Spatial attention control mechanism modulated by subliminal stimuli:
An Electroencephalography Study

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Introduction

Tsushima et al. (2006) found that task-irrelevant visual stimuli, when not consciously perceived, led to a stronger disturbance in task performance compared to consciously seen stimuli.
This finding has become a foundational piece of evidence for a series of emerging perceptual learning models and attention control theories (e.g., Attention Schema Theory).

Metacontrast Masking
A type of backward masking where a stimulus is followed by a mask in which the contour of the mask fits neatly around the stimulus (Koster et al., 2020).
Manipulations of stimulus-mask intervals (SOA) yields a U-shaped curve:
- Intermediate SOAs (~40-100ms) yield the lowest visibility.
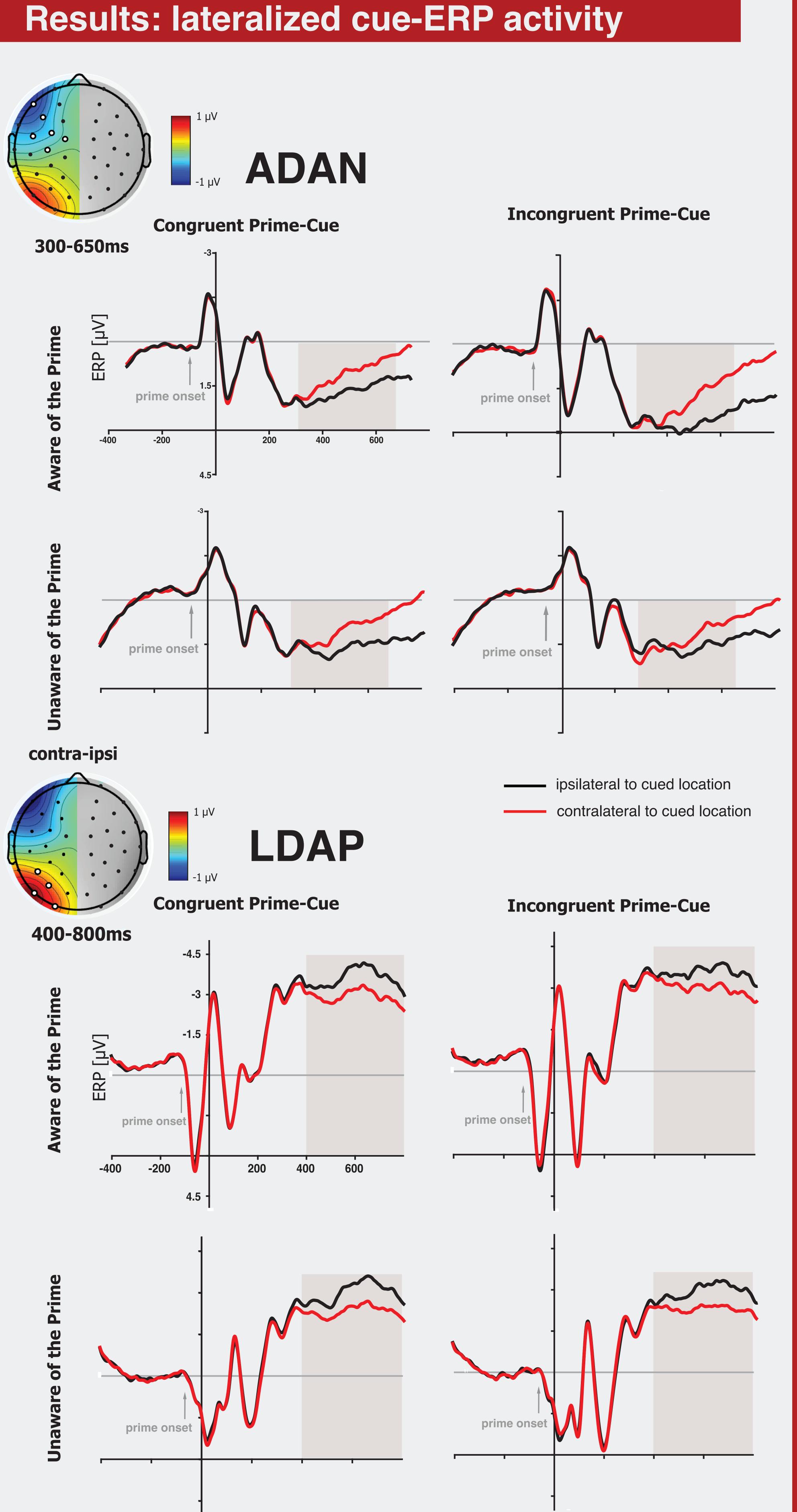- Very short (<30ms) or very long (>150ms) SOAs yield the highest visibility.

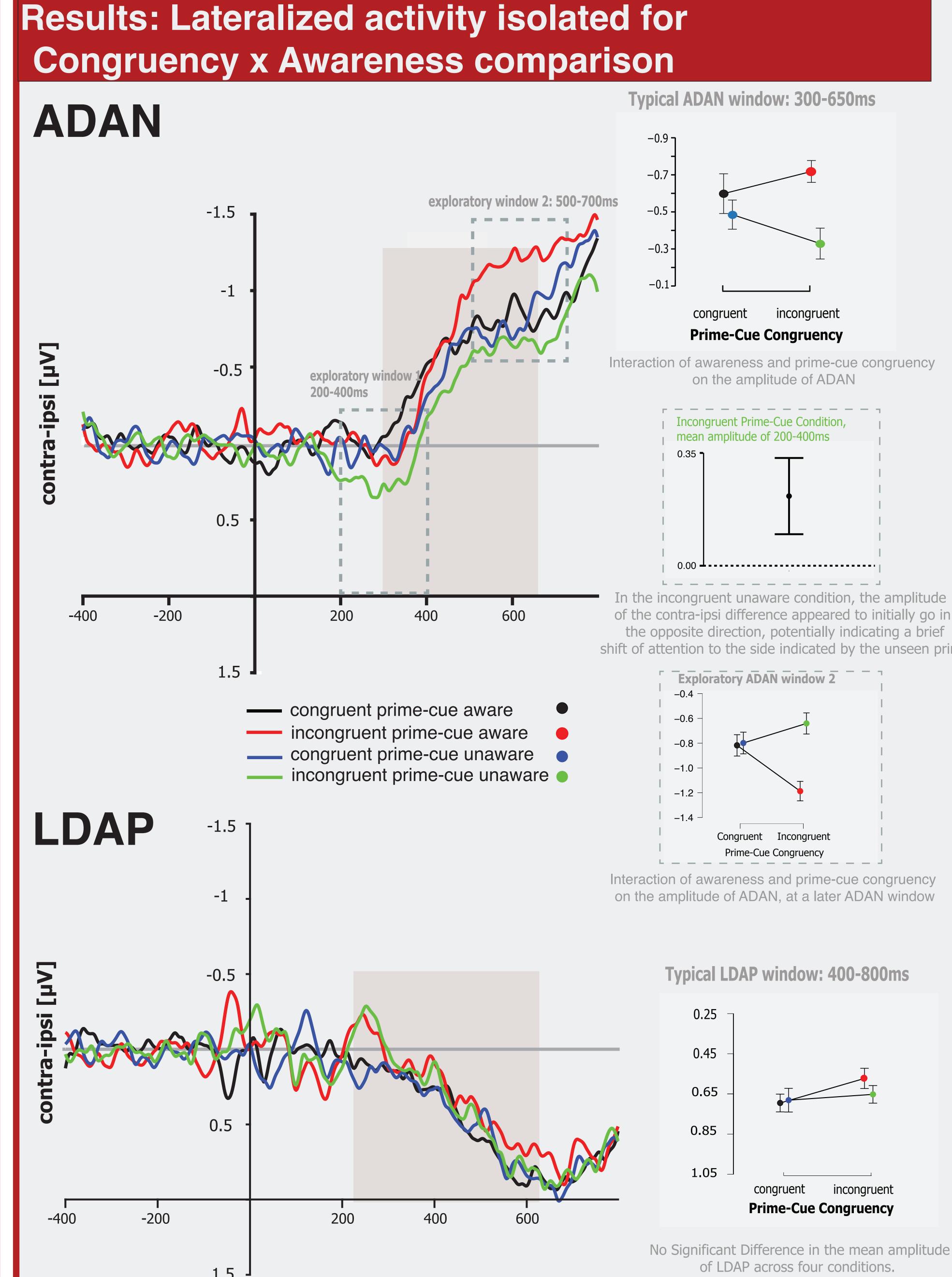**Neural Markers of Spatial Attention Modulation** (Jongen et al., 2007; Meyberg et al., 2017)

Anterior Directing Attention Negativity (ADAN): 300-500ms after cue onset, reflects the initiation of spatial attention control mechanisms.

Late Directing Attention Positivity (LDAP): 500ms-700ms after cue onset, reflects a selective preparatory biasing of neural activity in visual sensory areas in anticipation of the target.

attending to right target

5 μV
-5 μV

Contralateral
*For analysis, data were collapsed between leftward and rightward shifting trials together for every condition

Objective: What is the effect of subliminal primes on visual-spatial attention control?

Method

Quest Algorithm:
To determine invisibility threshold of individual's prime-cue SOA

prime
Prime-Cue SOA
cue

Prime is a square or a diamond?

Correct answer | Incorrect answer

More difficult - decrease SOA
Easier - increase SOA

Masked Prime Spatial Cueing Task (Palmer & Mattler, 2013)

prime
50% invisible
50% visible

Prime -cue SOA
32-108ms unaware
144ms aware

cue
Also served as a mask to the prime

cue-target SOA
805ms

target

report the tilting direction of the attended Gabor patch

Covert attention task

left   tilt   right

Congruent   Incongruent
left   attend   right   left   attend   right

Behavioral Reuslts

SOA Distribution

All Subjects (n=25)

Distribution of prime-cue SOAs that resulted in threshold detection of the prime (50% Y/N reports)

Awareness of Prime
○ Aware
● Unaware

Prime-Cue Congruency

Results: lateralized cue-ERP activity

ADAN
300-650ms
1 μV
-1 μV

Congruent Prime-Cue   **Incongruent Prime-Cue**

Aware of the Prime
prime onset

Unaware of the Prime
prime onset

contra-ipsi
400-800ms
1 μV
-1 μV

— ipsilateral to cued location
— contralateral to cued location

LDAP

Congruent Prime-Cue   **Incongruent Prime-Cue**

Aware of the Prime
prime onset

Unaware of the Prime
prime onset

Results: Lateralized activity isolated for Congruency x Awareness comparison

ADAN

contra-ipsi [μV]

exploratory window 200-400ms
exploratory window 2: 500-700ms

Typical ADAN window: 300-650ms

Prime-Cue Congruency

Interaction of awareness and prime-cue congruency on the amplitude of ADAN

— congruent prime-cue aware   ● congruent prime-cue aware
— incongruent prime-cue aware ● incongruent prime-cue aware
— congruent prime-cue unaware ● congruent prime-cue unaware
— incongruent prime-cue unaware ● incongruent prime-cue unaware

Incongruent Prime-Cue Condition, mean amplitude of 200-400ms

In the incongruent unaware condition, the amplitude of the contra-ipsi difference appeared to initially go in the opposite direction, potentially indicating a brief shift of attention to the side indicated by the unseen prime

Exploratory ADAN window 2

Prime-Cue Congruency

Interaction of awareness and prime-cue congruency on the amplitude of ADAN, at a later ADAN window

LDAP

contra-ipsi [μV]

Typical LDAP window: 400-800ms

Prime-Cue Congruency

No Significant Difference in the mean amplitude of LDAP across four conditions.

Summary

- In all conditions, we observed the ADAN and LDAP components consistent with previous research (McDonald & Green, 2008).
- ADAN amplitude was modulated by congruency and awareness of the prime.
- These results suggest that a subliminal task-irrelevant prime can disrupt attentional control mechanisms, possibly due to a failure to establish inhibitory control over the influence of the unseen prime.
- An exploratory analysis of early time-windows (200-400ms post-cue) in the incongruent condition suggested that attention may have initially followed the unseen prime before inhibitory mechanisms were able to control attention based on the seen cue.

Reference

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