

Qualitatively different neural mechanisms for conscious and subliminal multiple word integration

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ICON, July 2014

Thanks to



Stanislas Dehaene



Laurent Cohen



Lionel Naccache



Alexandra Leighton



Anouk van Loon



Julia Meuwese

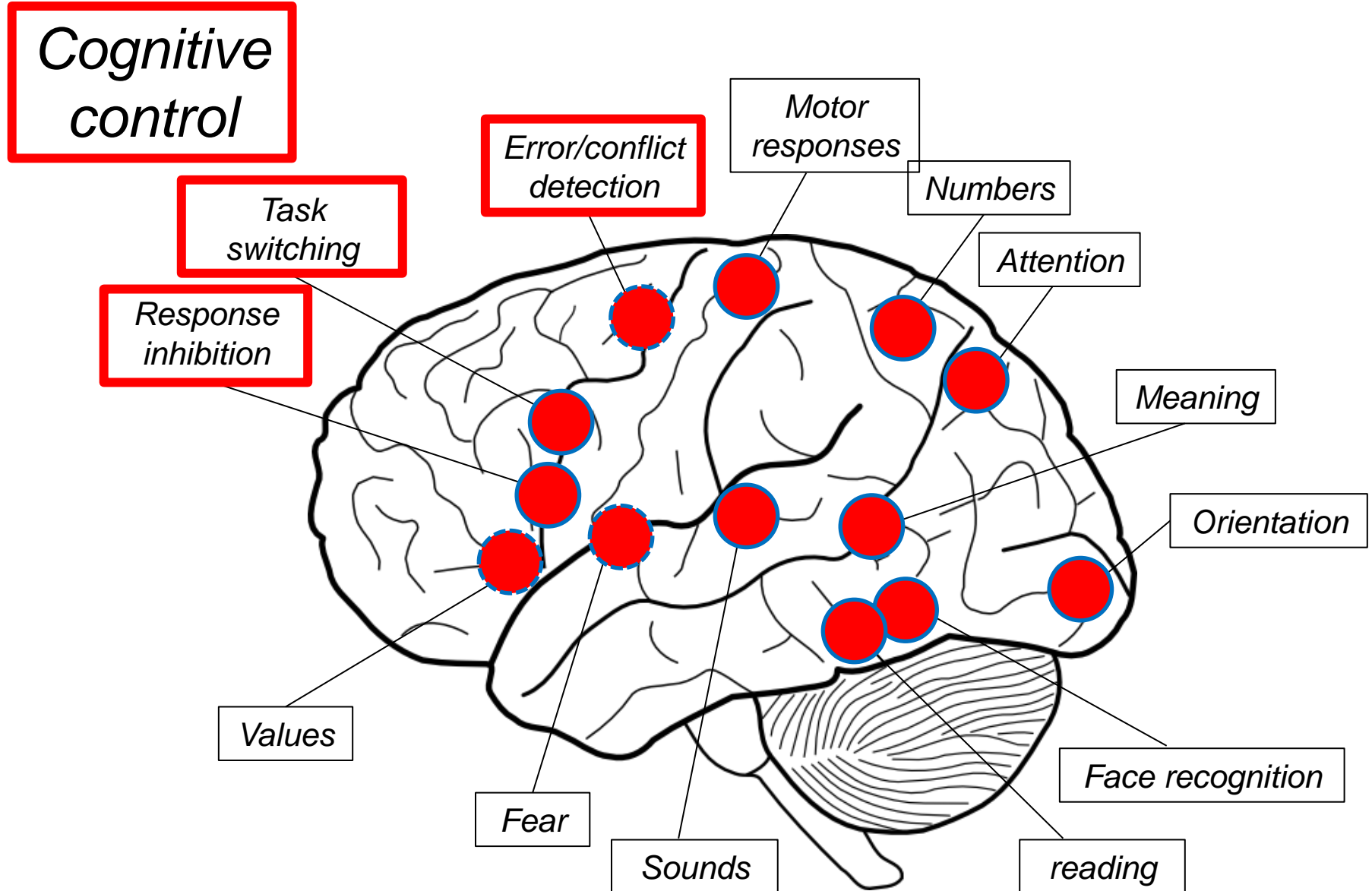


The general questions

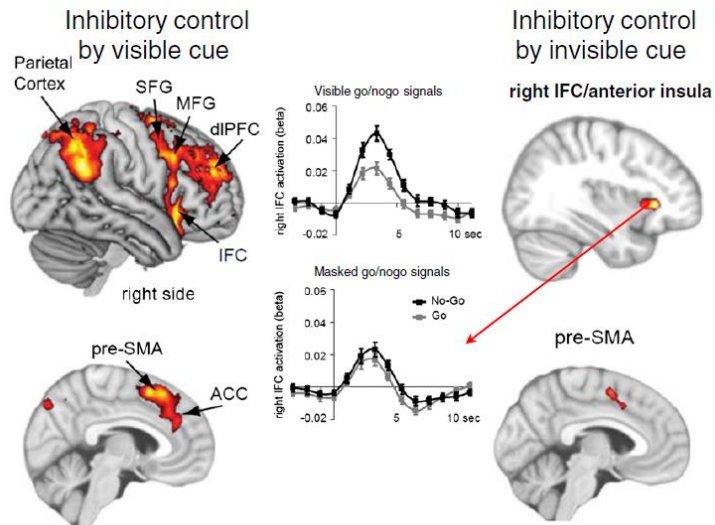
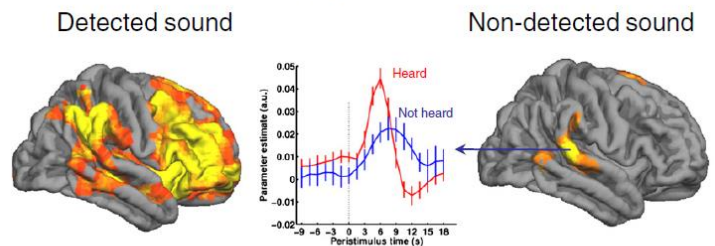
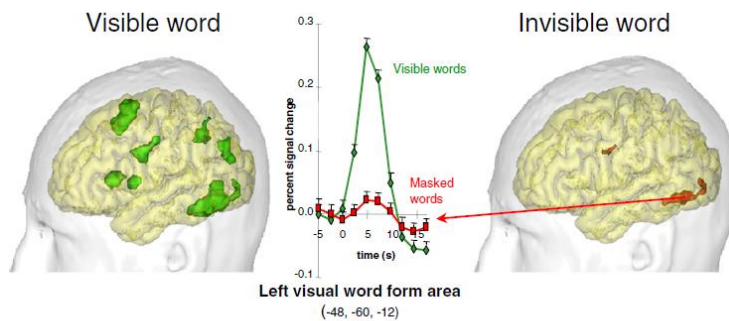
What are the limits of unconscious cognition?

What is consciousness good for?

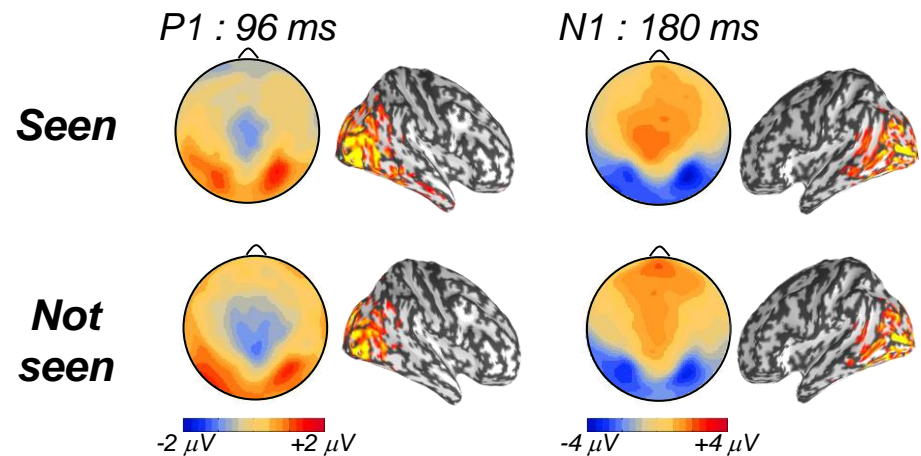
Are there any limits to unconscious processing?



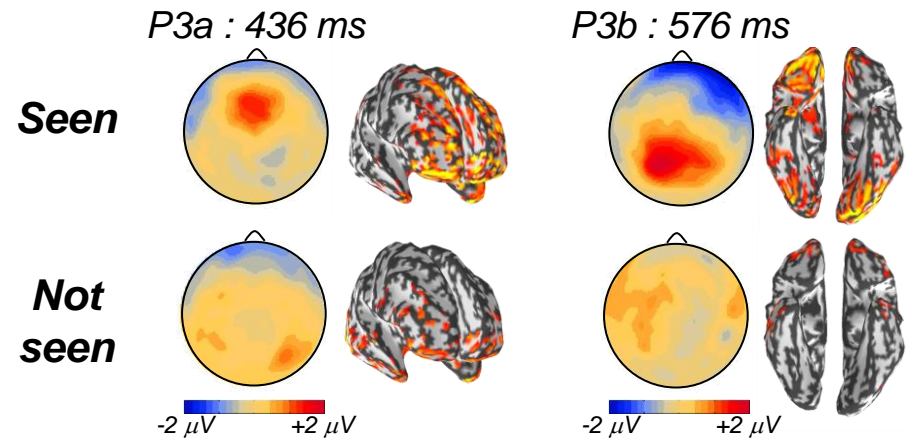
Consciousness: It is all about the **extent** and **duration** of activation



Similar initial sensory processing



Late "all-or-none" waveforms



Dissociating conscious and unconscious processes

<i>Conscious processing</i>	<i>Unconscious processing</i>
<i>Durable information maintenance</i>	<i>Fleeting information (decays quickly)</i>
<i>“Global” information processing</i>	<i>Processing in “local” modules</i>
<i>Rich recurrent information sharing among distant regions (recurrent broadcasting mode)</i>	<i>Limited (recurrent) information sharing among regions (“feedforward mode”)</i>

What are the consequences of these neural differences for cognition and behavior?

Hypothesis:

Stimulus awareness becomes crucial when multiple stimuli have to be maintained and flexibly integrated (requires information sharing among regions)

- *de Lange*, van Gaal* et al., (2011) PLoS Biology*

Can the meaning of multiple words be integrated unconsciously?

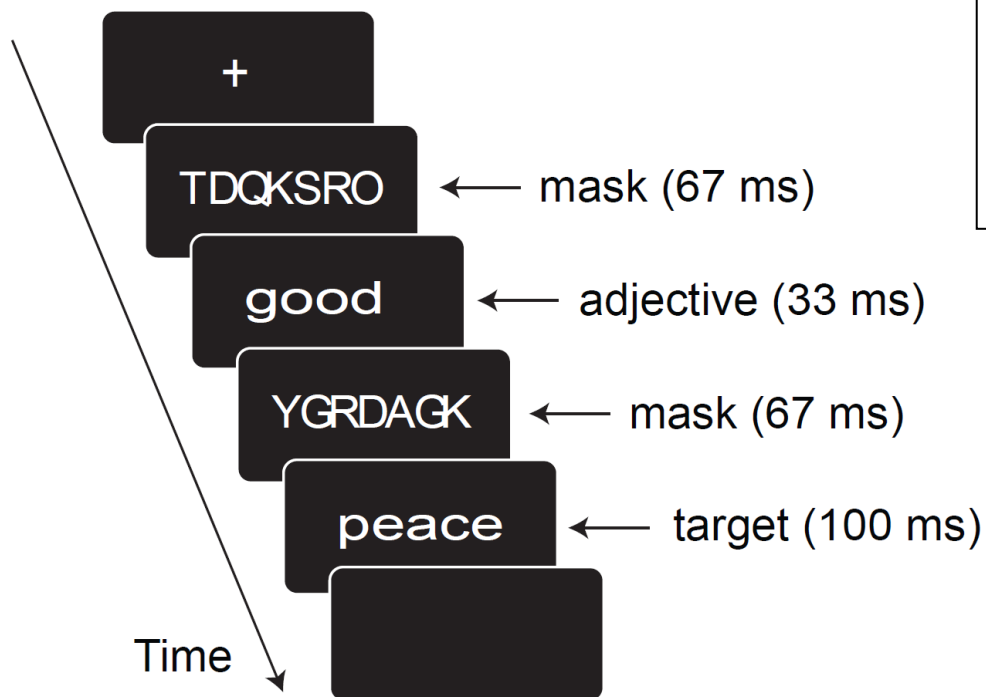
More specifically:

*Can negation processes operate unconsciously? (e.g., I am **not happy**)*

- *Armstrong and Dienes (2013, Consc. & Cogn.) for behavioral evidence for unconscious negation*
- *Sklar et al., (2012, PNAS) for behavioral evidence for unconscious multiple word integration*

Negation is difficult, takes time, and probably relies on high-level control processes and working memory (e.g., Deutsch et al., 2006)

The classical masking paradigm

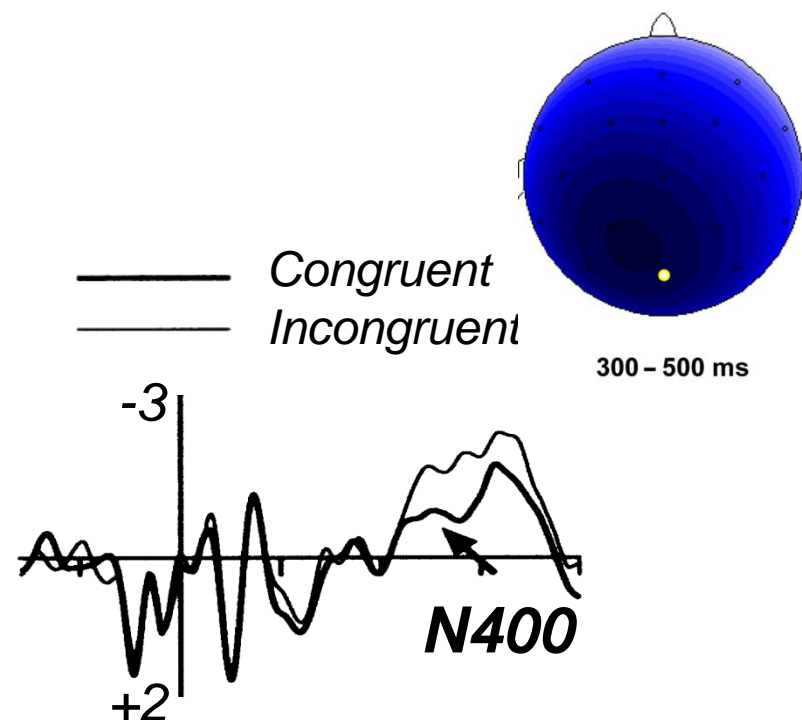


Response: is the final target word positive or negative?

*Incongruent trials (bad-peace, good-war)
Congruent trials (good-peace, bad-war)*

Priming effect:

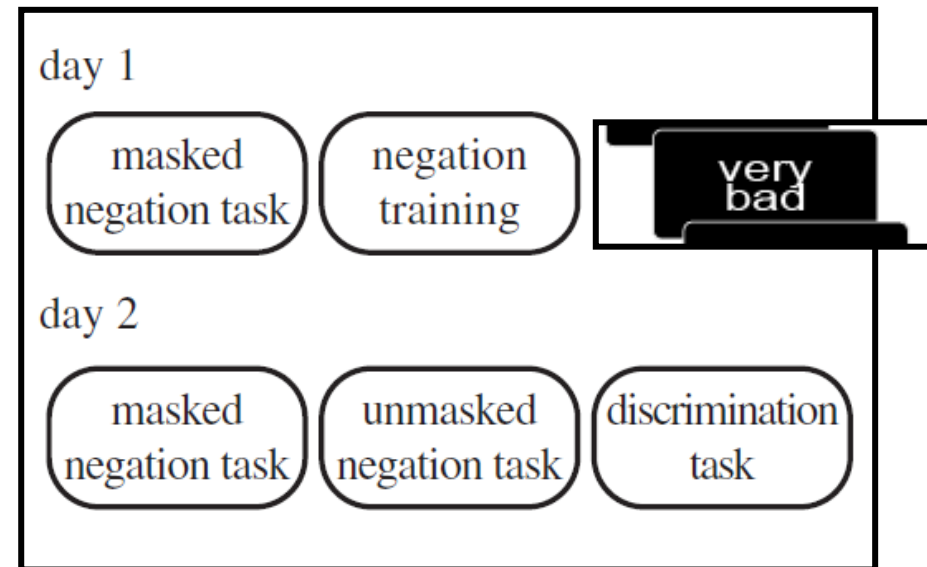
Worse performance to incongruent than congruent trials (RTs and error rates)



Masking, negation, EEG (N=25)



- Discrimination performance for masked stimuli at chance-level (Bayes = ~ 3 for H_0)
- 2 sessions: 1st behavioral, 2nd EEG



In conscious trials masks are replaced by blanks (same overall timing).

Behavior (conscious, but no unconscious negation)

490

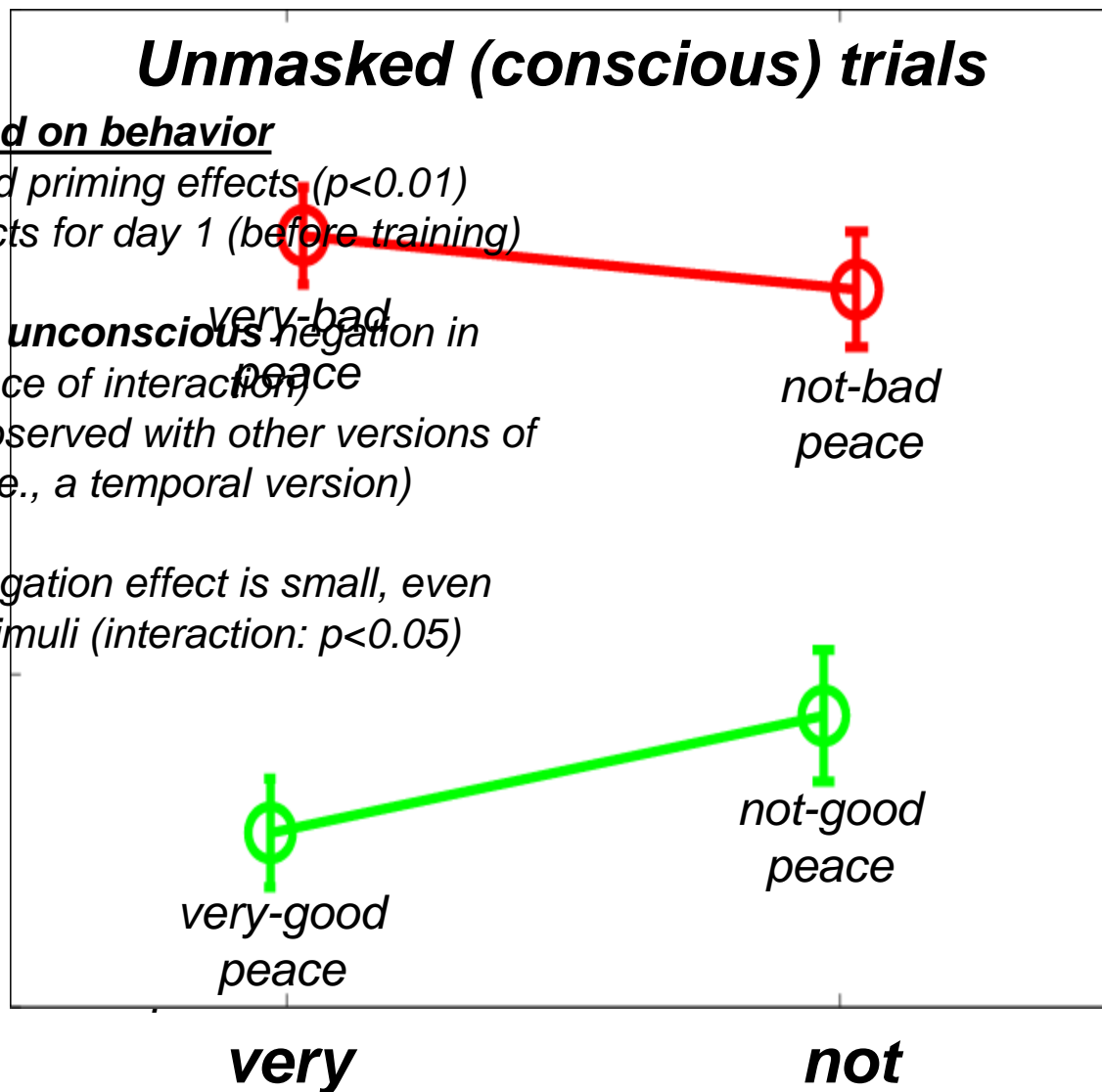
Unmasked (conscious) trials

Conclusions based on behavior

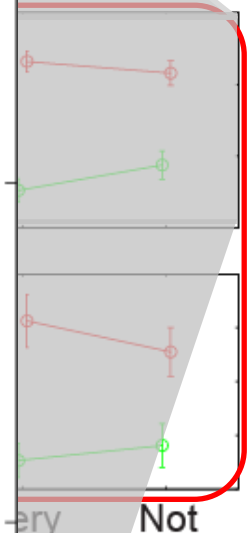
- Typical one-word priming effects ($p < 0.01$)
 - Same effects for day 1 (before training)
- No evidence for unconscious negation in behavior (absence of interaction)
 - Also not observed with other versions of this task (i.e., a temporal version)
- Note that the negation effect is small, even for conscious stimuli (interaction: $p < 0.05$)

450

430



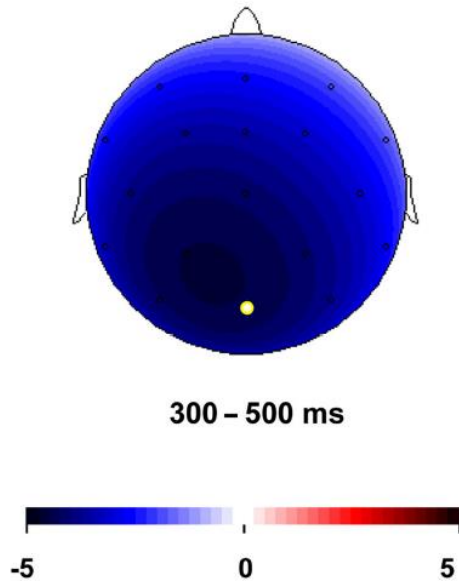
both primes
asked (day 2)



incongruent
congruent
effective-target)

EEG analysis: two typical "language-related" EEG components

N400



*The N400 is associated with (simple) semantic or lexical violations and thought to reflect rather “**automatic**” processes that are specific to language*

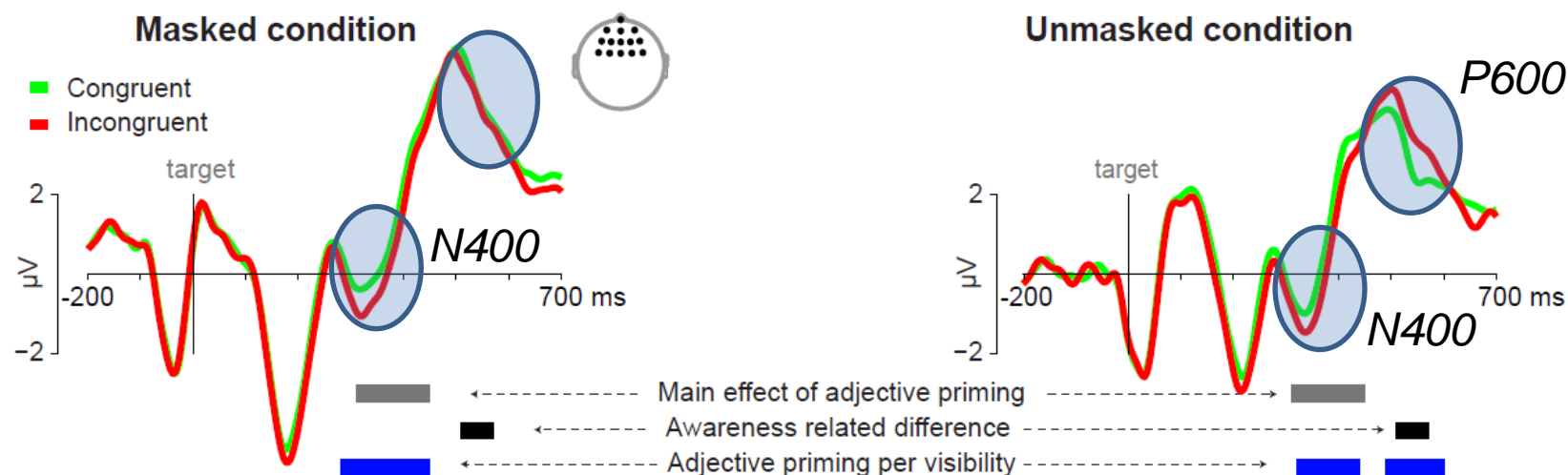
“Adjective priming” (single prime effects)

incongruent vs. congruent

(e.g., bad-peace/good-war vs. good-peace/bad-war)

collapsed across modifier identity (very, not)

Adjective priming effects

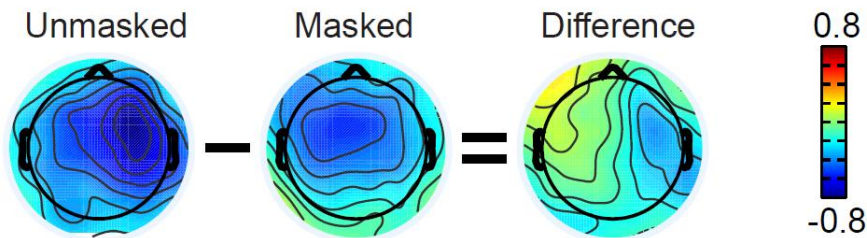


FDR<0.05, corrected across time, no other significant components

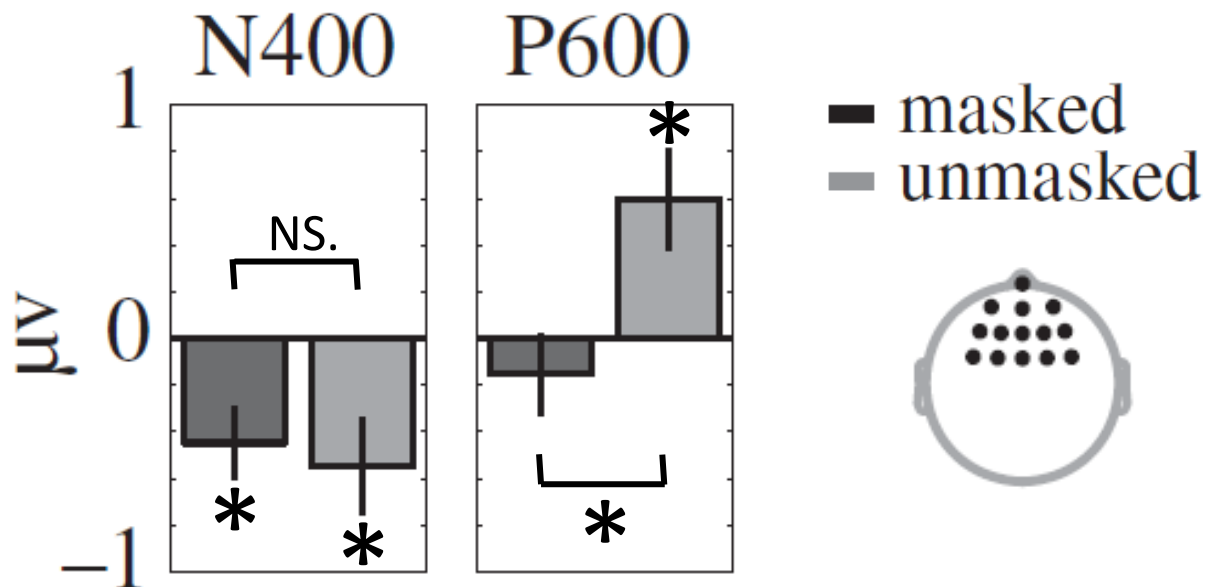
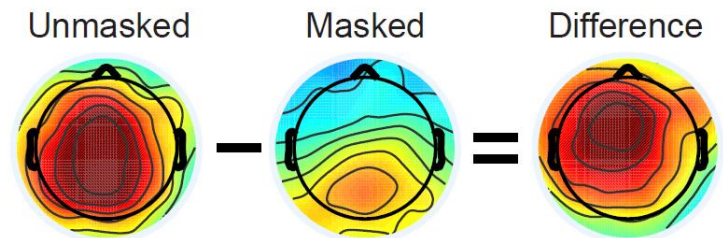
“Adjective priming” (single prime effects)

Head maps: incongruent – congruent

N400 adjective priming



P600 adjective priming

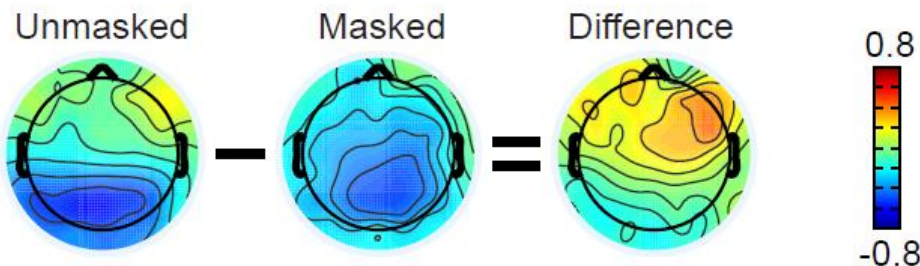


"Negation effect" (two prime effects)

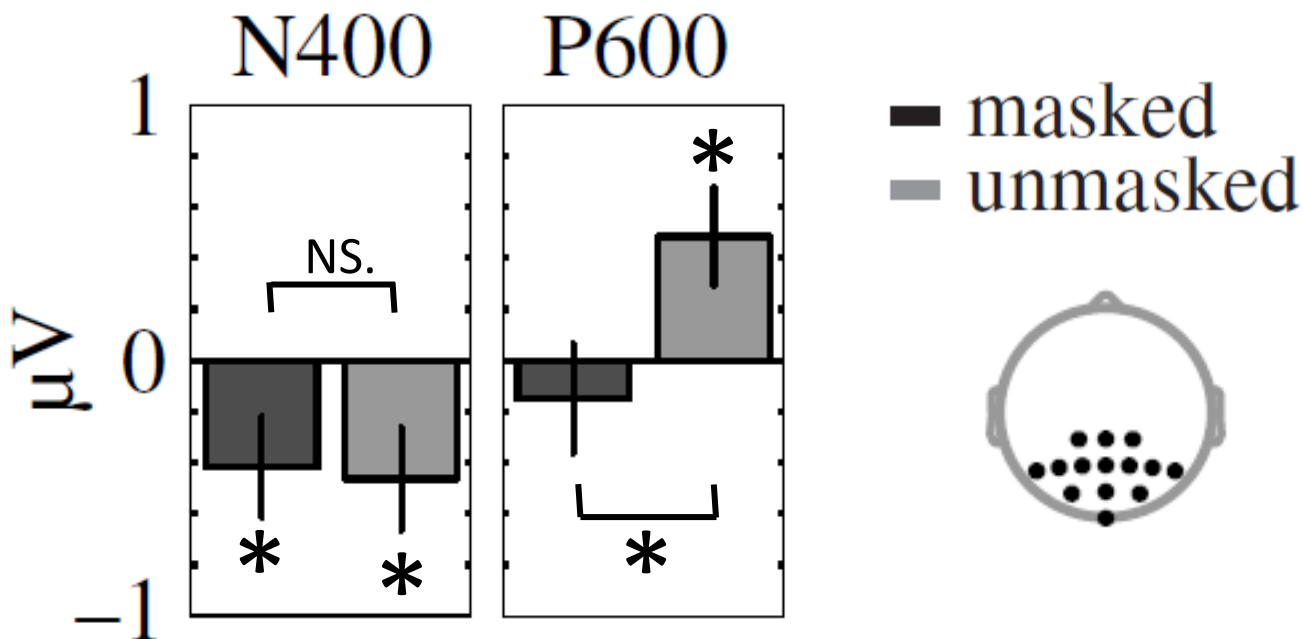
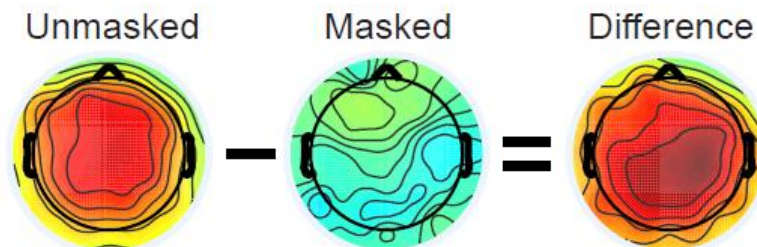
Head maps: Incongruent – congruent

(e.g., very-bad-peace /not-good-peace > not-bad-peace/very-good-peace)

N400 negation effect



P600 negation effect



Behavior

- *No behavioral evidence for unconscious negation (Draine, 1997).*
 - *But see Armstrong and Dienes, Consciousness and Cognition (2013)*

EEG

- *Replicated N400 single word priming effects*
- *Negations could unfold partly unconsciously*
 - *similar **N400** effects for conscious and unconscious negations (“early processing is similar”)*
- *Only conscious inconsistent three word sequences elicited **P600** effects (“late all-or-none effects”).*

Interpretation

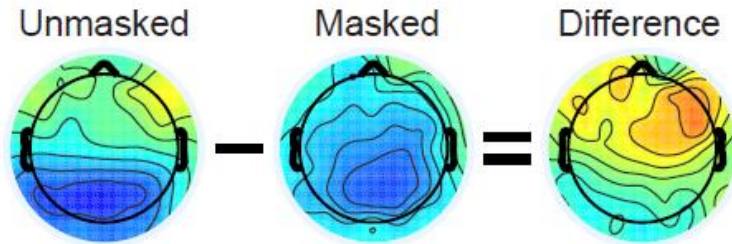
- *Two unconscious words can be rapidly integrated and an unconscious negation can automatically “flip the sign” of an unconscious adjective*
- *However, multiple word integration seems qualitatively different for conscious and unconscious words (at least for negation)*

Hypothesis:

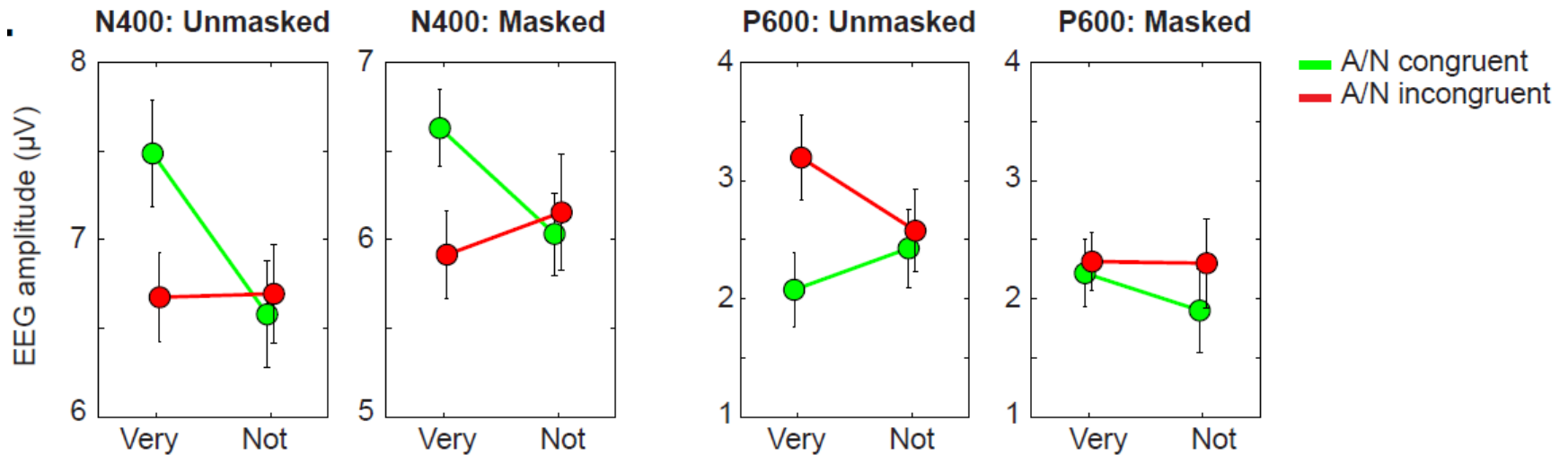
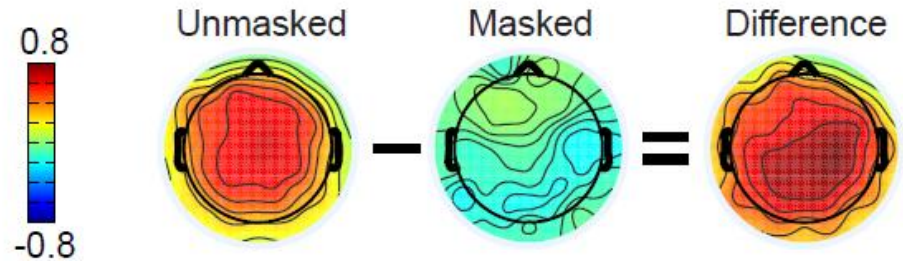
- *The time-consuming “re-analysis” of the preceding word sequence (reflected in the P600), which relies on active working memory mechanisms, might require conscious awareness*

Thanks for your attention

N400 negation effect



P600 negation effect

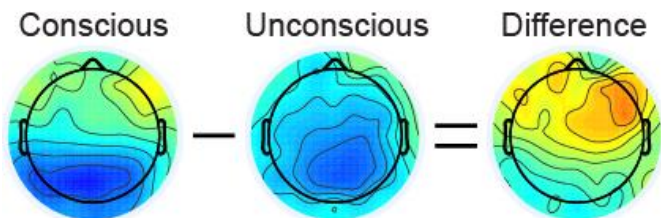


"Negation effect" (two prime effects)

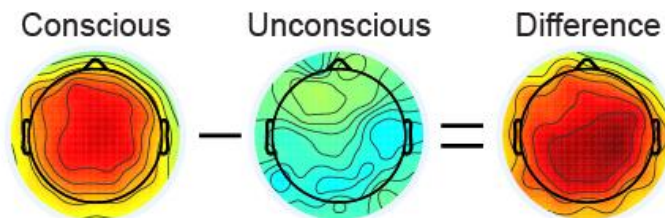
Head maps: Incongruent – congruent

(e.g., very-bad-peace > not-bad-peace)

N400 (380-440 ms)

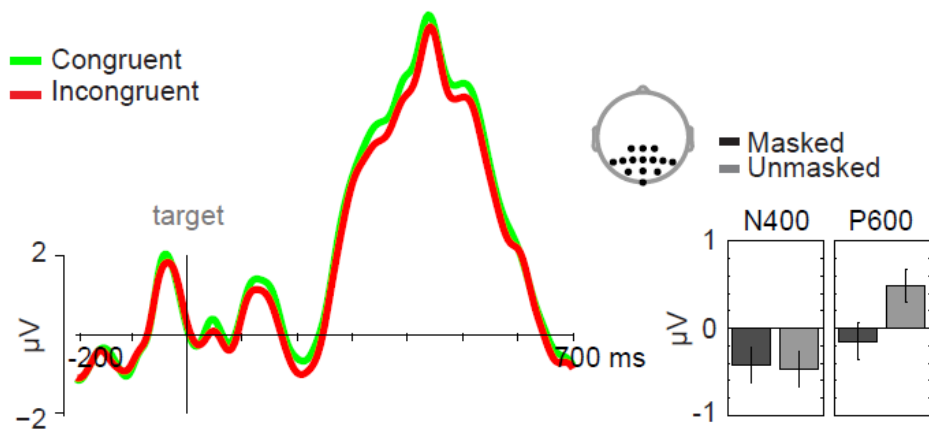


P600 (550-630 ms)

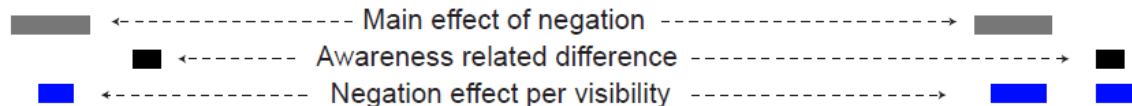
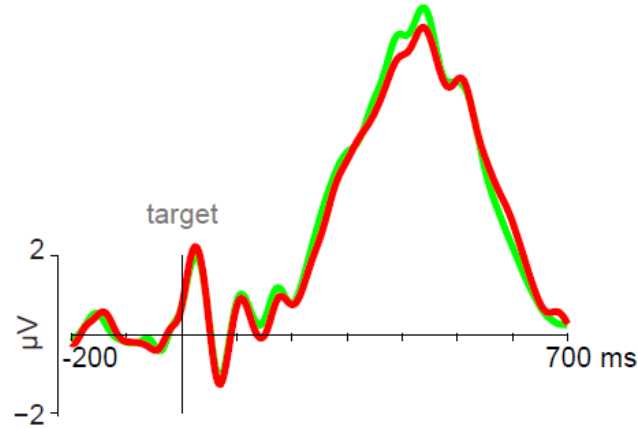


Negation effects

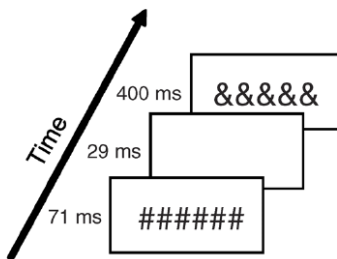
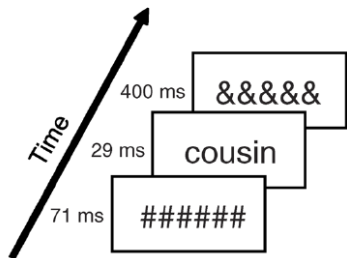
Masked condition



Unmasked condition



Sophisticated unconscious information processing

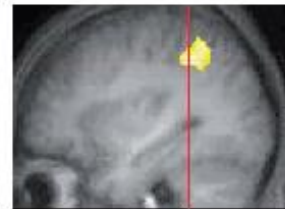


Words
stimuli



*Dehaene et al.,
Nat. Neurosci., 2001*

Numbers



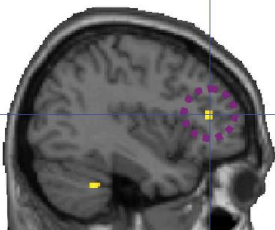
*Naccache et al.,
Cereb. Cortex, 2002*

Emotional



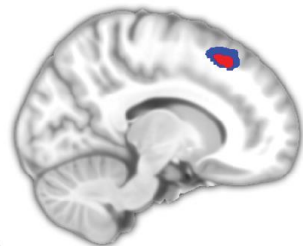
*Whalen et al.,
Science, 1998*

Unconsciously triggered
task-set preparation



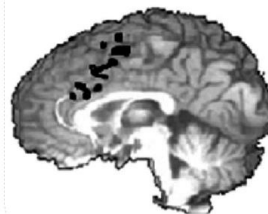
*Lau & Passingham
J. Neurosci., 2007*

Unconsciously triggered
response conflict



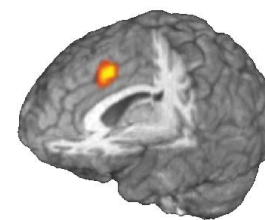
*van Gaal et al.,
JoCN, 2011*

Unnoticed
response errors



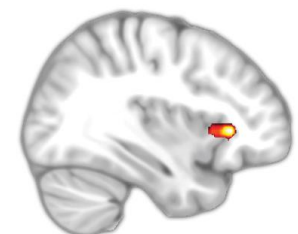
*Hester et al.,
Neuroimage, 2005*

Implicit violation
of expectancies



*Ursu et al.,
Biol. Psy., 2009*

Unconsciously triggered
response inhibition



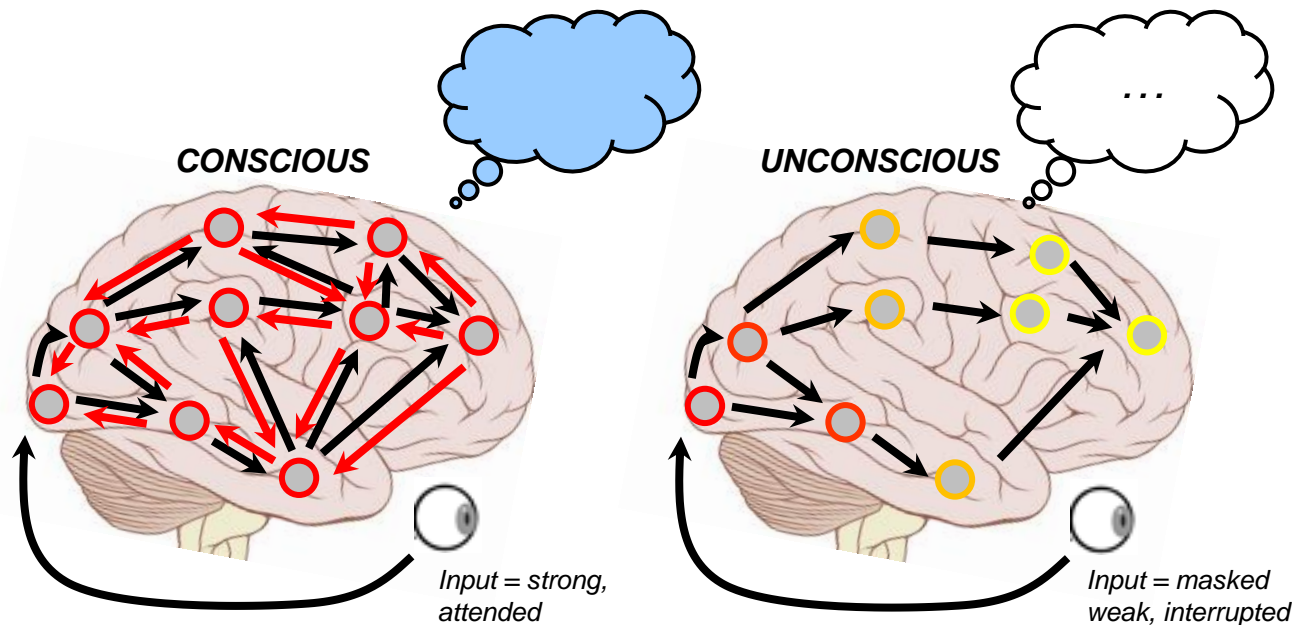
*van Gaal et al.,
J. Neurosci., 2010*

The general question

***What are the limits of unconscious information processing?
What is consciousness good for?***

Hypothesis:

*Awareness is beneficial/necessary for the **integration/accumulation** of **multiple** pieces of information **across time***



How Awareness Changes the Relative Weights of Evidence During Human Decision-Making

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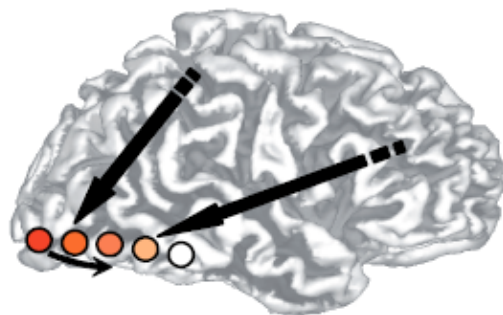
Conclusion:

Qualitative differences in the accumulation of evidence across time depending on the level of awareness of the sensory information (see also Sackur & Dehaene, Cognition, 2009)

Dissociating conscious and subliminal processing

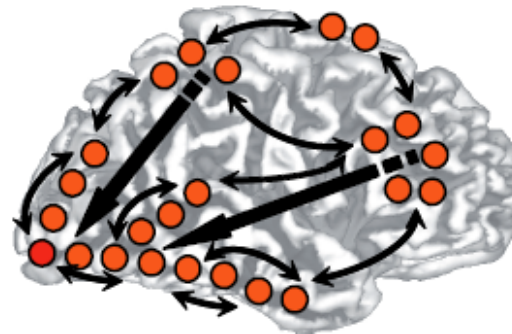
Subliminal (attended)

- Strong feed-forward activation
- Activation decreases with depth
- Depth of processing depends on attention and task set
- Activation can reach semantic level
- Short-lived priming
- No durable frontoparietal activity
- No reportability



Conscious

- Orientation of top-down attention
- Amplification of sensori-motor activity
- Intense activation spreading to parietofrontal network
- Long distance loops and global synchrony
- Durable activation, maintained at will
- Conscious reportability



Reading and doing arithmetic nonconsciously

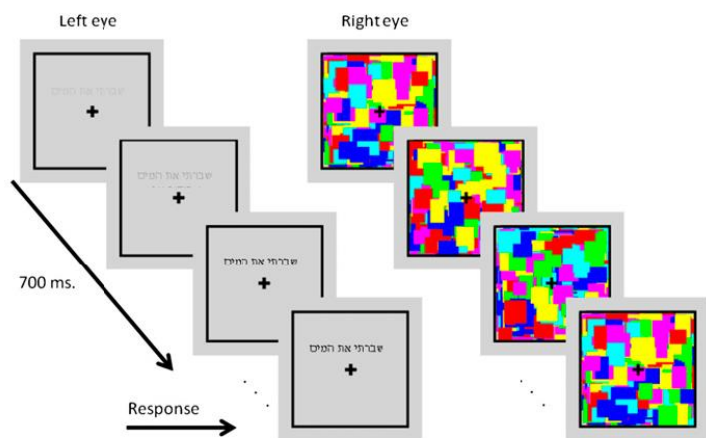
Asael Y. Sklar^a, Nir Levy^{a,1}, Ariel Goldstein^{b,1}, Roi Mandel^a, Anat Maril^{a,b}, and Ran R. Hassin^{a,c,2}

^aPsychology Department, ^bCognitive Science Department, and ^cCenter for the Study of Rationality, Hebrew University, Jerusalem 91905, Israel

Edited* by Michael I. Posner, University of Oregon, Eugene, OR, and approved October 5, 2012 (received for review July 12, 2012)

The modal view in the cognitive and neural sciences holds that consciousness is necessary for abstract, symbolic, and rule-following computations. Hence, semantic processing of multiple-word expressions, and performing of abstract mathematical computations, are widely believed to require consciousness. We report a series of experiments in which we show that **multiple-word verbal expressions can be processed outside conscious awareness and that multistep, effortful arithmetic equations can be solved unconsciously.** All experiments used **Continuous Flash Suppression** to render stimuli invisible for relatively long durations (up to 2,000 ms). Where

of experiments, we show that humans can semantically solve effortful arithmetic equations. In the first experiment, we presented a target stimulus to one eye and a series of rapidly changing masks to the other eye.



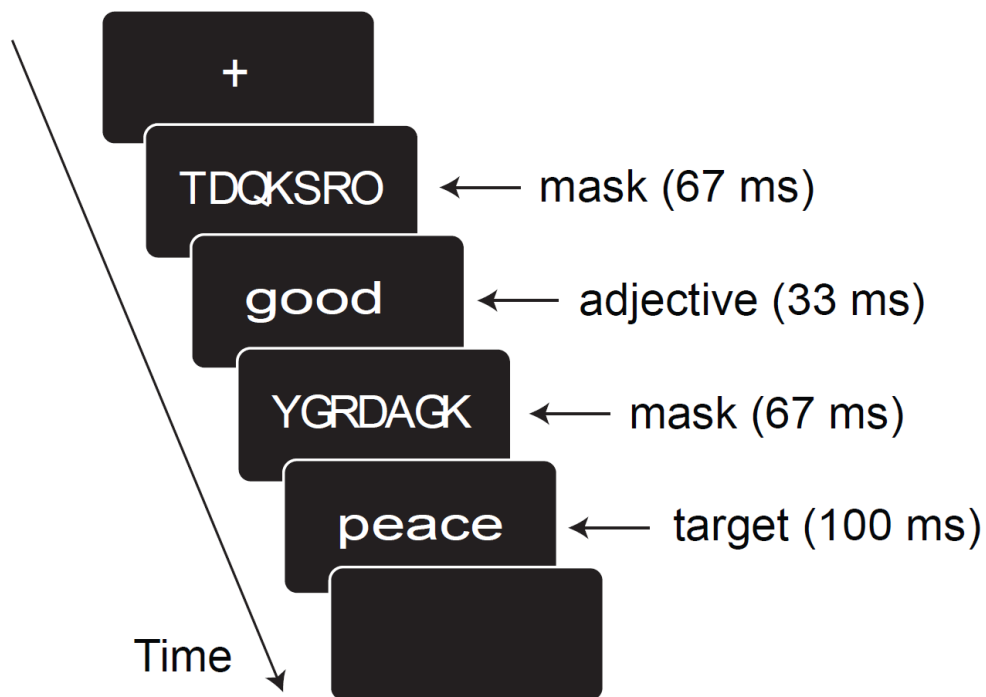
I played the melody (congr.)

VS.

smelled the melody (incongr.)

Breaks suppression
~20 ms earlier

The classical masking paradigm



Response: is the final target word positive or negative?

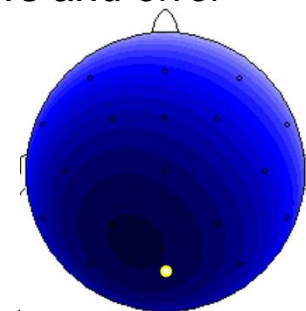
Incongruent trials (bad-peace, good-war)

Congruent trials (good-peace, bad-war)

Priming effect:

Worse performance to incongruent than congruent trials (RTs and error rates)

— Congruent
— Incongruent



300 – 500 ms

