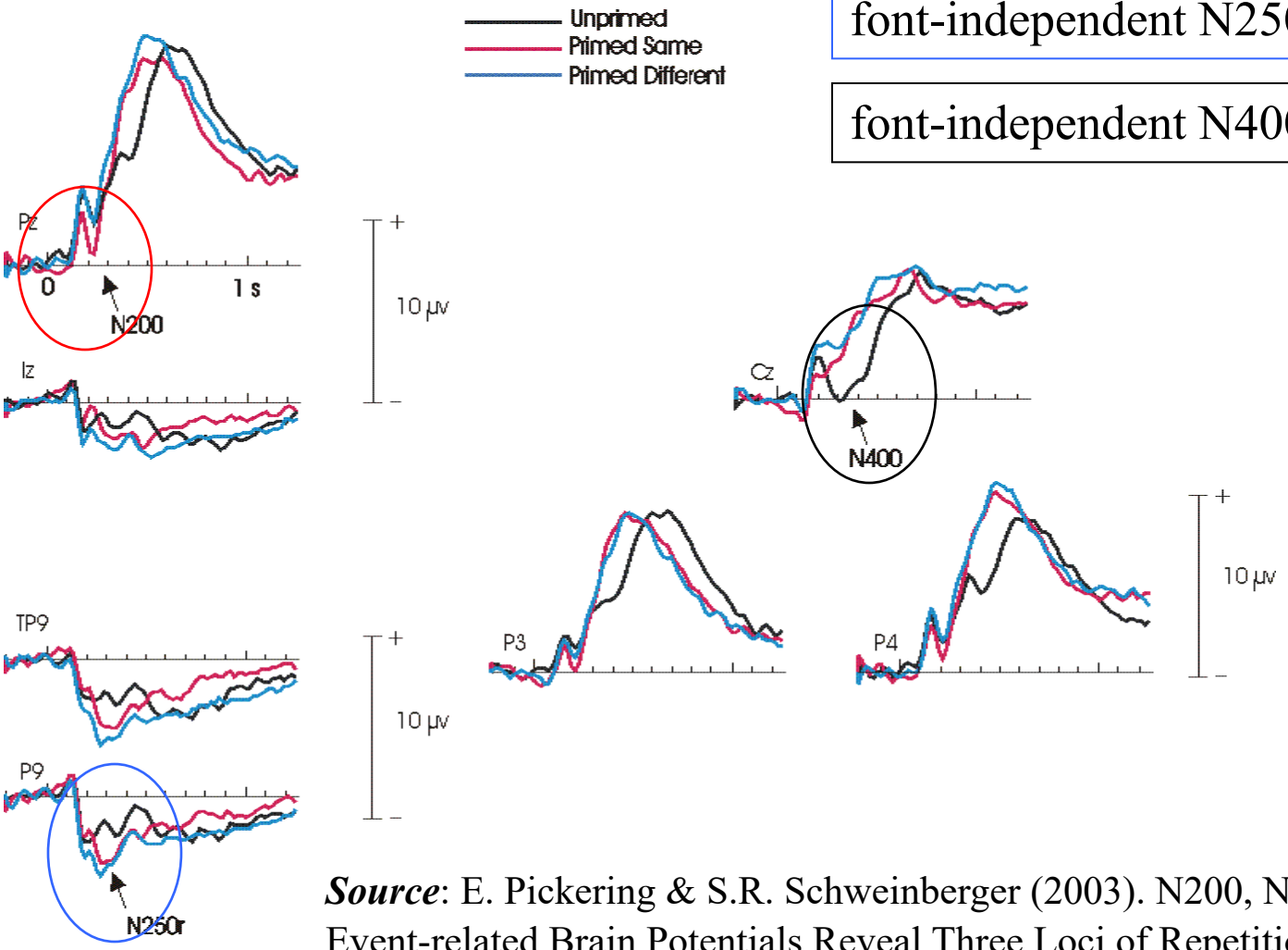
Font-specific vs. font-independent repetition priming



font-specific N200 effect

font-independent N250 effect

font-independent N400 effect



Source: E. Pickering & S.R. Schweinberger (2003). N200, N250r and N400 Event-related Brain Potentials Reveal Three Loci of Repetition Priming for Familiar Names. **Journal of Experimental Psychology: Learning, Memory, and Cognition, 29**, 1298-1311.

Cross-domain repetition priming

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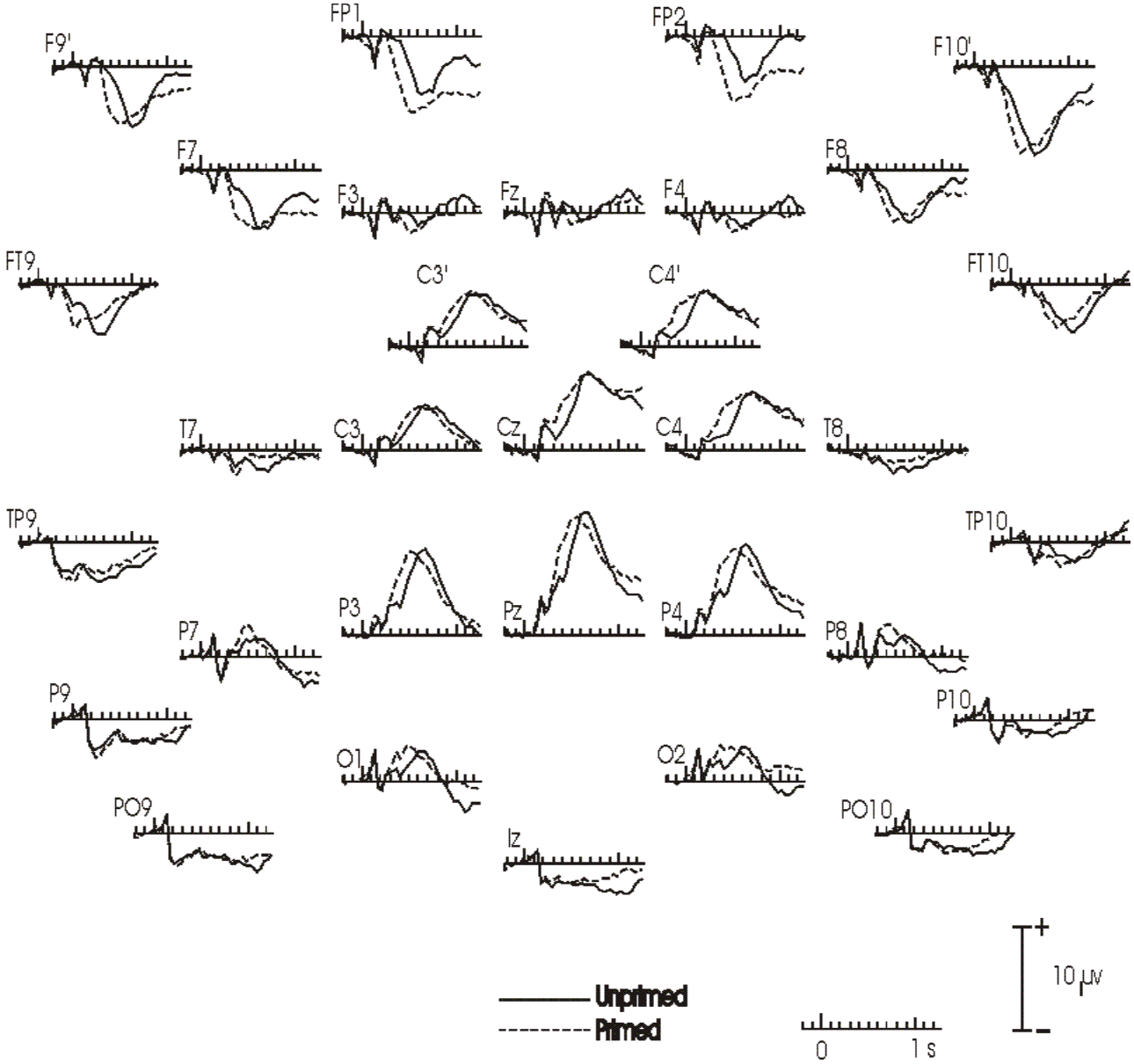


Priming: Within-domain Cross-domain

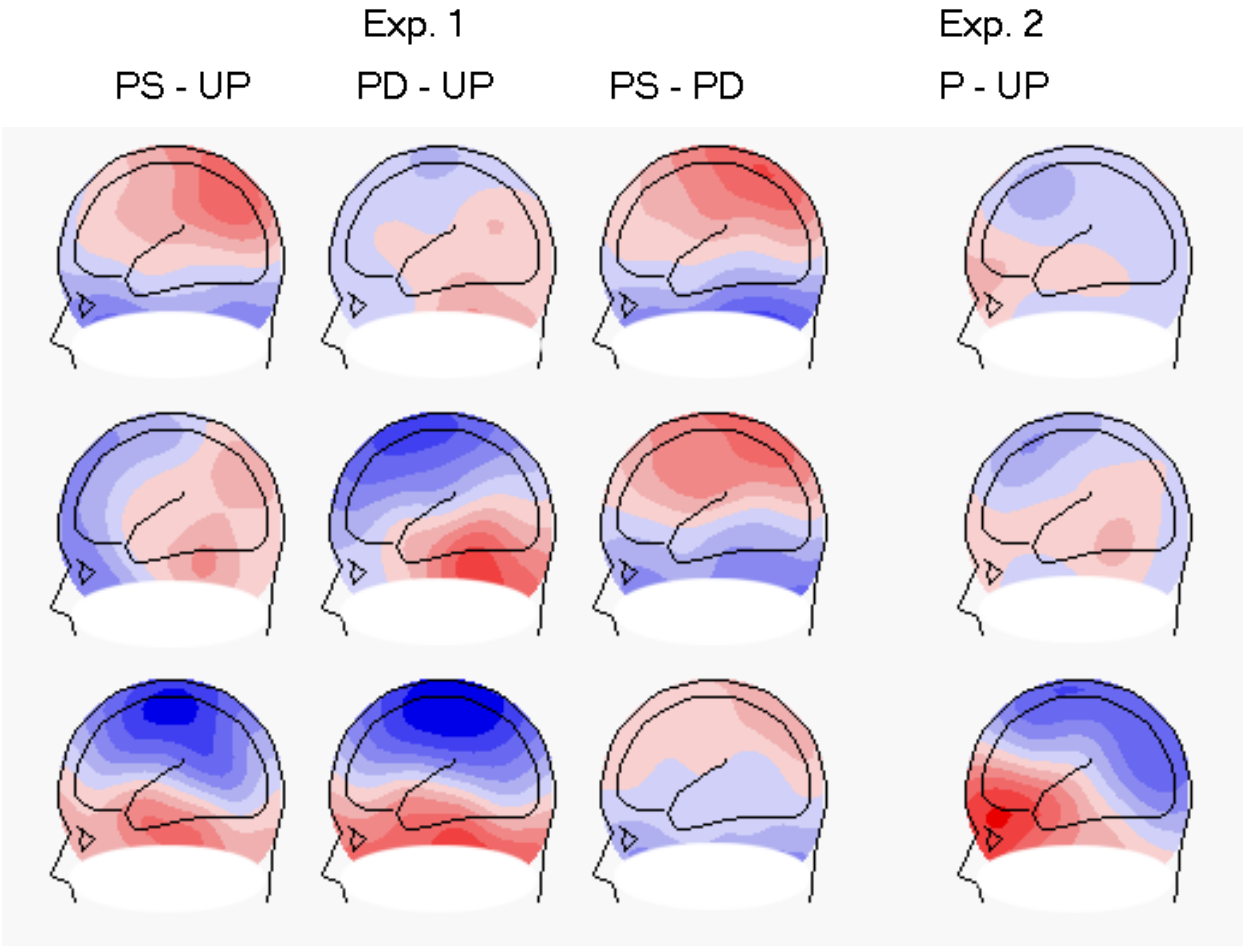


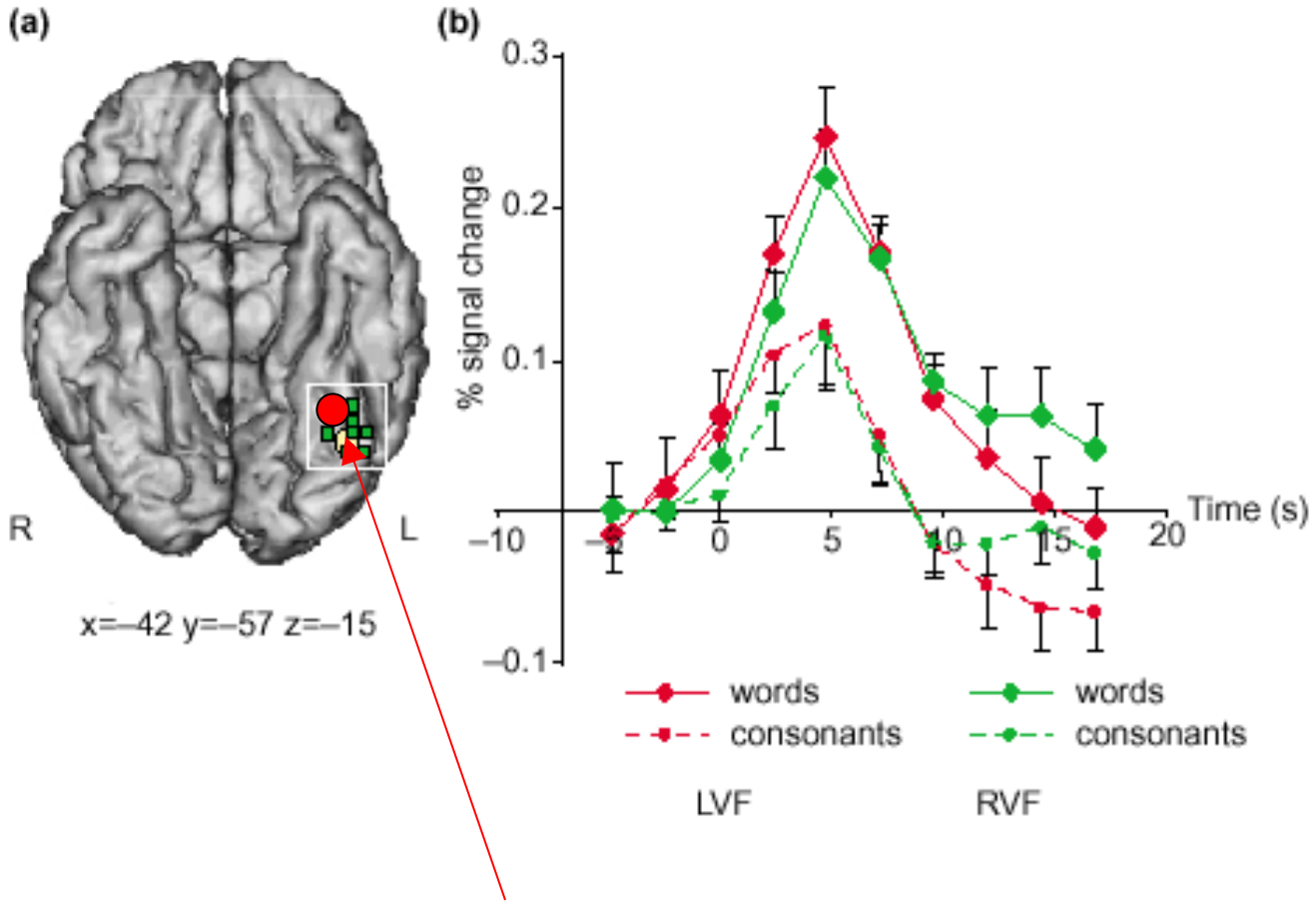
Figure 4. Topographical voltage maps of ERP differences between primed and unprimed conditions show the three qualitatively different priming effects at 200 ms (top, N200), 260 ms (middle, N250r) and 350 ms (bottom row, N400).
PS - primed same; PD - primed different; UP - unprimed.
Spherical spline interpolations. Equipotential lines are separated by 0.5 μV/line.
Negativity is red.

Conclusions

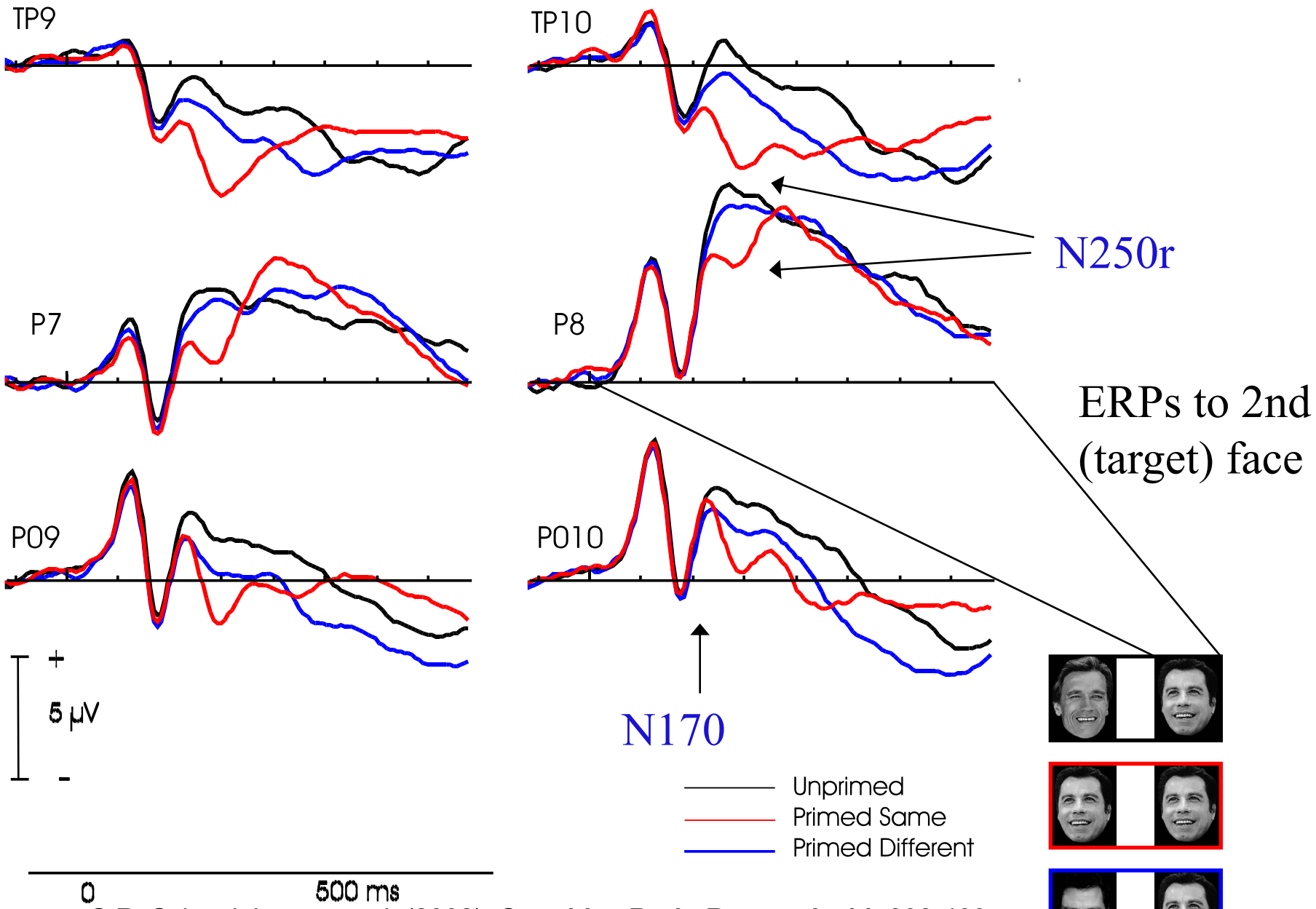
- ERPs can distinguish separate stages at which priming facilitates processing during word/name reading
- Posterior N200: font-specific featural processing
- Left temporal N250r: lexical representation (visual word-form)
- Central-parietal N400: semantic processing

The Visual Word Form Area

(McCandliss, Cohen, Dehaene, 2003. Trends in Cognitive Sciences)



Names (N250r ERP): x=36,y=-43, z=-6



Source: S.R. Schweinberger et al. (2002). **Cognitive Brain Research, 14**, 398-409.

Lateralized Repetition Priming for Names: Font-specific vs. Abstractive Priming

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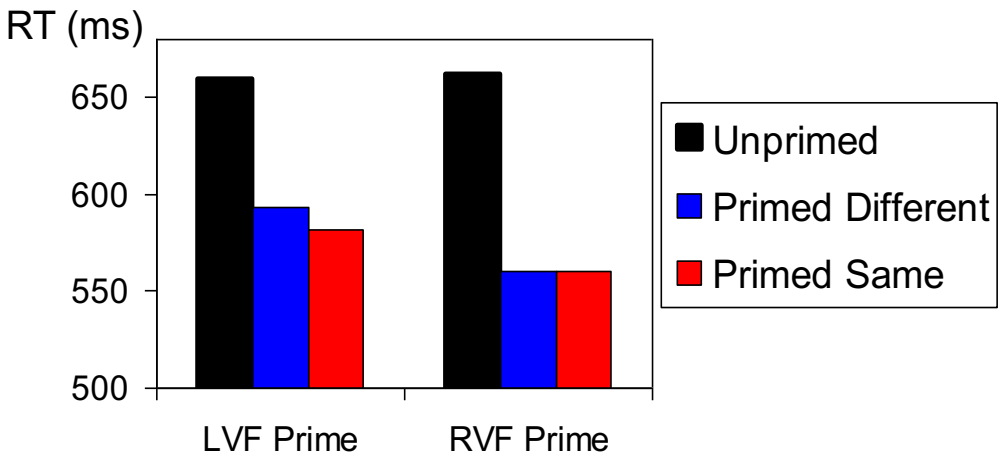
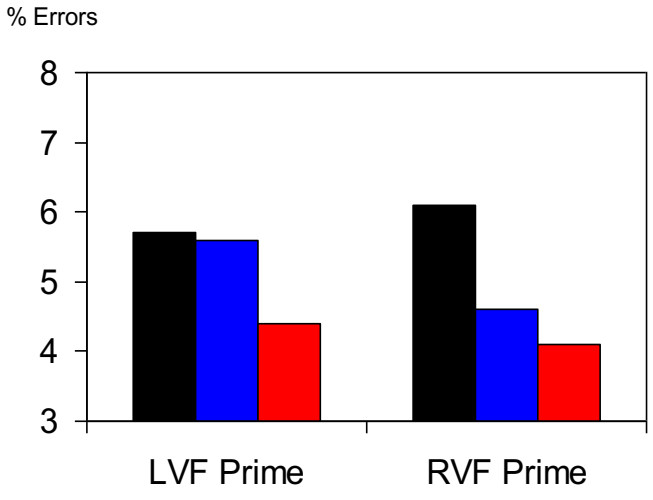
Prime presented to LVF or RVF for 150 ms

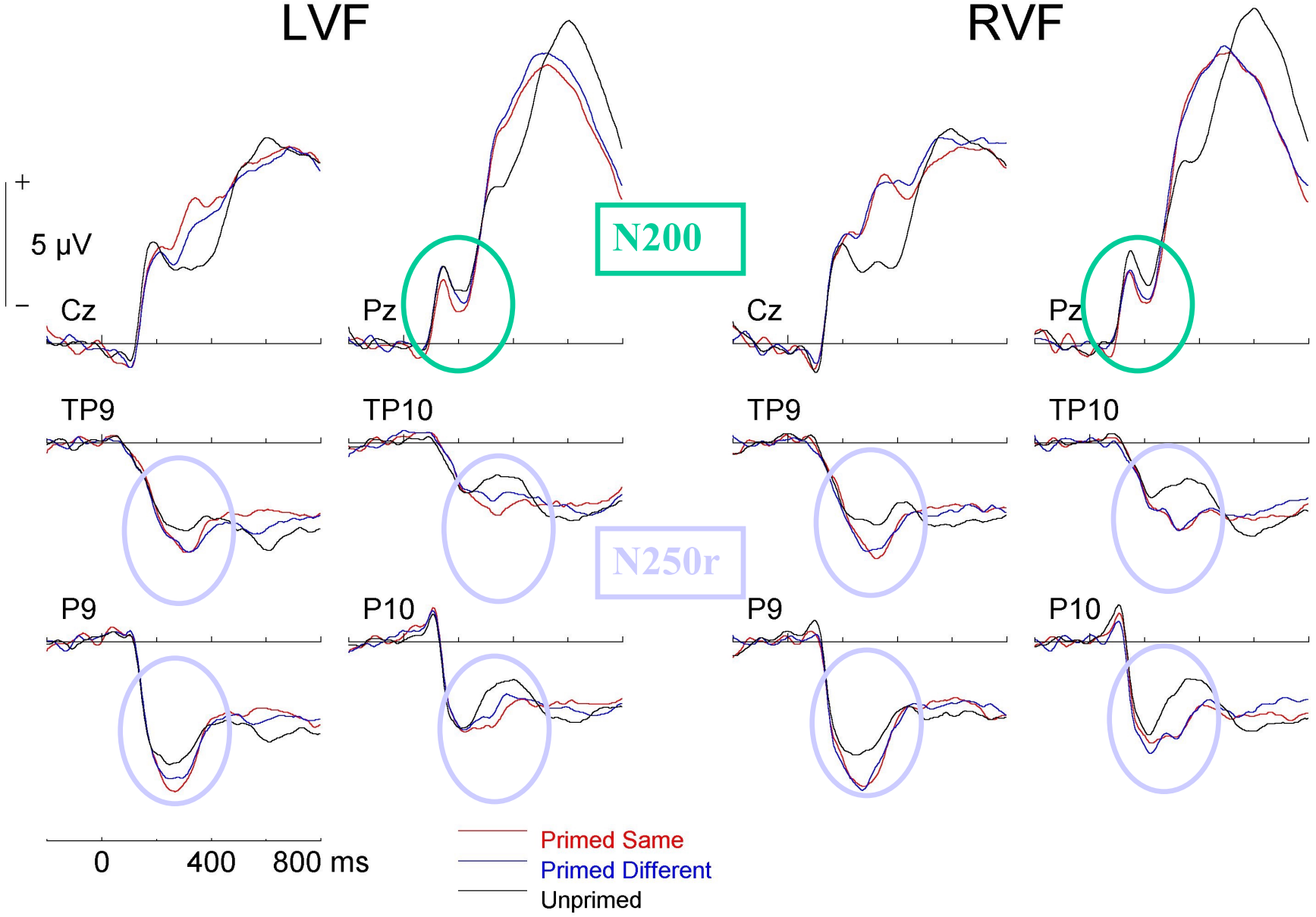
Prime-Target SOA: 1500 ms

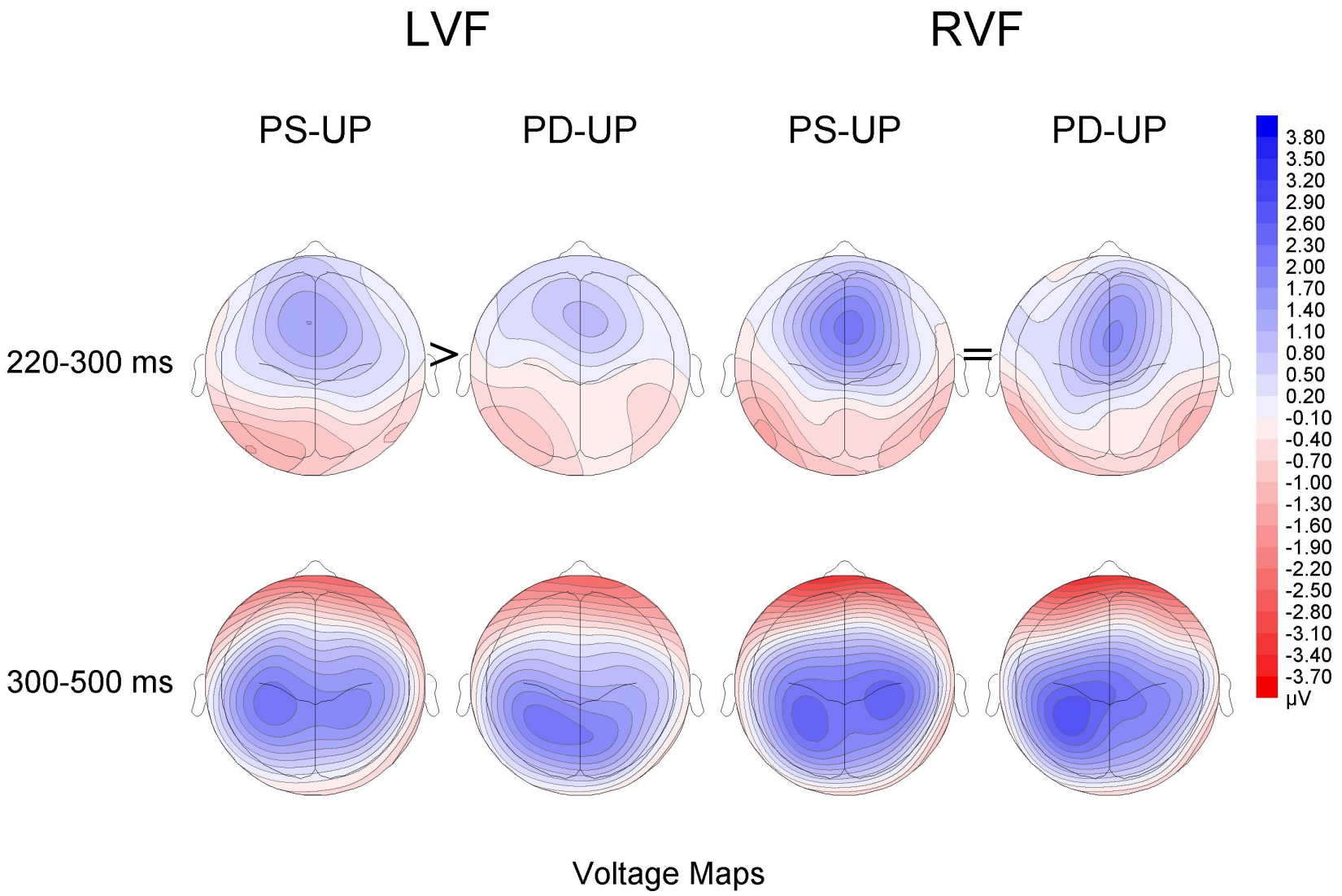
Target presented centrally

Task: Target familiar (yes/no)






LVF
RVF
+
5 µV
−
Cz
Pz
Cz
Pz
N200
TP9
TP10
TP9
TP10
N250r
P9
P10
P9
P10
0
400
800 ms
Primed Same
Primed Different
Unprimed



Source: Schweinberger, S.R., Ramsay, A.L., & Kaufmann, J.M. (2006). Hemispheric asymmetries in font-specific and abstractive priming of written personal names: Evidence from event-related brain potentials. **Brain Research, 1117**, 195-205.

Schlussfolgerungen

- Die rechte Hemisphäre (speziell der rechte fusiforme Gyrus) repräsentiert Stimuli auf bildspezifische Art und Weise und ist eine zentrale Struktur für die Repräsentation von Gesichtern.
- Diese bildspezifische Art der Repräsentation komplexer visueller Stimuli in der RH zeigt sich auch für Wörter.
- Die linke Hemisphäre (spez. der linke fusiforme gyrus) repräsentiert Stimuli auf abstrakte Art und Weise und ist eine zentrale Struktur für die Repräsentation von geschriebenen Worten.
- Diese Ergebnisse bestätigen und erweitern andere Befunde (Marsolek et al., 1992, 1995, 1999, DeHaene et al., 2001)

Kontrollfragen

1. Was versteht man unter dem sogenannten Wortüberlegenheitseffekt (word superiority effect)?
2. Was ist das sog. Visuelle Wortform-Areal (visual word form area; VWFA)?
3. Welche Eigenschaften der visual word form area kennen Sie?