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How to Evaluate an ERP Study

Noisy Data

Top Ten Problems in ERP Studies

Data problems

1. Noisy data
2. Baseline problems
3. Blinks or eye movements

Analysis problems

4. Inappropriate filtering
5. Inappropriate amplitude or latency measures
6. Statistical problems

Design and interpretation problems

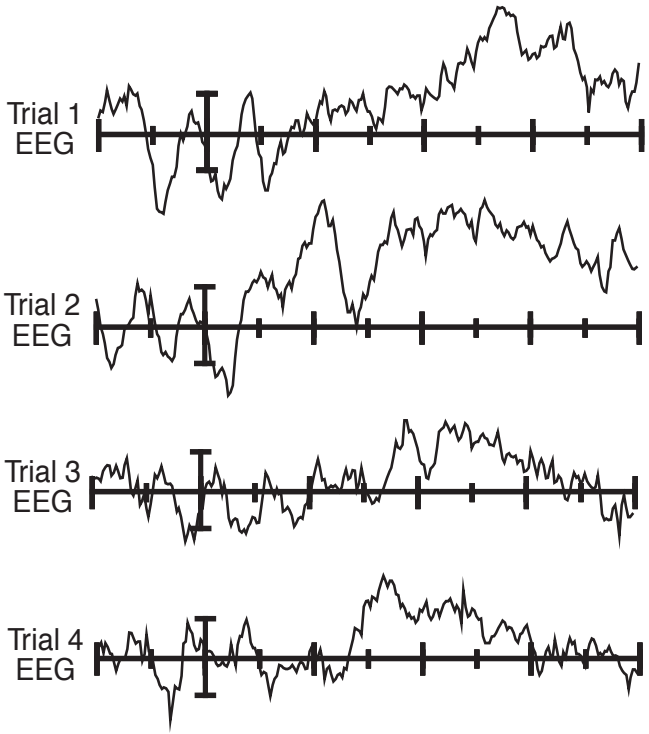
7. Lack of specific predictions
8. Physical stimulus confounds
9. Failure to isolate the component of interest
10. Overreliance on source localization

https://mitpress.mit.edu/books/introduction-event-related-potential-technique-second-edition

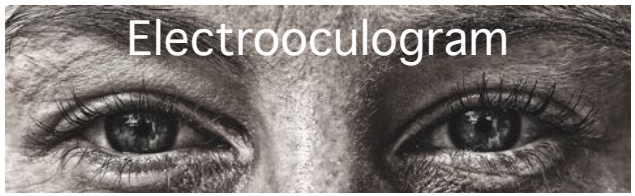
Chapter 15: Reading, Writing, and Reviewing ERP Papers (free online-only chapter)

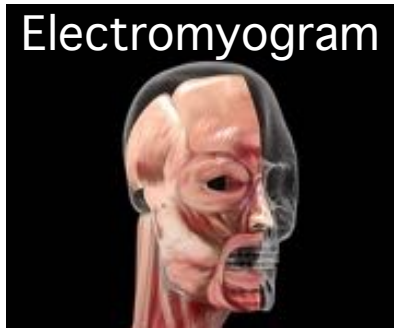
Where does the noise come from?

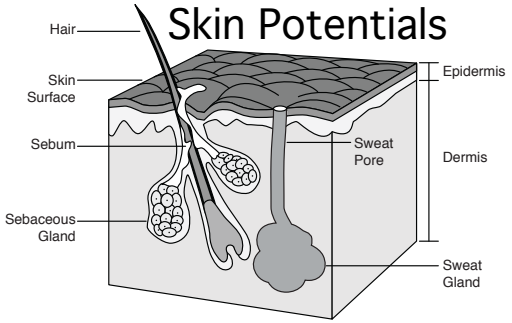
1: Brain activity that is not time-locked to the event of interest



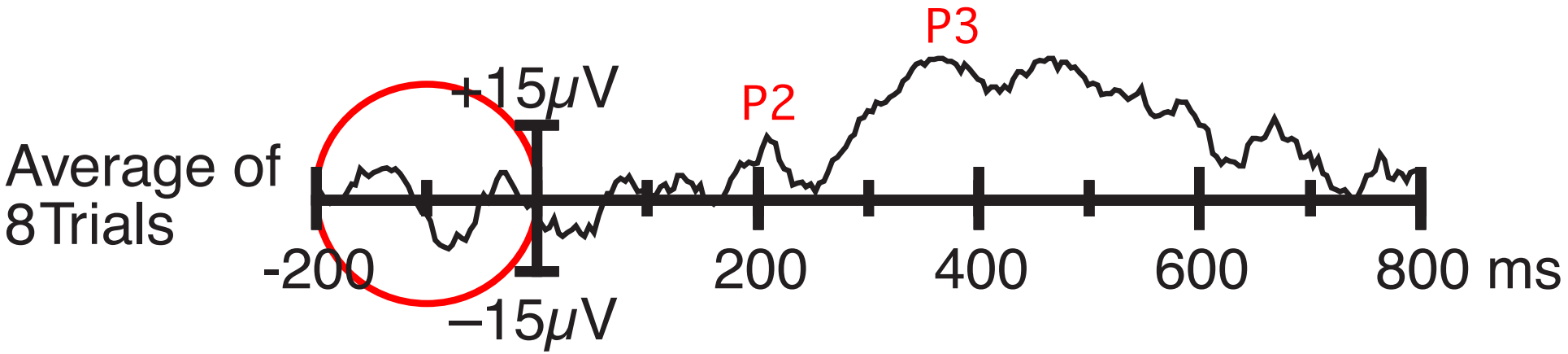
2: Biological Artifacts



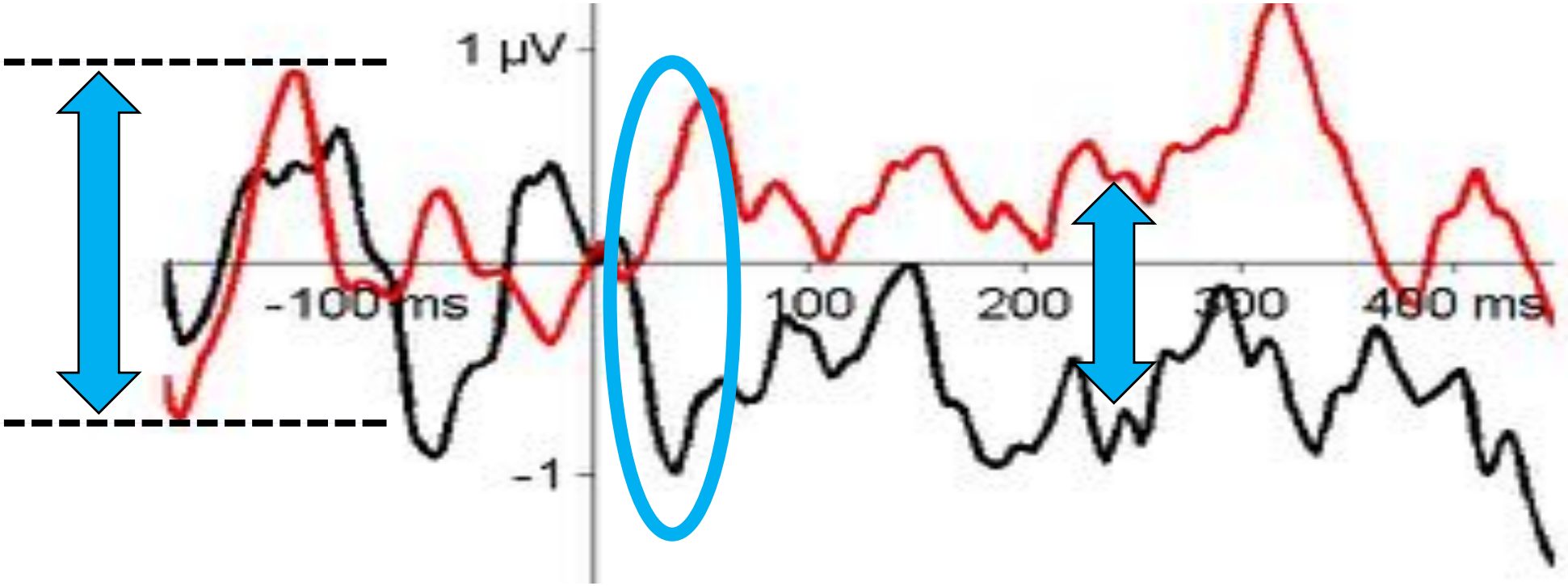




3: Induced electrical activity from the recording environment



If the experimental effects in a study aren't much bigger than the baseline noise, you should be skeptical of the effects (even if they're significant).



The difference between the waveforms after the stimulus was smaller than the noise deflections in the baseline.

The effect started at about 20 milliseconds, which is way too early. It takes 40 to 60 milliseconds for visual information to reach the cortex, and it's very rare for a difference in cognitive processing to occur before 100 ms.

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How to Evaluate an ERP Study

Small Effects & Replication

Risa Sawaki

Attention, Perception, & Psychophysics
2010, 72 (6), 1455-1470
doi:10.3758/APP.72.6.1455

RESEARCH ARTICLES

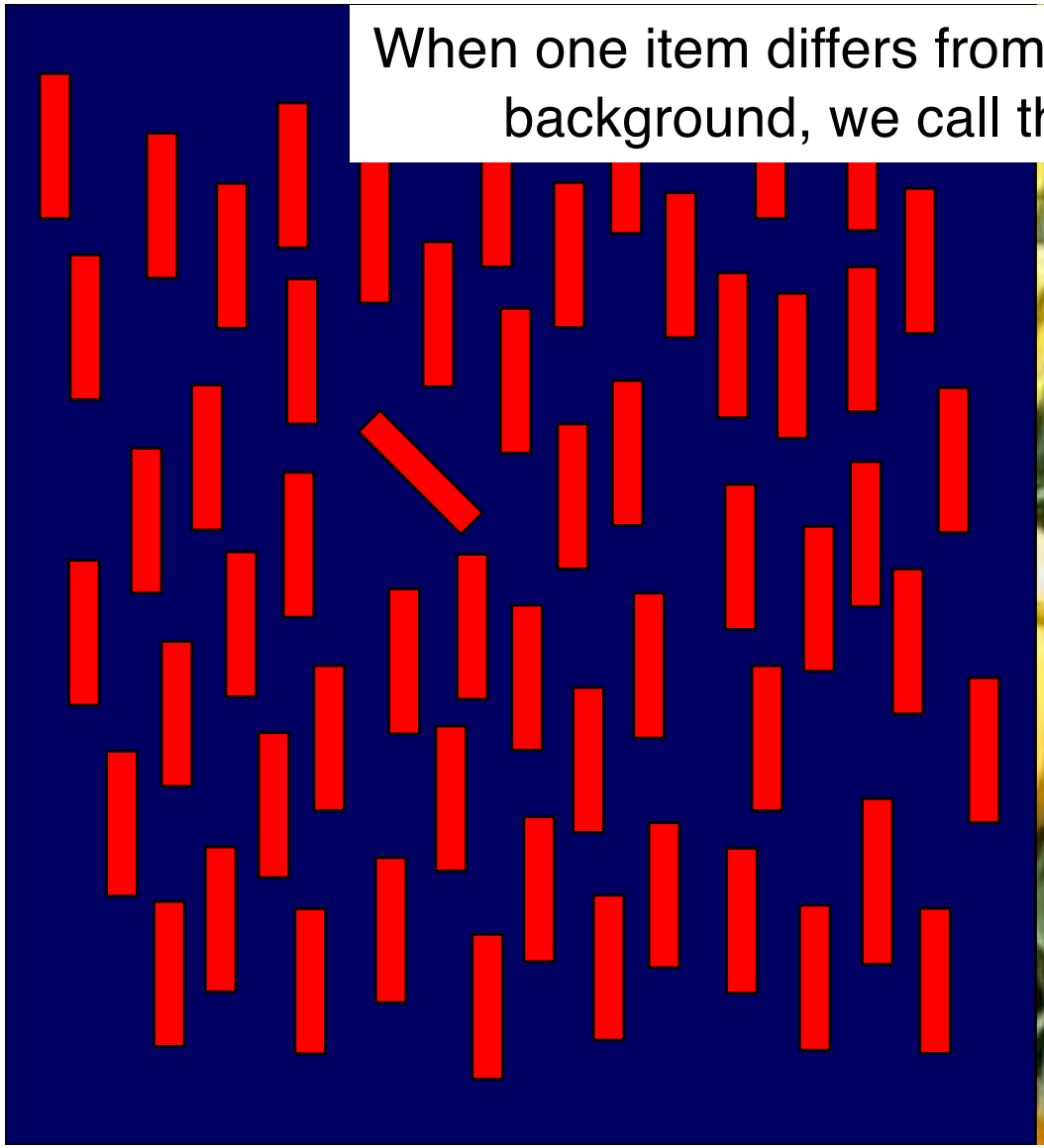
Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal

RISA SAWAKI AND STEVEN J. LUCK
University of California, Davis, California

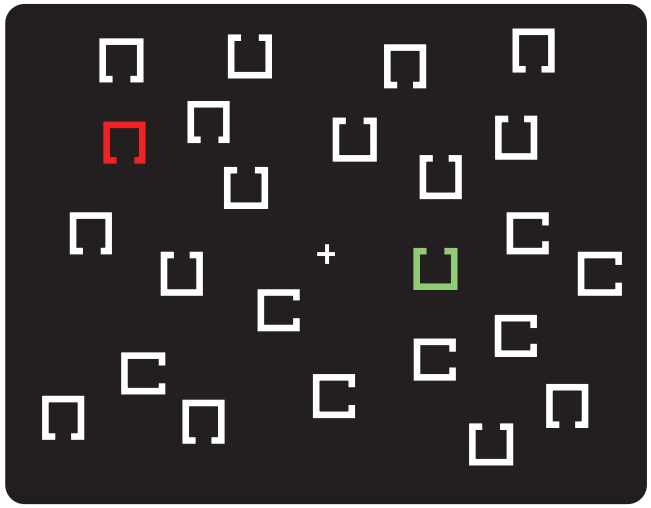
There is considerable controversy about whether salient singletons capture attention in a bottom-up fashion, irrespective of top-down control settings. One possibility is that salient singletons always generate an attention capture signal, but this signal can be actively suppressed to avoid capture. In the present study, we investigated this issue by using event-related potential recordings, focusing on N2pc (N2-posterior-contralateral; a measure of attentional deployment) and Pd (distractor positivity; a measure of attentional suppression). Participants searched for a specific letter within one of two regions, and irrelevant color singletons were sometimes present. We found that the irrelevant singletons did not elicit N2pc but instead elicited Pd; this occurred equally within the attended and unattended regions. These findings suggest that salient singletons may automatically produce an attend-to-me signal, irrespective of top-down control settings, but this signal can be overridden by an active suppression process to prevent the actual capture of attention.

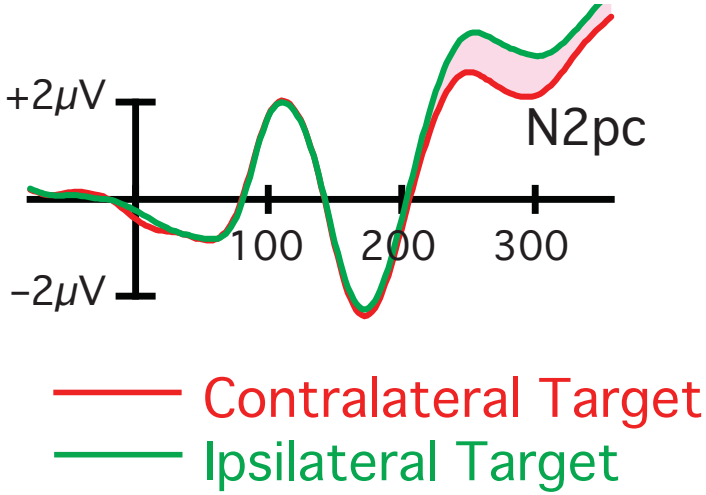
Sawaki, R., & Luck, S. J. (2010). Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal. *Attention, Perception, & Psychophysics*, *72*, 1455–1470.

When one item differs from a relatively homogeneous background, we call that item a “singleton”.



N2pc





If singletons automatically capture attention, then they should elicit an N2pc even if they're task-irrelevant

Do Singletons Elicit N2pc?

200 ms

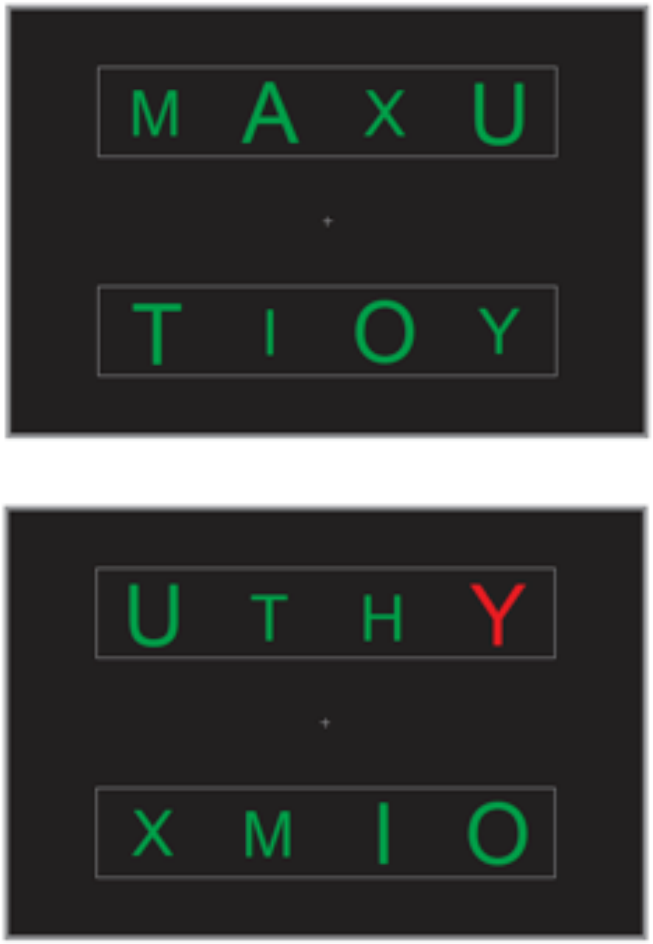
200 ms

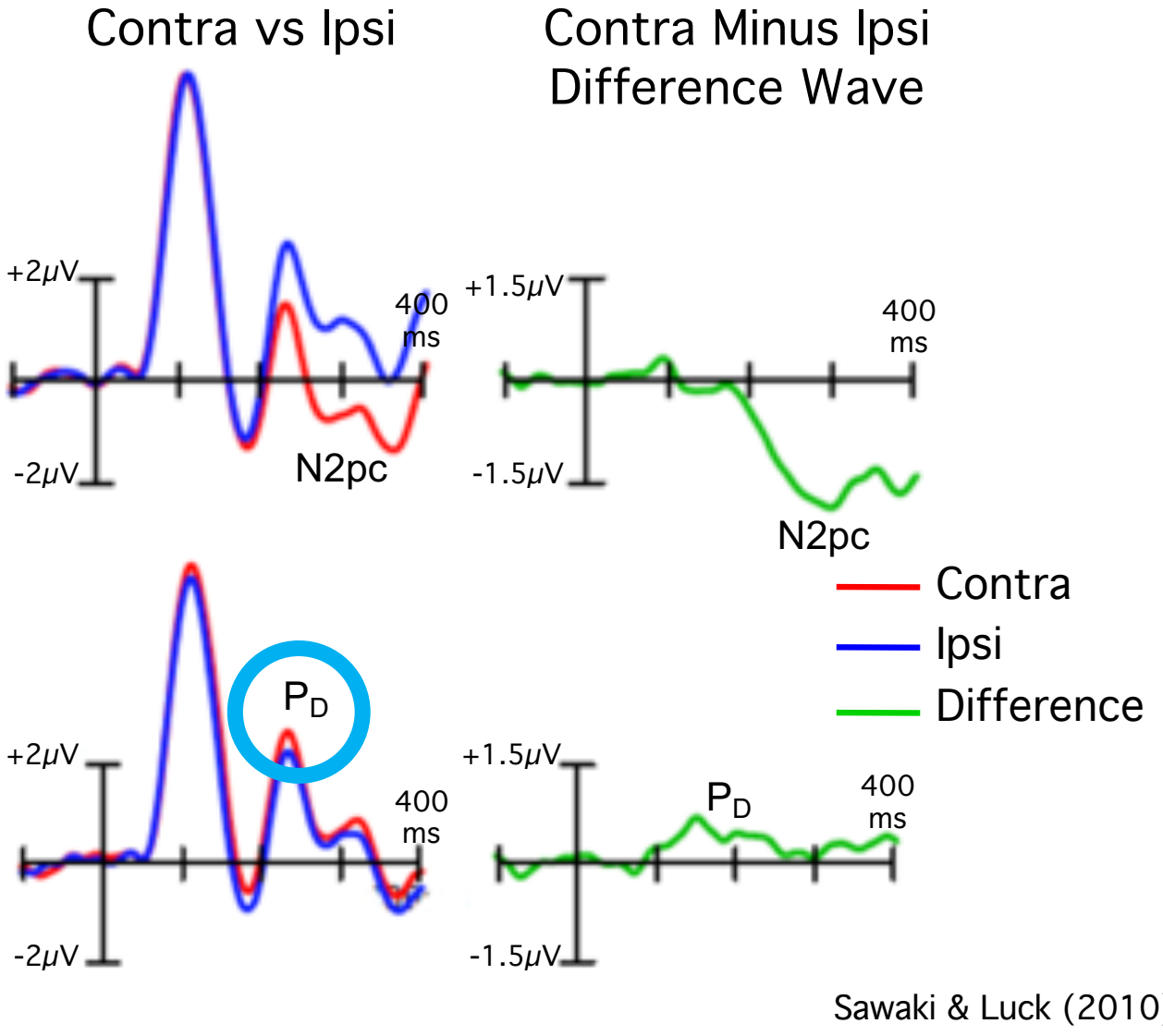
Target: Specific letter of specific size (e.g., large A)

Task: Press a button whenever a target is detected

Irrelevant Singleton: Red Item

Sawaki & Luck (2010)





Sawaki & Luck (2010)

Active suppression of distractors that match the contents of visual working memory

Risa Sawaki and Steven J. Luck

University of California, Davis, CA, USA

Behavioral/Cognitive

Cortical Mechanisms of Prioritizing Selection for Rejection in Visual Search

Sarah E. Donohue,[1,2] Mandy V. Bartsch,[2] Hans-Jochen Heinze,[1,2] Mircea A. Schoenfeld,[1,2,3] and Jens-Max Hopf[1,2]

[1]Department of Neurology, Otto-von-Guericke University, 39120 Magdeburg, Germany, [2]Leibniz Institute for Neurobiology, 39118 Magdeburg, Germany, and [3]Kliniken Schmieder Heidelberg, 69117 Heidelberg, Germany

ORIGINAL ARTICLE

WILEY PSYCHOPHYSIOLOGY SPR

Salient-but-irrelevant stimuli cause attentional capture in difficult, but attentional suppression in easy visual search

Caroline Barras | Dirk Kerzel

A temporal dependency account of attentional inhibition in oculomotor control

Matthew D. Weaver*, Wieske van Zoest, Clayton Hickey

Center for Mind/Brain Sciences, University of Trento, 38068 Rovereto, TN, Italy

Direct Evidence for Active Suppression of Salient-but-Irrelevant Sensory Inputs

Psychological Science
2015, Vol. 26(11) 1740–1750
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DOI: 10.1177/0956797615597913
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Nicholas Gaspelin[1], Carly J. Leonard[1], a
[1]Center for Mind and Brain and [2]Department of Psychology, Uni

Learned and cued distractor rejection for multiple features in visual search

Brad T. Stilwell[1] · Shaun P. Vecera[1]

Enhancement and Suppression Flexibly Guide Attention

Psychological Science
1–9
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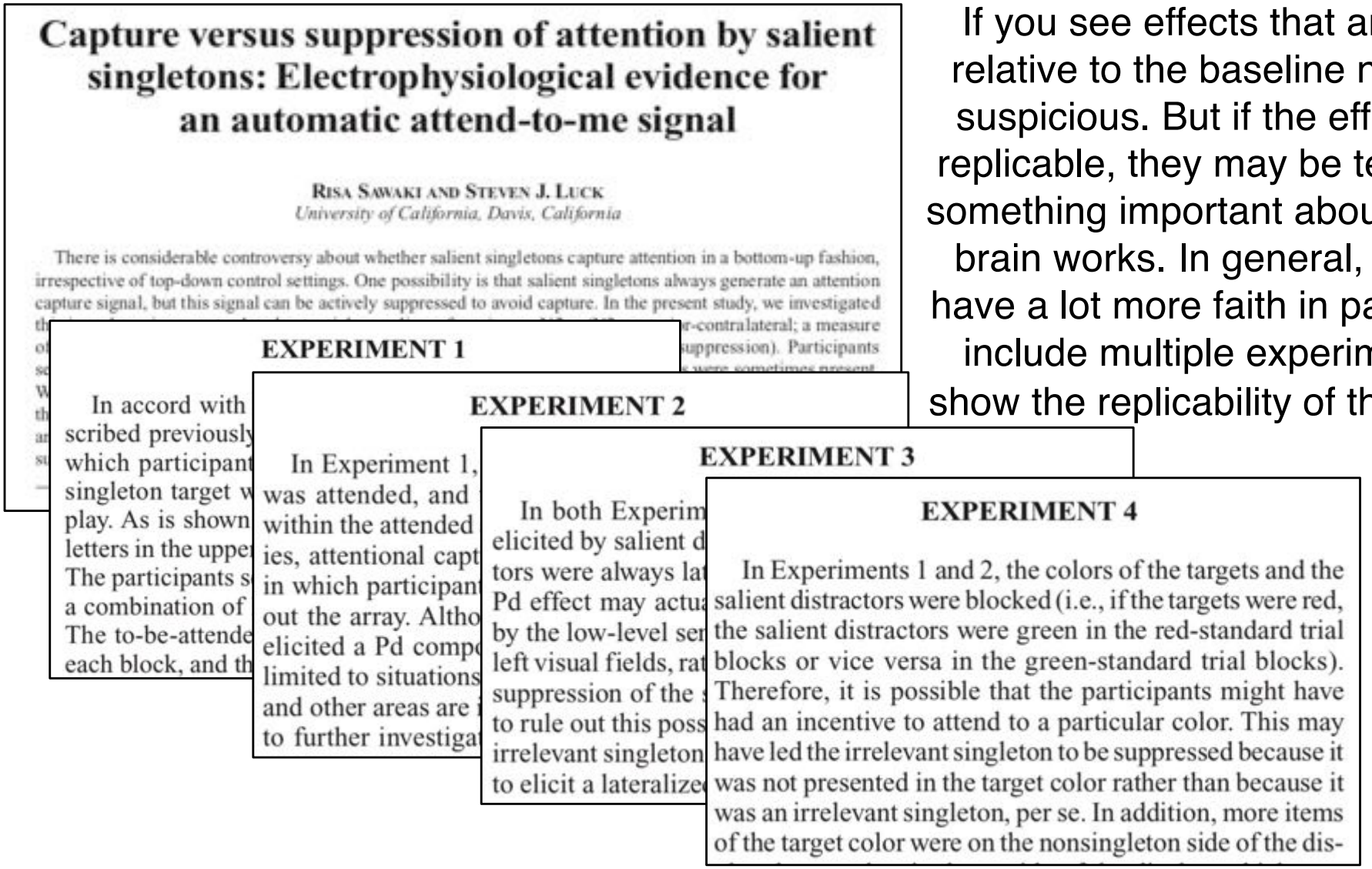
DOI: 10.1177/0956797619878813
www.psychologicalscience.org/PS
SAGE

Seah Chang and Howard E. Egeth
Department of Psychological and Brain Scie

Suppression of overt attentional capture by salient-but-irrelevant color singletons

Nicholas Gaspelin[1] · Carly J. Leonard[1] · Steven J. Luck[1]



If you see effects that are small relative to the baseline noise, be suspicious. But if the effects are replicable, they may be telling you something important about how the brain works. In general, you can have a lot more faith in papers that include multiple experiments to show the replicability of the effects.

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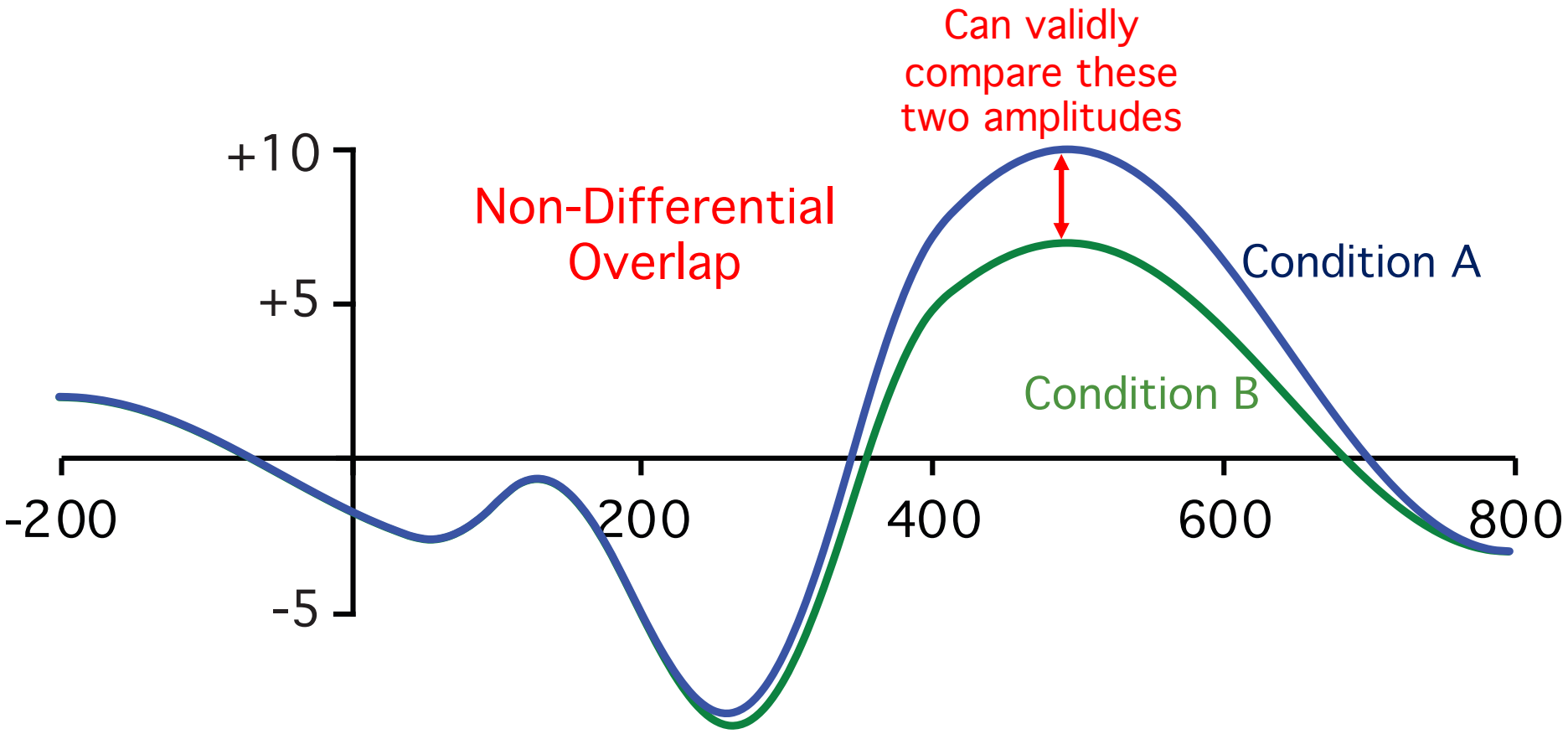
How to Evaluate an ERP Study

Baseline Problems and Artifacts

Overlap and Preparatory Activity

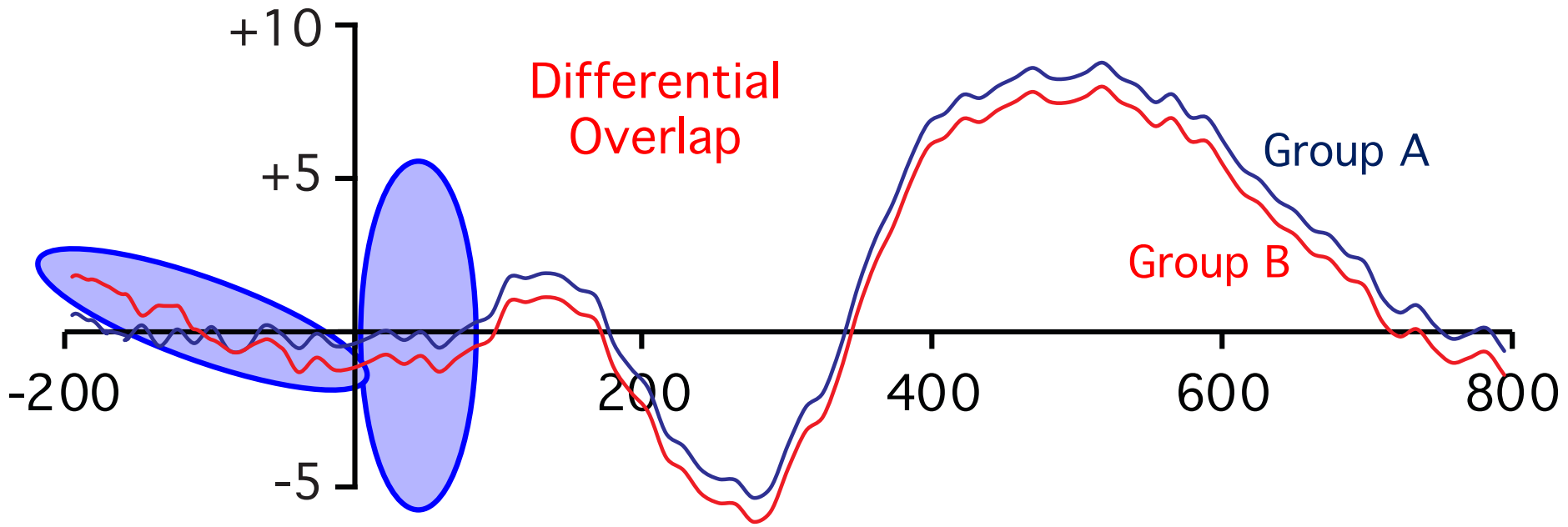


Overlap and preparatory activity are not usually a problem unless they differ between conditions

Overlap and Preparatory Activity

To avoid differential overlap, it helps to use experimental designs where the stimuli for the different conditions are randomly intermixed.

The targets and singletons in Sawaki & Luck (2010) appeared in random order. Subjects couldn't differentially prepare for the targets and the singletons, and the baselines for the targets and the singletons should be the same.



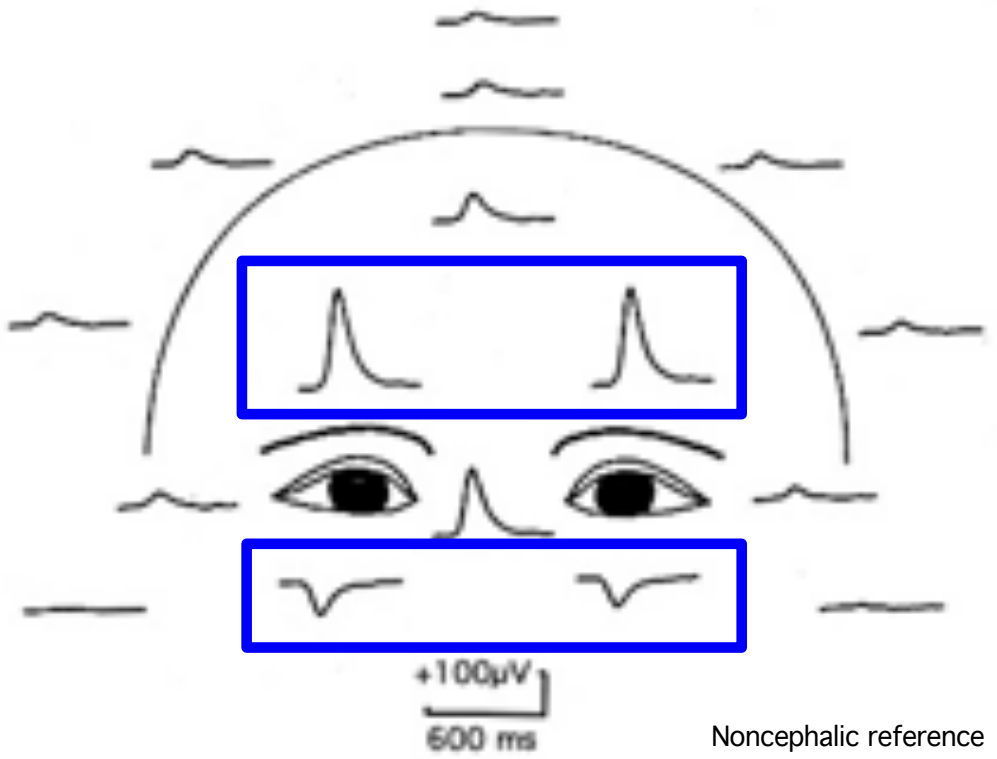
Whenever you look at ERP waveforms, you should look closely at the baseline to see if the tilt is different for the waveforms being compared.

Because of baseline correction, differences in tilt will often result in differences between conditions starting around time zero. If you see an effect that begins unrealistically early and persists for a long time, you should suspect differences in overlap or preparatory activity.

Blinks are huge, easy to detect, and can be corrected using ICA. Most studies don't have differences in blink-related activity between conditions or between groups.

If you see an effect that is biggest at the very front of the head, and you suspect that blinks are the reason, you should look at the data from under the eyes.

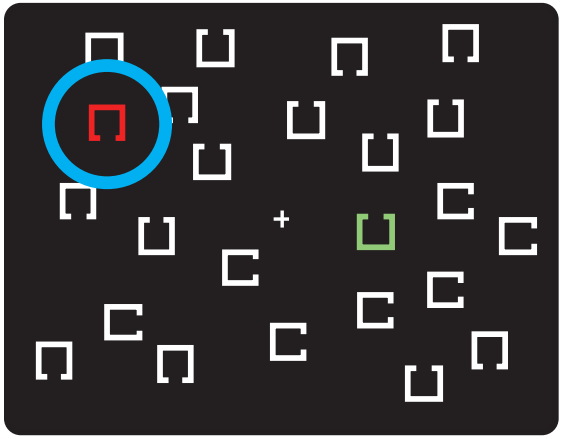
If the experimental effect is blink-related, the polarity of the effect will be opposite under versus over the eyes.

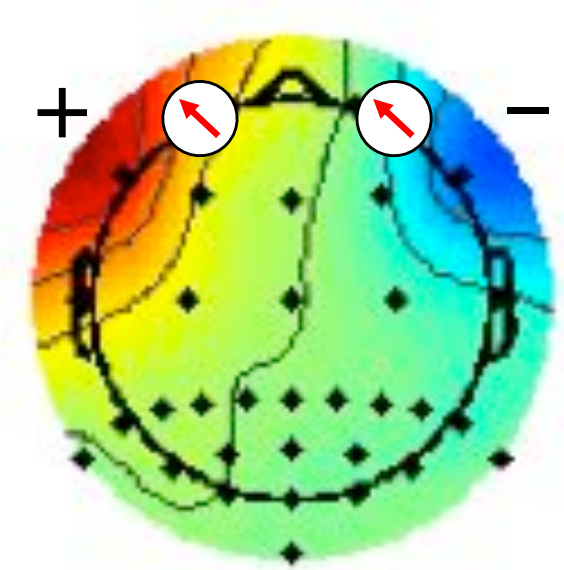


Lins, Picton, Berg, & Scherg (1993)

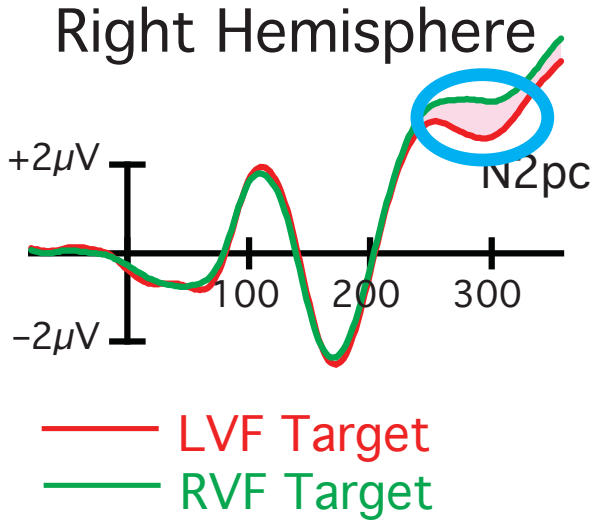
Lateral eye movements produce lateralized voltage fields on the scalp, with a more negative voltage contralateral to the target of the eye movement, just like an N2pc.

N2pc
(pc: posterior contralateral)





The eye movements produce a more frontal scalp distribution than the N2pc or CDA, but they can still produce a statistically significant contralateral negativity over the posterior electrodes where we look at the N2pc.



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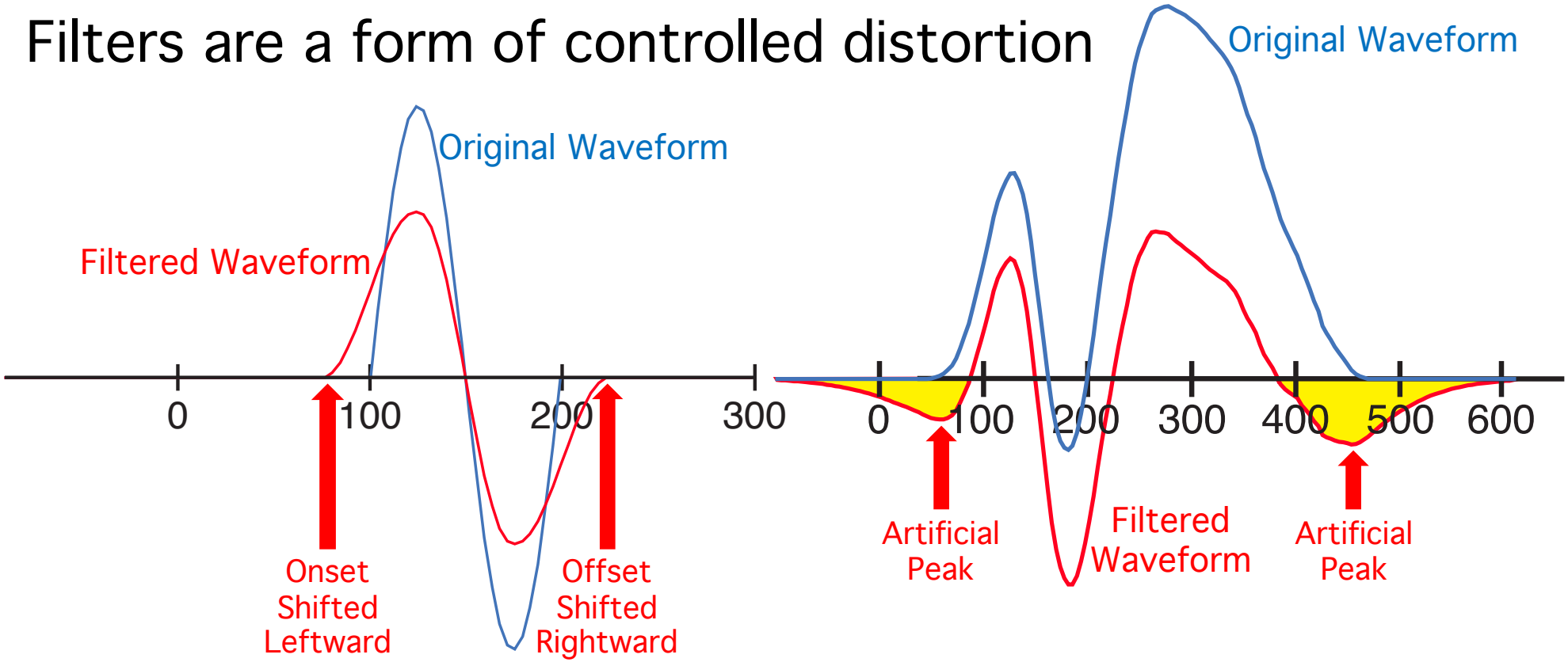
How to Evaluate an ERP Study

Analysis Problems

Filters are a form of controlled distortion



Low-pass filters tend to distort the onset and offset times of the ERPs.

Extreme high-pass filters can cause artificial peaks to appear in the waveforms.

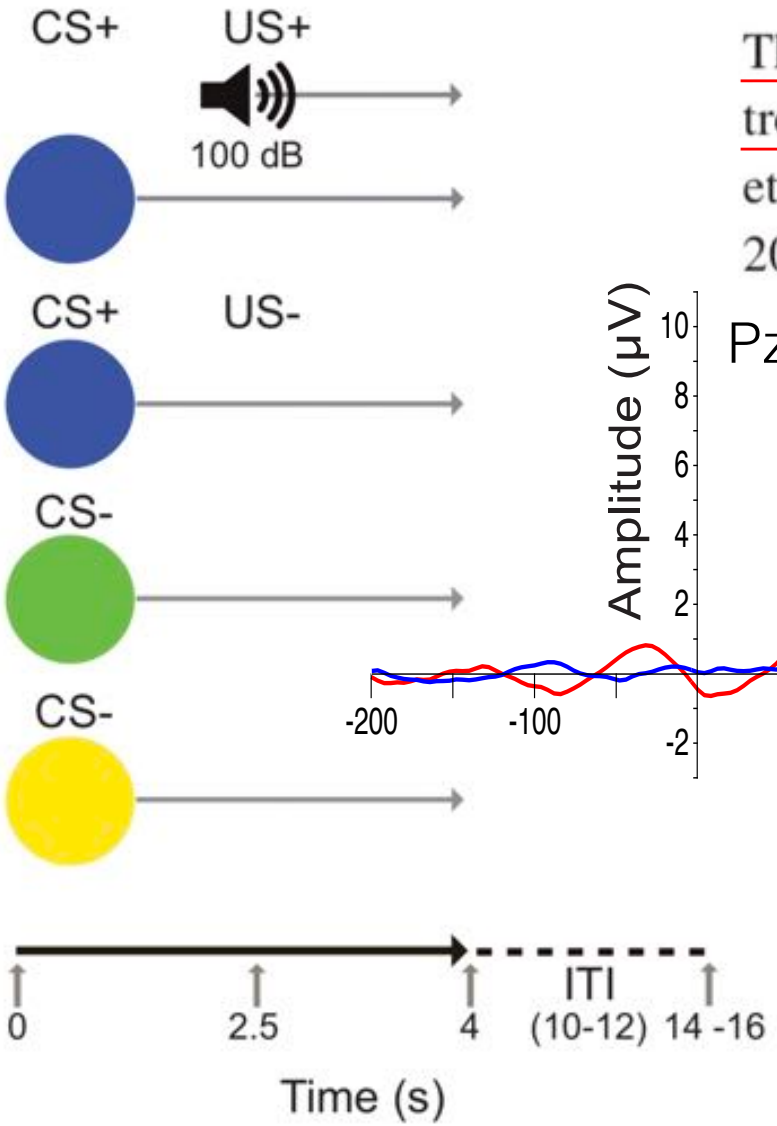
But some filtering is necessary.

Recommendations

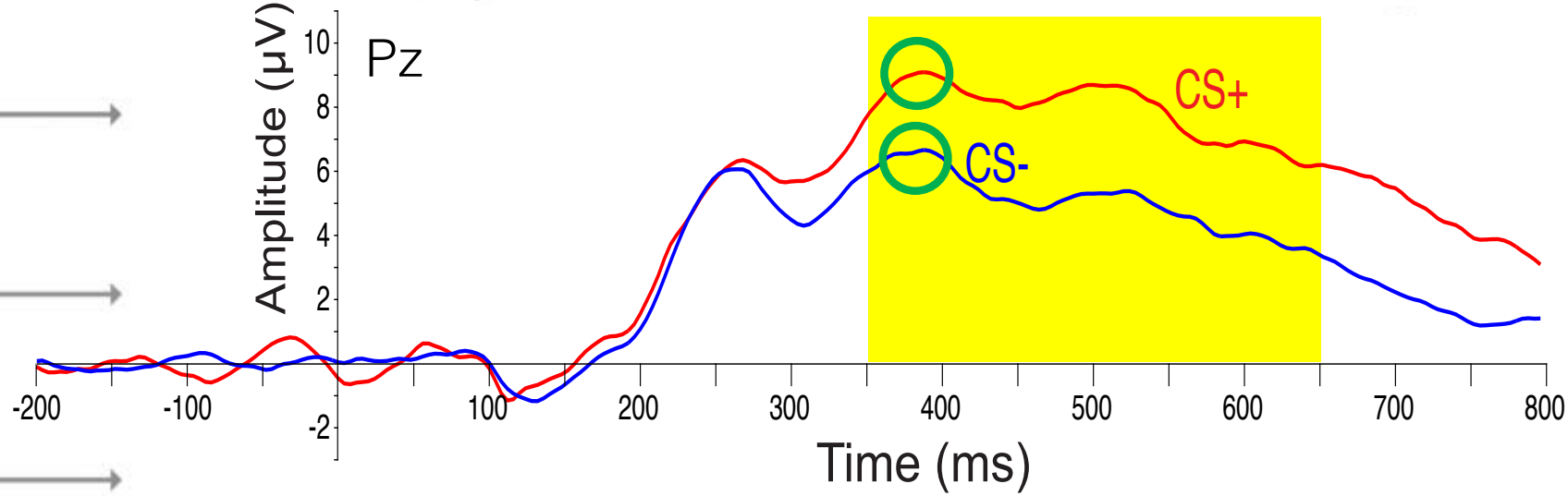
for cognitive research in adults

	High-pass cutoff	Low-pass cutoff
Don't worry	≤ 0.1 Hz	≥ 20 Hz
Worry a little	0.1-0.5 Hz	10-20 Hz
Worry a lot*	> 0.5 Hz	< 10 Hz

*Especially when slope is > 12 dB/octave



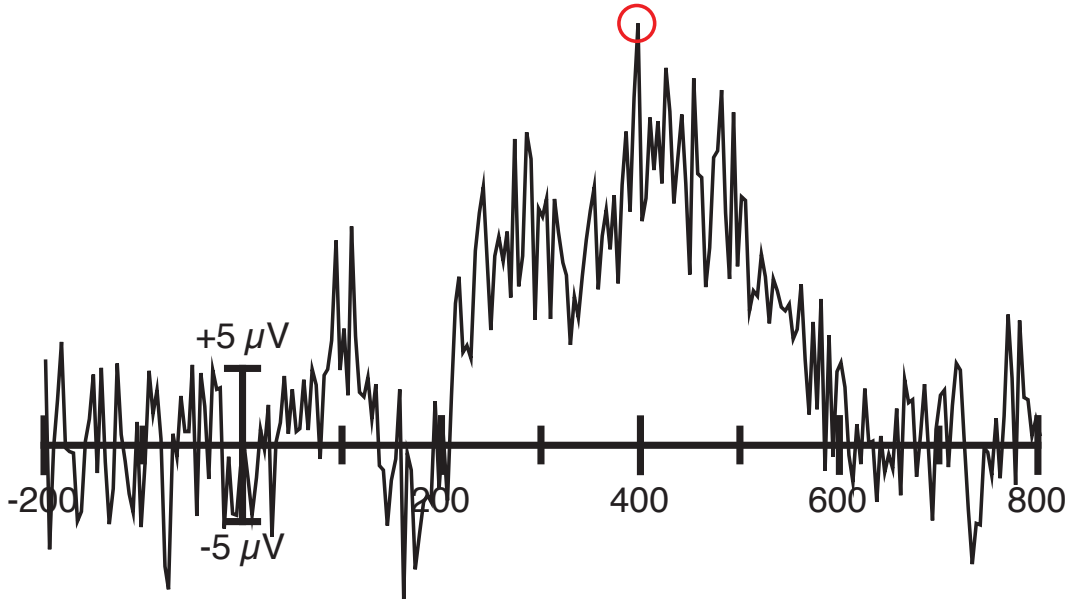
The LPP was measured as the mean amplitude at the Pz electrode site in the time window between 350–650 ms (Liu et al., 2012; Weinberg, Hilgard, Bartholow, & Hajcak, 2012).

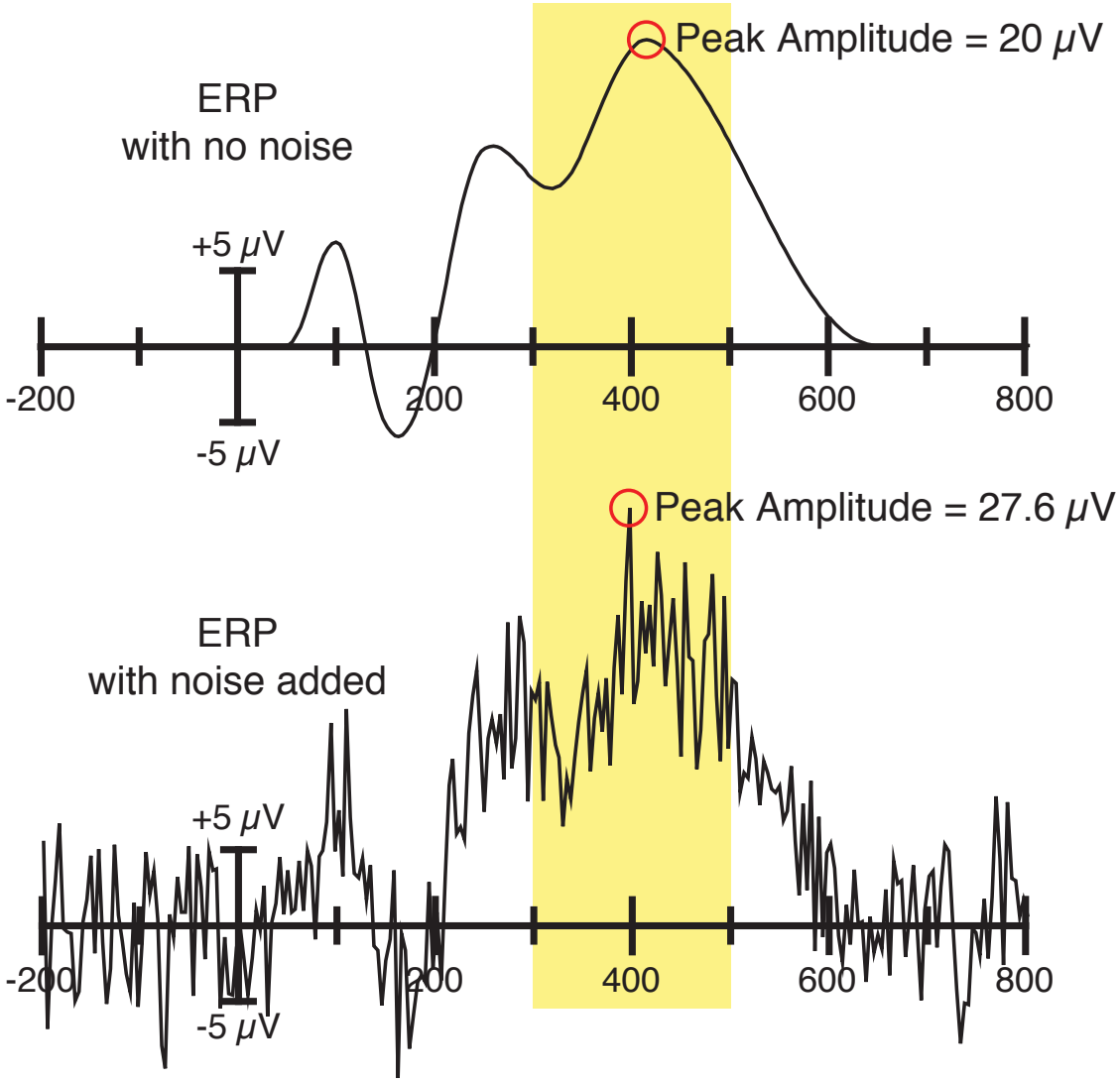


Mean amplitude is a common way of quantifying the amplitude of an ERP component.

Another common approach is to find the peak voltage in each condition.

Peaks are easily distorted by high-frequency noise,
which reduces statistical power





Peak amplitude is biased by the noise level. The noisier the data, the bigger the peak.

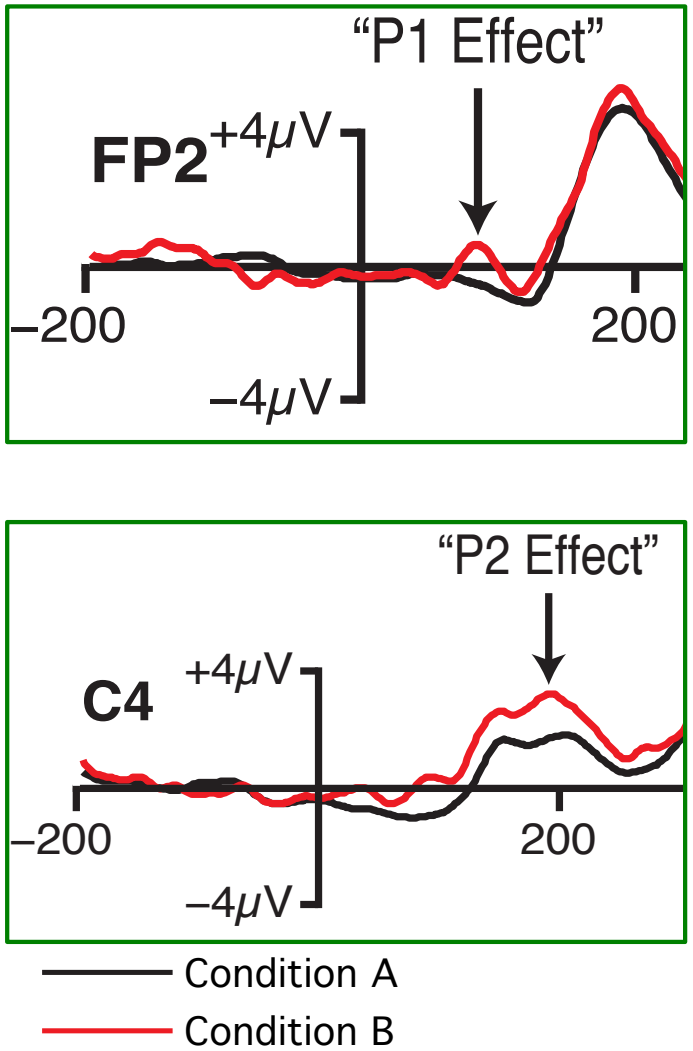
It is not valid to compare peak amplitudes in two groups or conditions where the noise level differs.

Mean amplitude is not biased by the noise level. Noise is equally likely to make the mean amplitude larger or smaller.

The most common statistical problem in ERP studies is an inflation of the false positive rate.

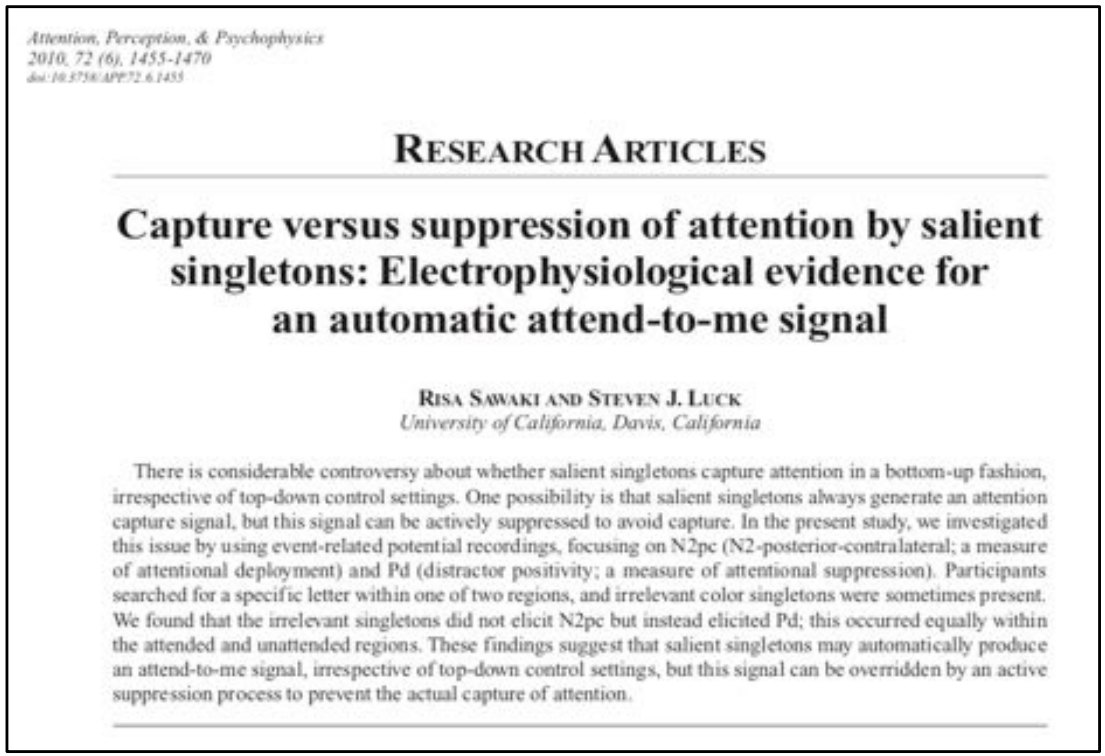
This problem arises when researchers look at the data and use the observed effects to decide on what time windows and electrode sites to use in their analyses.

When they do that, they can almost always find a significant effect that's just a result of noise.



Luck & Gaspelin (2017)

In this study, we couldn't use previous research to make an a priori decision about how to analyze the P_D effect. So we just used the same electrode sites for the P_D as we used for the N2pc, and we picked a time window that seemed reasonable.



Attention, Perception, & Psychophysics
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RESEARCH ARTICLES

Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal

RISA SAWAKI AND STEVEN J. LUCK
University of California, Davis, California

There is considerable controversy about whether salient singletons capture attention in a bottom-up fashion, irrespective of top-down control settings. One possibility is that salient singletons always generate an attention capture signal, but this signal can be actively suppressed to avoid capture. In the present study, we investigated this issue by using event-related potential recordings, focusing on N2pc (N2-posterior-contralateral; a measure of attentional deployment) and Pd (distractor positivity; a measure of attentional suppression). Participants searched for a specific letter within one of two regions, and irrelevant color singletons were sometimes present. We found that the irrelevant singletons did not elicit N2pc but instead elicited Pd; this occurred equally within the attended and unattended regions. These findings suggest that salient singletons may automatically produce an attend-to-me signal, irrespective of top-down control settings, but this signal can be overridden by an active suppression process to prevent the actual capture of attention.

As a result, it was important that we replicated the results using the same electrode sites and time window.

If a study doesn't have a good justification for the electrode sites and time window, you should be cautious about the results until you see a replication.

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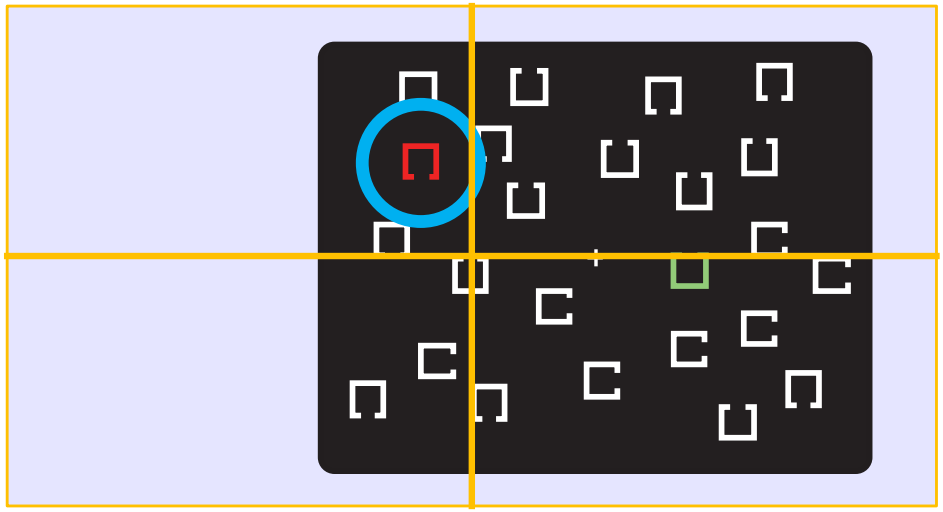
How to Evaluate an ERP Study

Design & Interpretation Problems (Part 1)

Physical Stimulus Confounds



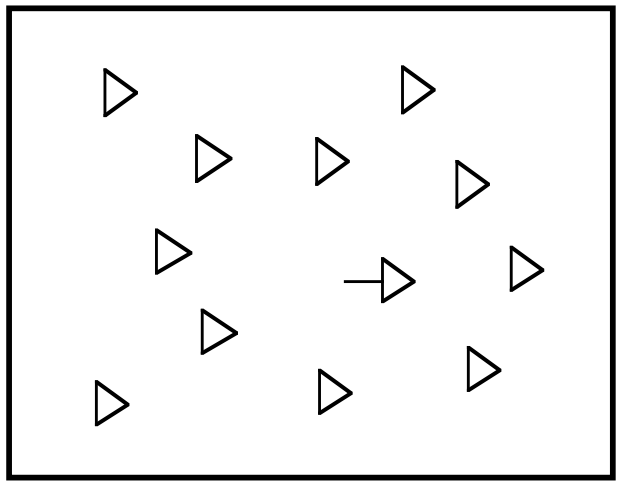
If the target was more likely to be on the left side than on the right side, subjects might shift their gaze to the left side of the display before the display appears.

As a result, most of the display would be in the right visual field, which would give you a lateralized ERP.

It would be difficult to tell the difference between this sensory lateralization and the N2pc.

The problem with this design is that the contralateral and ipsilateral sides of the display were physically different.

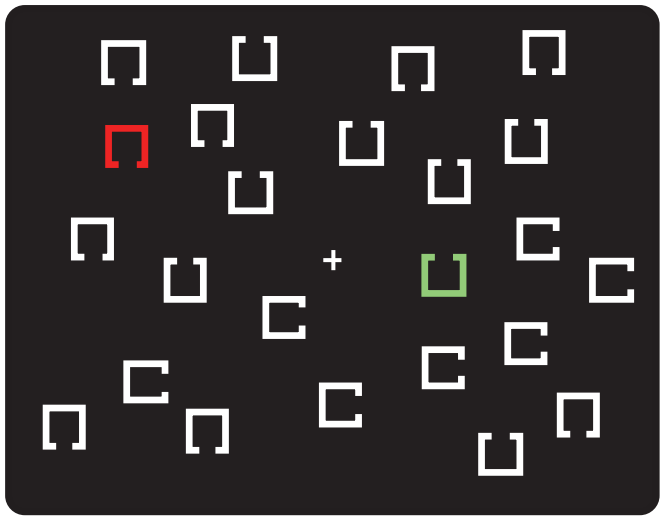
The contralateral side had a horizontal line, but the ipsilateral side did not.



Luck & Hillyard (1990)

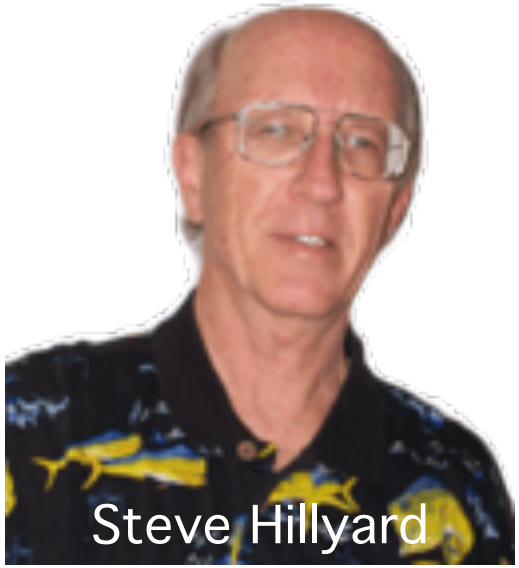
This design allows us to compare the same physical stimuli while varying whether the subject is attending to the left side or the right side.

For this array, subjects will shift their attention to the left side in the attend-red trial blocks and to the right side in the attend-green blocks. Same stimulus, but different directions of attention.



The Hillyard Principle

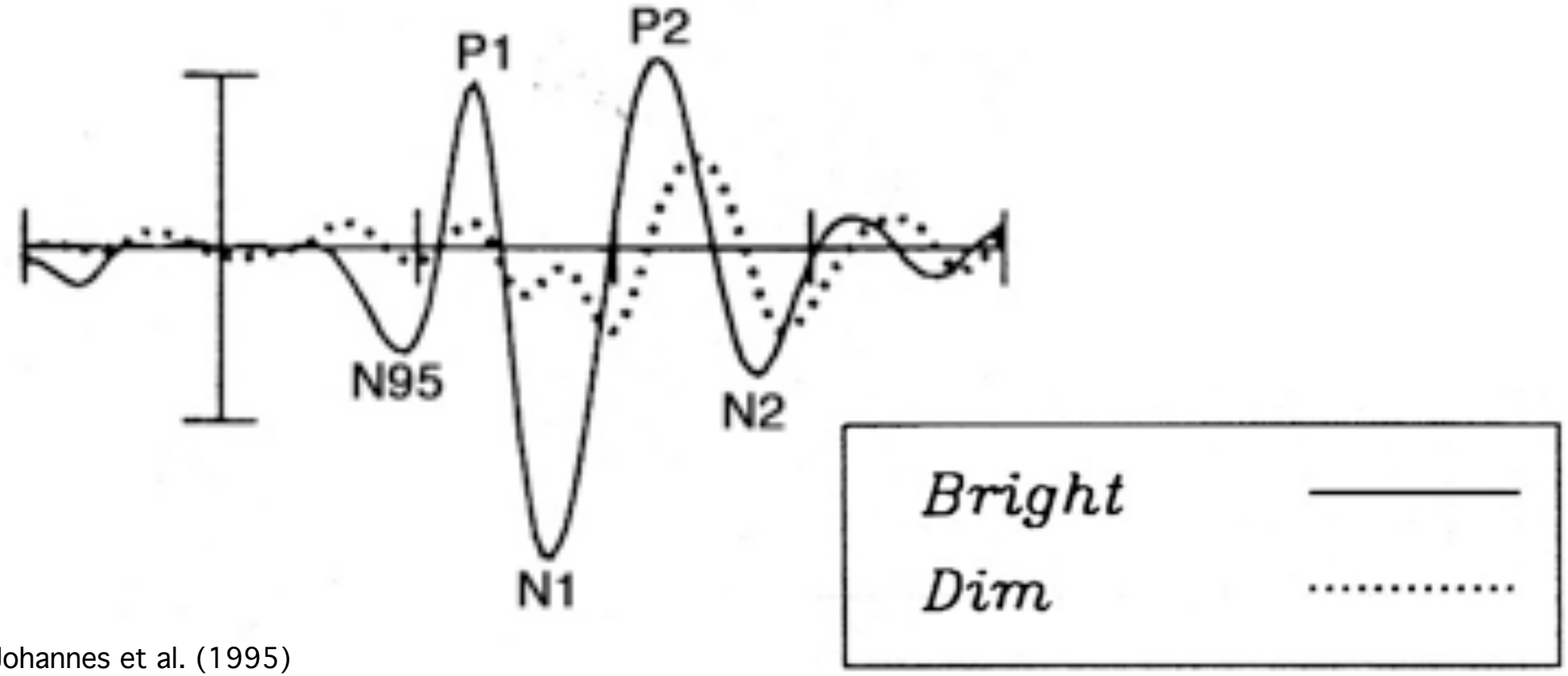
To avoid physical stimulus confounds, use identical stimuli across conditions and vary only the task instructions.


Steve Hillyard

CAT

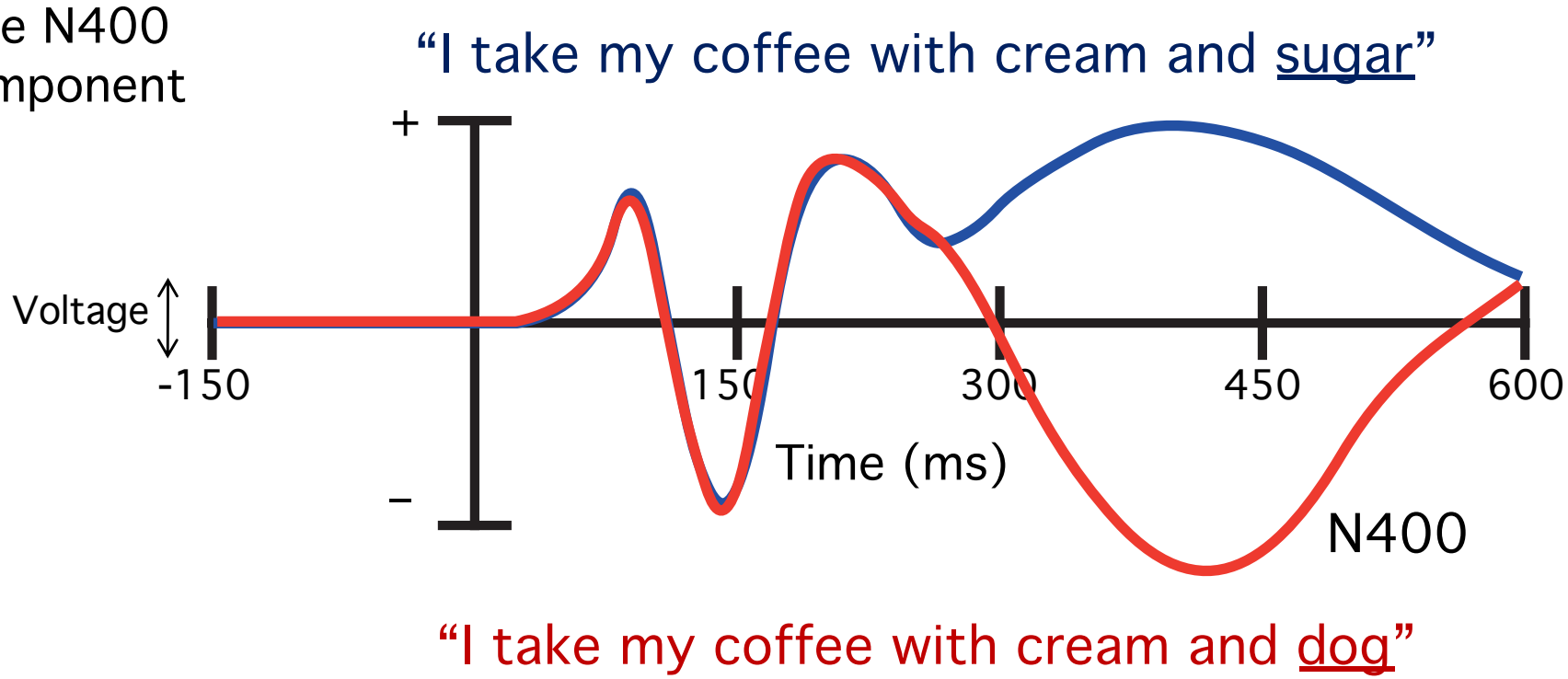
Not every study can follow the Hillyard Principle. For example, language studies usually need to compare physically different words.

The early sensory ERP components are particularly sensitive to small physical stimulus differences, so be particularly concerned about effects within the first 200-300 milliseconds.



Johannes et al. (1995)

The N400 Component



When you read an ERP paper, and they say that they're measuring some particular component, you need to think about whether they might actually be picking up on a different component that represents a very different neurocognitive process.

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How to Evaluate an ERP Study

Design & Interpretation Problems (Part 2)

Many ERP studies involve taking a previous behavioral paradigm and having subjects perform the task while the EEG is recorded. That almost never leads to conclusive findings.

If the researcher does not design the experiment to isolate the component of interest, they probably won't have a very solid conclusion.

There may be differences in the ERPs between the conditions, but it will be difficult to know what ERP component is varying and what it means.

Many ERP studies are “fishing expeditions”. The researchers just want to see what happens when they use a given task or manipulation. But if they don’t have specific predictions, then they’re probably going to look at the data before they decide what time windows and electrode sites to use. That often leads to bogus but statistically significant effects.

Psychophysiology, *31* (1994), 291–308. Cambridge University Press. Printed in the USA.

Electrophysiological correlates of feature analysis during visual search

STEVEN J. LUCK AND STEVEN A. HILLYARD
Department of Neurosciences, University of California-San Diego, La Jolla

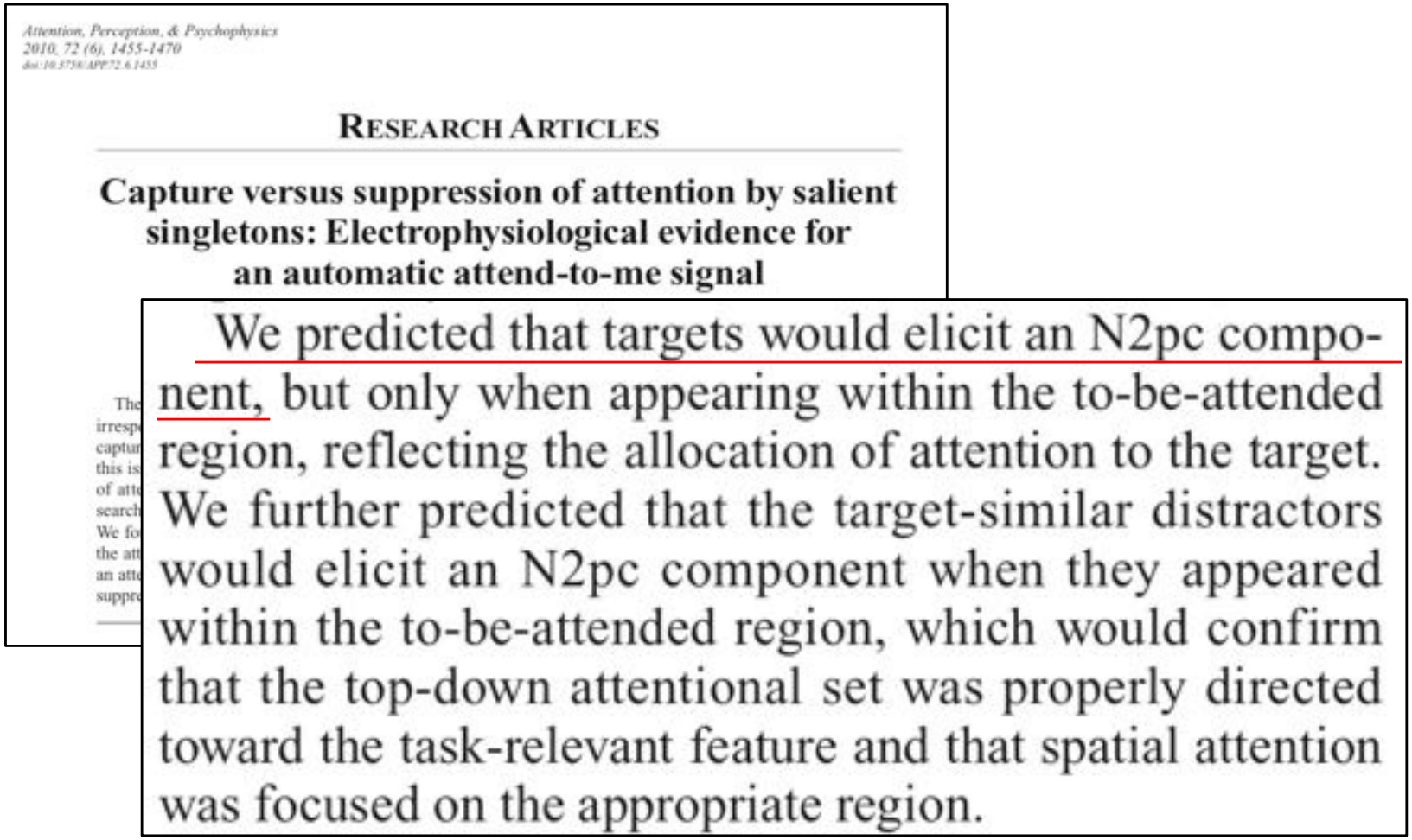
Abstract

Event-related brain potentials (ERPs) were recorded from normal young adults during visual search tasks in which the stimulus arrays contained either eight identical items (homogeneous arrays) or seven identical items and one deviant item (pop-out arrays). Four experiments were conducted in which different classes of stimulus arrays were designated targets and the remaining stimulus arrays were designated nontargets. In Experiments 1 and 2, both target and nontarget pop-out stimuli elicited an enhanced anterior N2 wave and a contralaterally larger posterior P1 wave, but Experiments 3 and 4 demonstrated that these components do not reflect fully automatic pop-out detection processes. In all four experiments, target pop-outs elicited enlarged anterior P2, posterior N2, occipital P3, and parietal P3 waves. The target-elicited posterior N2 wave contained a contralateral subcomponent (N2pc) that exhibited a focus over occipital cortex in maps of current source density. The overall pattern of results was consistent with guided search models in which preattentive stimulus information is used to guide attention to task-relevant stimuli.

Fishing expeditions aren't always a bad thing. The first study in any area is usually a fishing expedition.

If a study is a fishing expedition, the results must be replicated before they can be believed.

Example of predictions (Introduction to Experiment 1)



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RESEARCH ARTICLES

Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal

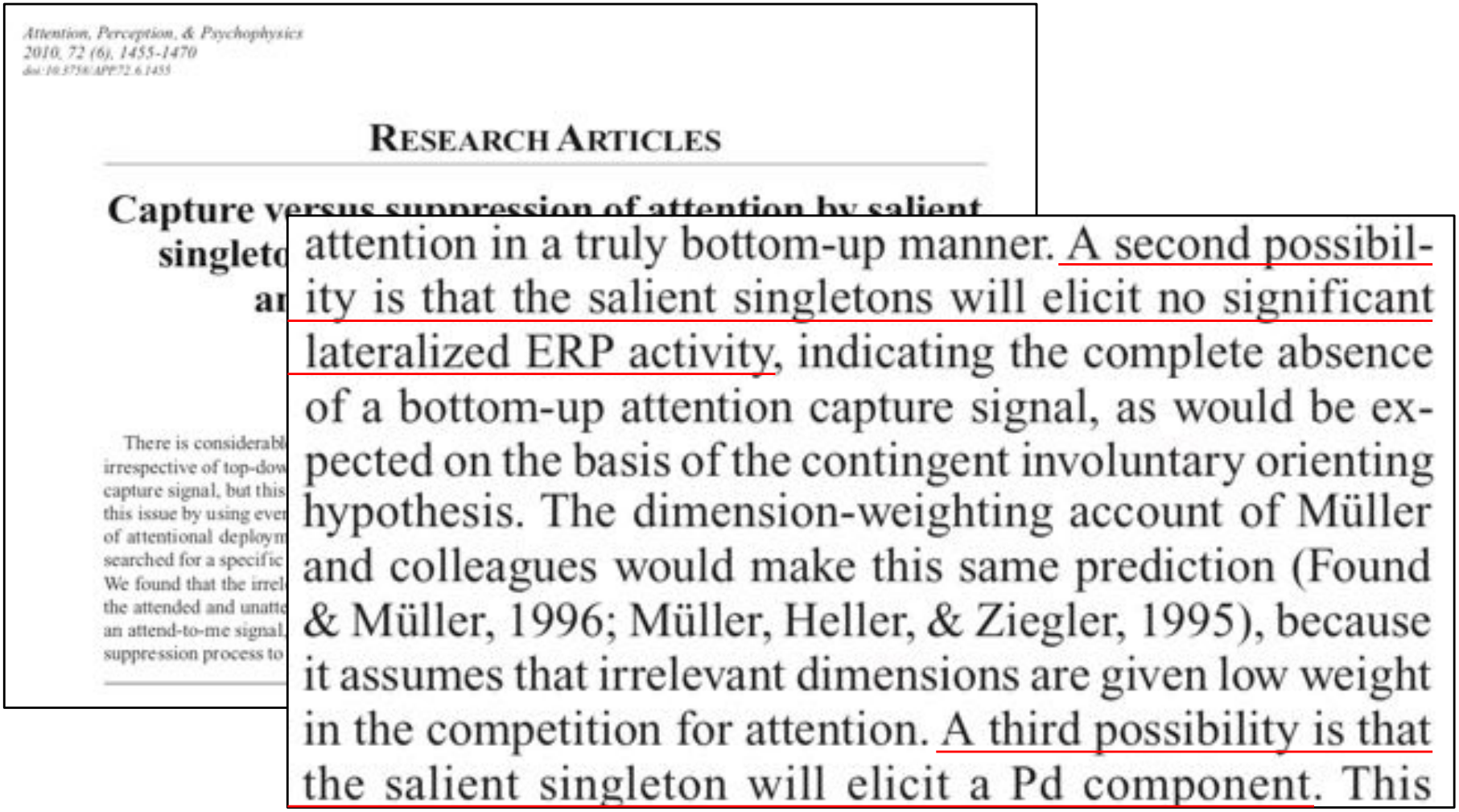
We predicted that targets would elicit an N2pc component, but only when appearing within the to-be-attended region, reflecting the allocation of attention to the target. We further predicted that the target-similar distractors would elicit an N2pc component when they appeared within the to-be-attended region, which would confirm that the top-down attentional set was properly directed toward the task-relevant feature and that spatial attention was focused on the appropriate region.

Example of predictions (Introduction to Experiment 1)

Attention, Perception, & Psychophysics
2010, 72 (6), 1455-1470
doi:10.3758/APP.72.6.1455

We anticipated three possible outcomes for the salient singleton distractor. First, if attention is deployed toward salient distractors in a completely bottom-up fashion, the salient singleton distractor should elicit an N2pc component (as has been found many times when color singletons were targets; see, e.g., Luck & Hillyard, 1994a, 1994b). This N2pc component might be limited to singletons presented within the to-be-attended region if salient singletons capture attention only when they appear within the focus of spatial attention (as is proposed by the modified version of the bottom-up saliency hypothesis). In addition, if the salient distractor elicits an N2pc component, the du-

Example of predictions (Introduction to Experiment 1)



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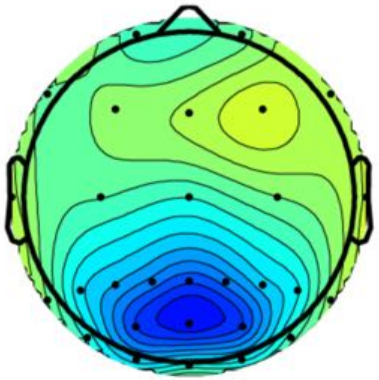
attention in a truly bottom-up manner. A second possibility is that the salient singletons will elicit no significant lateralized ERP activity, indicating the complete absence of a bottom-up attention capture signal, as would be expected on the basis of the contingent involuntary orienting hypothesis. The dimension-weighting account of Müller and colleagues would make this same prediction (Found & Müller, 1996; Müller, Heller, & Ziegler, 1995), because it assumes that irrelevant dimensions are given low weight in the competition for attention. A third possibility is that the salient singleton will elicit a Pd component. This

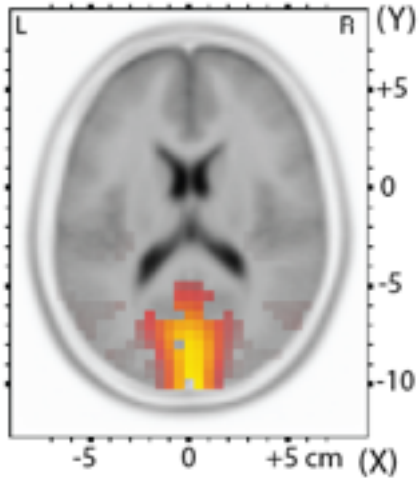
It's perfectly fine for a paper to include information about the plausible neural generator sources of their effects.

They just need to be careful to say that the data are CONSISTENT with a particular generator source rather than that the data DEMONSTRATE that a particular part of the brain is involved.

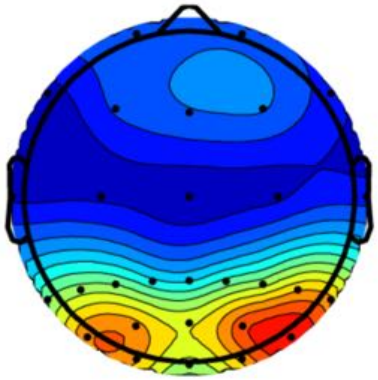
C1 Scalp Distribution



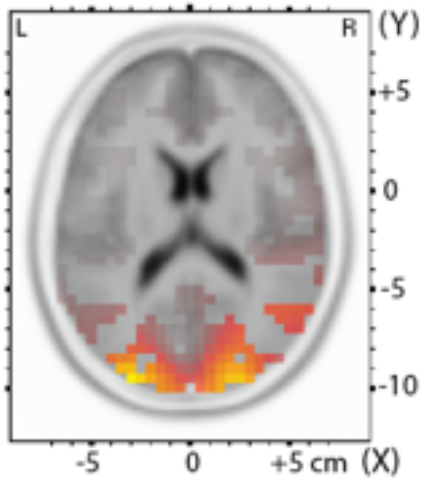
sLORETA Estimate



P1 Scalp Distribution

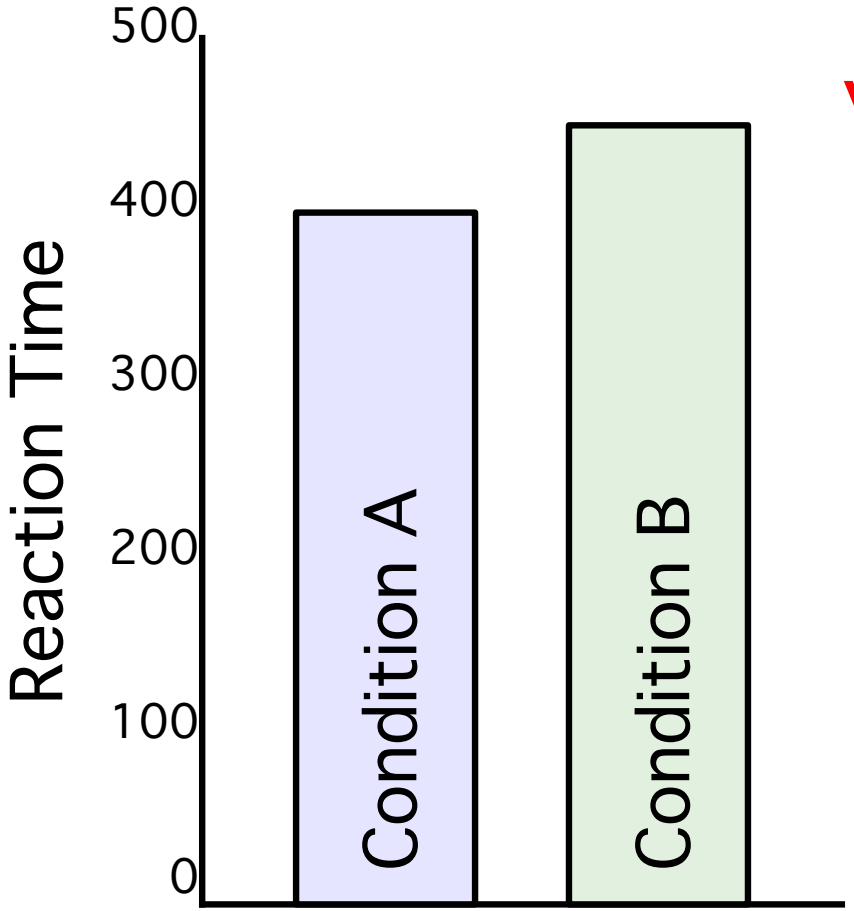


sLORETA Estimate

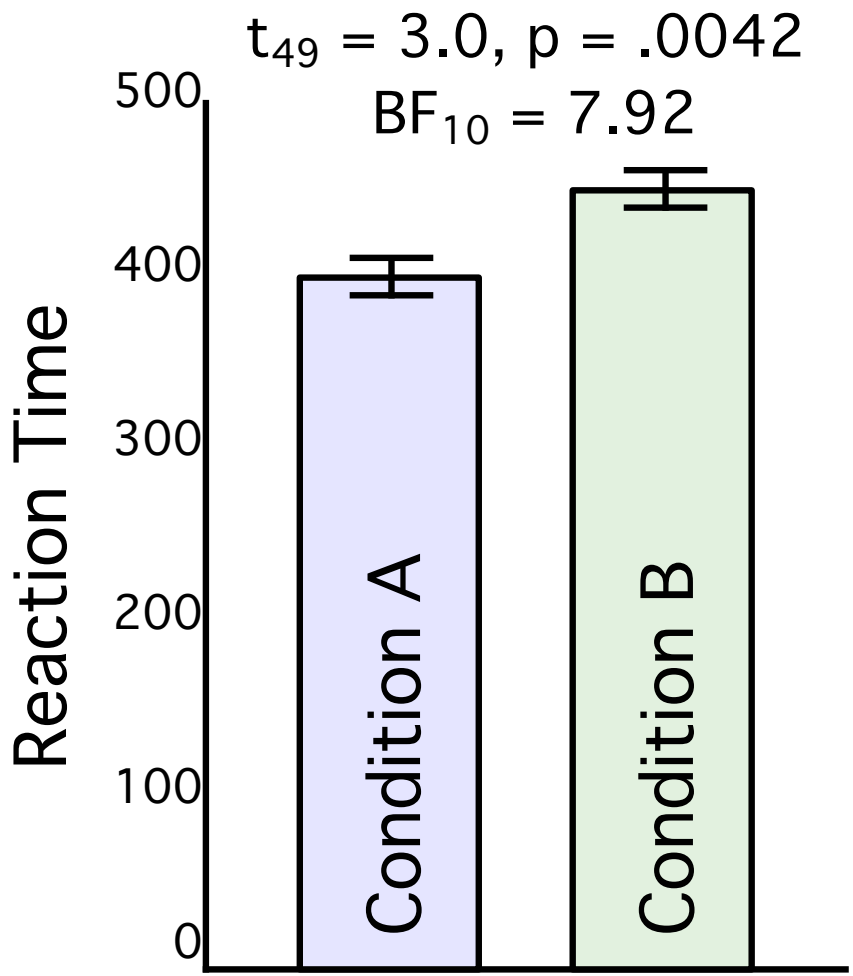


Miller, C. E., Luck, S. J., & Shapiro, K. L. (2015). Electrophysiological measurement of the effect of inter-stimulus competition on early cortical stages of human vision. Neuroimage, 105, 229–237.

If you read a paper saying that mean reaction time was 50 milliseconds greater in one condition than in another, would you believe it if they provided nothing but the means?



versus



Top Ten Problems in ERP Studies

Data problems

1. Noisy data
2. Baseline problems
3. Blinks or eye movements

Analysis problems

4. Inappropriate filtering
5. Inappropriate amplitude or latency measures
6. Statistical problems

Design and interpretation problems

7. Physical stimulus confounds
8. Failure to isolate the component of interest
9. Lack of specific predictions
10. Overreliance on source localization