When more is more: Multisensory stimulation enhances performance improvement by temporal expectations

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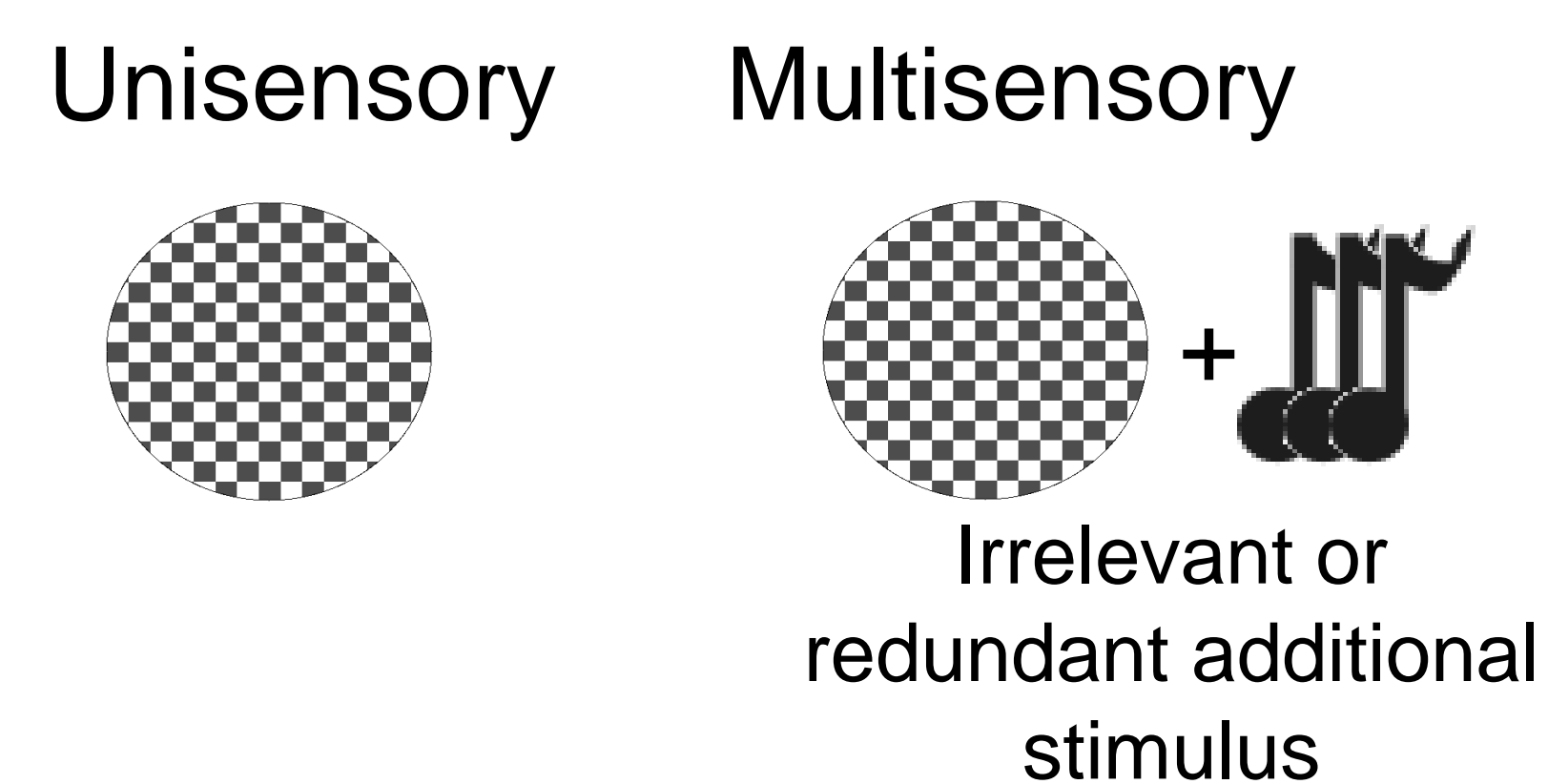[3]Center for Behavioral Brain Research, Magdeburg, Germany

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Background

- natural environment is continuous stream of multisensory information
- information integration to generate reliable mental model of our world
- two optimization mechanisms to integrate incoming information
  → multisensory interplay (MSI) and temporal expectations (TE)
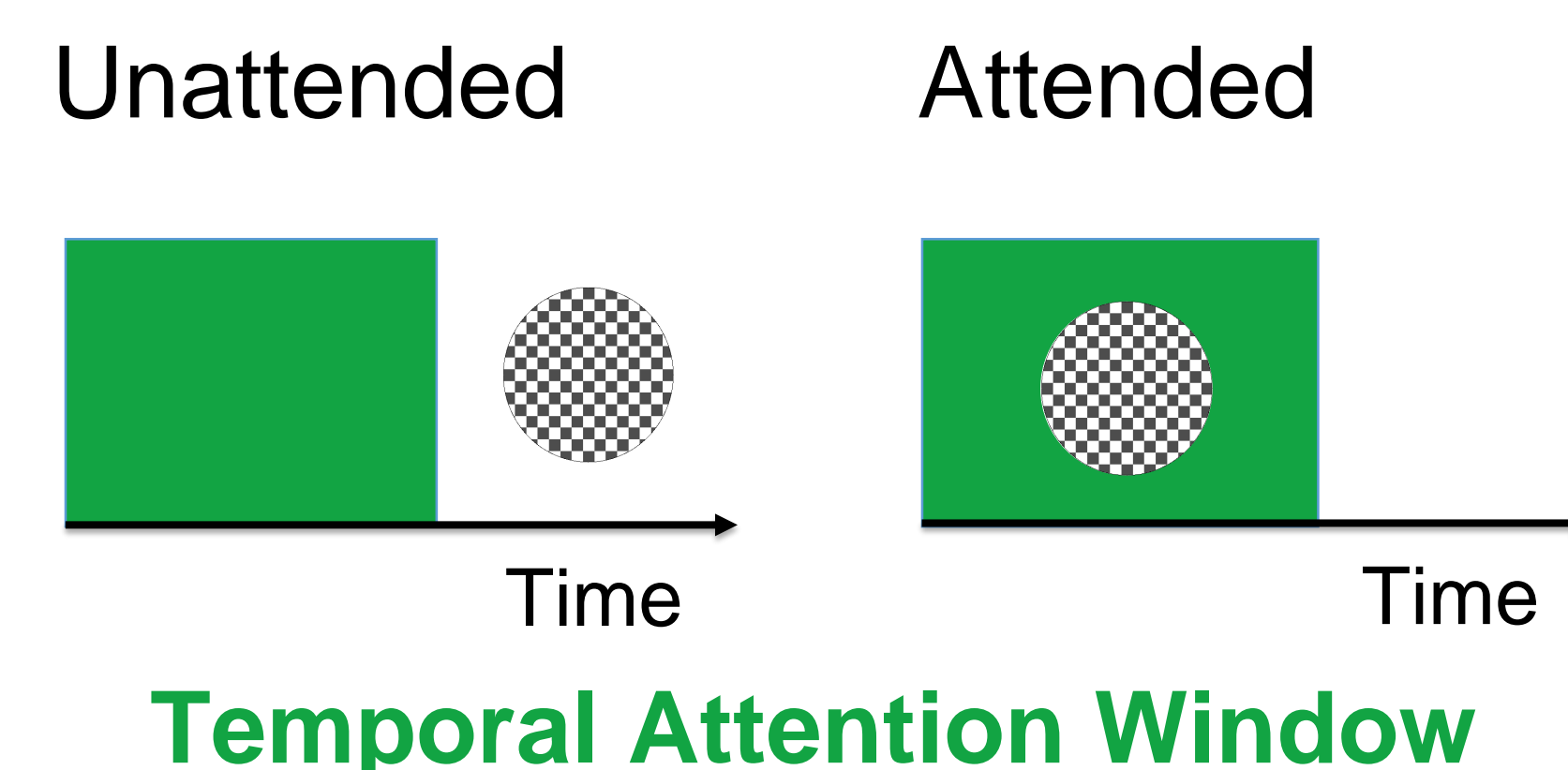- **However, how these mechanisms interact is currently unknown**

Multisensory Interplay (MSI) [1,2,3,4]

Unisensory   Multisensory

Irrelevant or redundant additional stimulus

Temporal Expectations (TE) [5]

Unattended   Attended

Time   Time

Temporal Attention Window

Performance (e.g. d-prime)

Unisensory < Multisensory

Unattended < Attended

Methods

2 Examples for one trial: unisensory and multisensory sequence

Early target

ITI
200 – 400 ms

Stimulus sequence (11 stimuli)
Stimulus: 100 ms, Gap ISI: 100 ms

Frequency judgment
max. 1500 ms

Manipulation of TE through ratio of early/late targets within run

'Expected Early' Run (85 % Early)   'Expected Late' Run (42 % Early)

☐ early target
■ late target

Trials

Manipulation of difficulty/level of noise (4 experiments, N = 120)

Spatial uncertainty

Target uncertainty

A
V
AV

AV(A)
AV(V)
AV

Low: Speaker   *High: headphones*   *Low: mixed sequences*   *High: only multisensory sequences*

Interaction of MSI & TE? (n = 120)
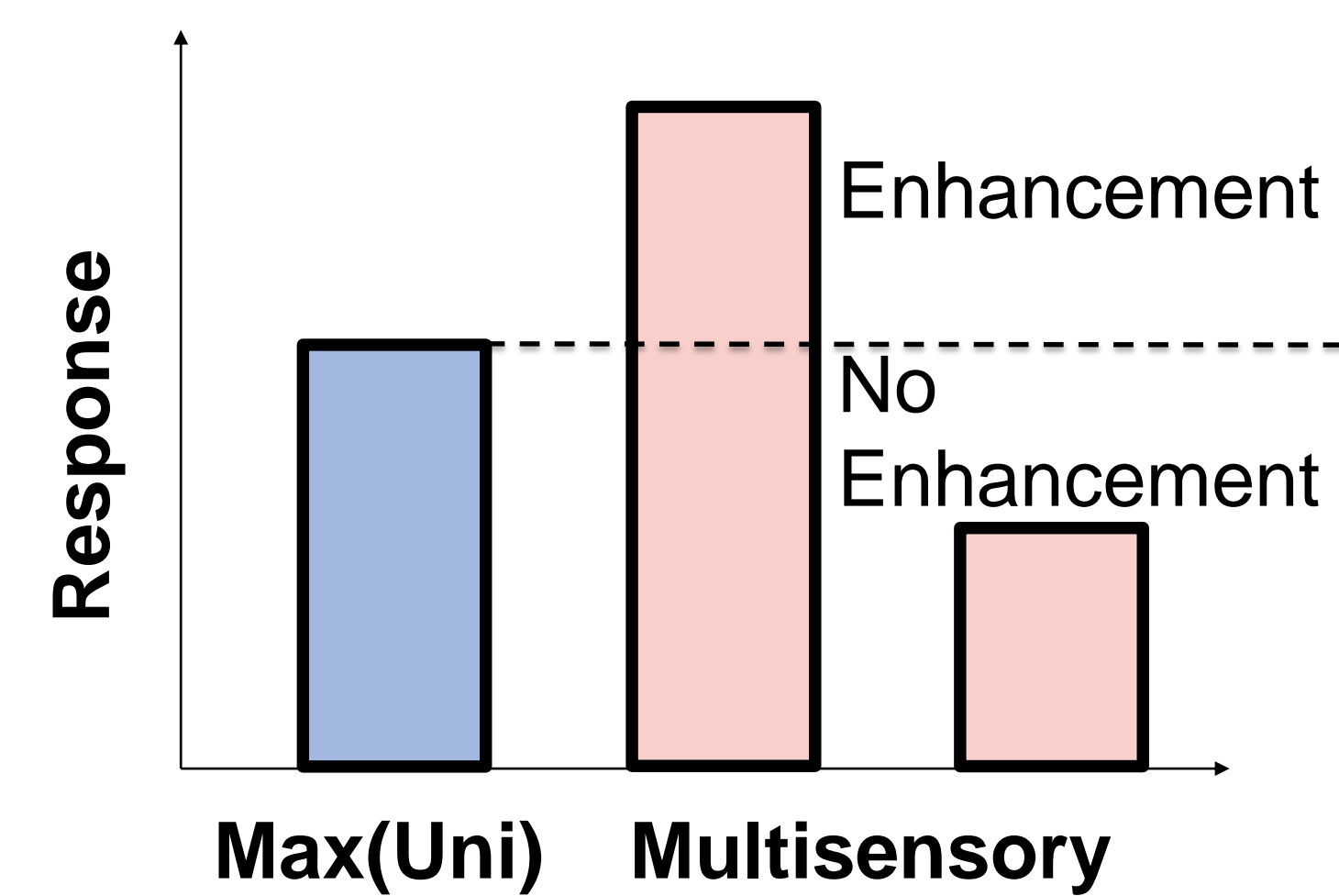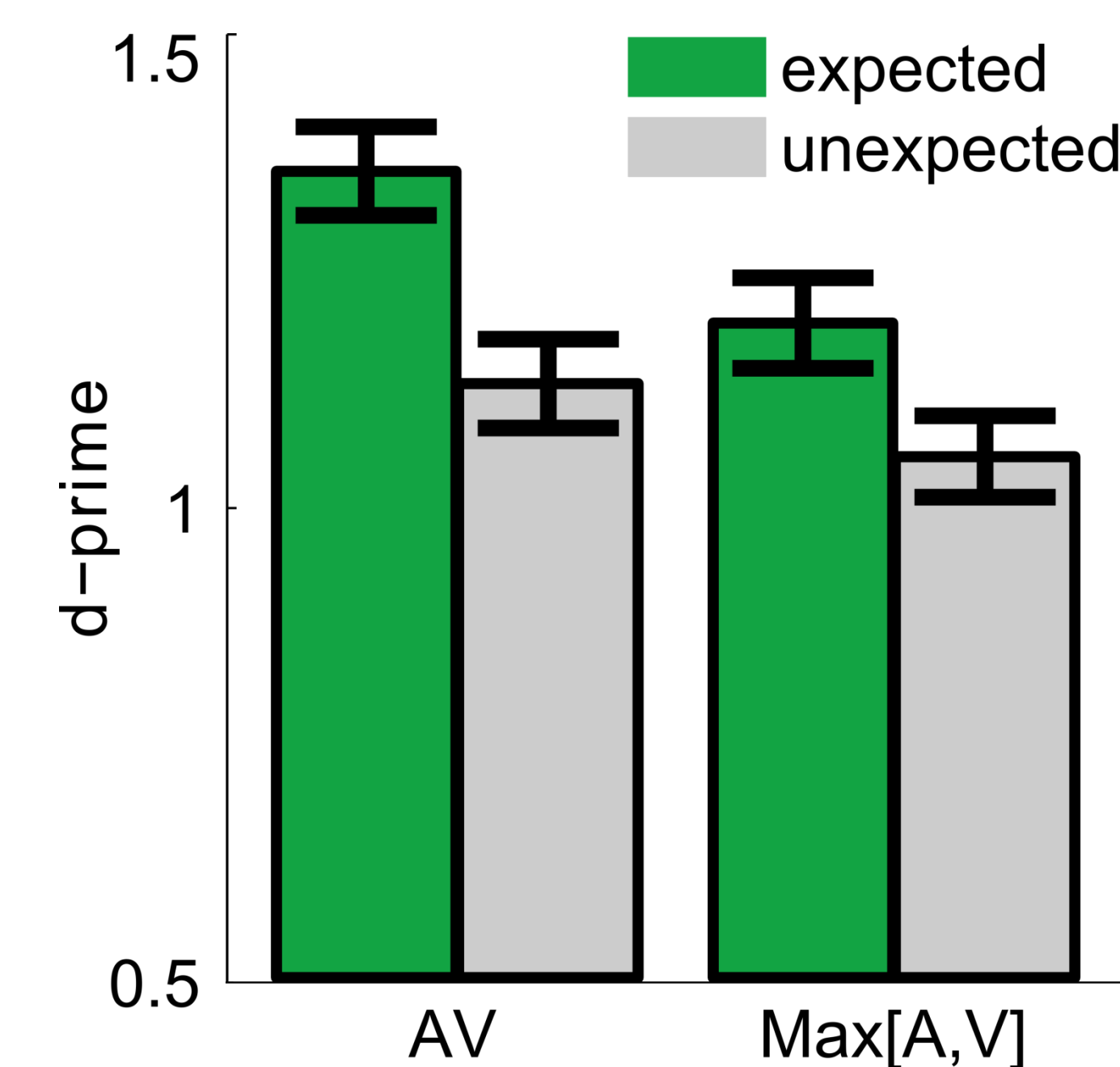
Quantifying MSI

- 2 task relevant modalities: A and V
- take unisensory maximum (max. criterion)

Response

Enhancement
No Enhancement

Max(Uni)   **Multisensory**

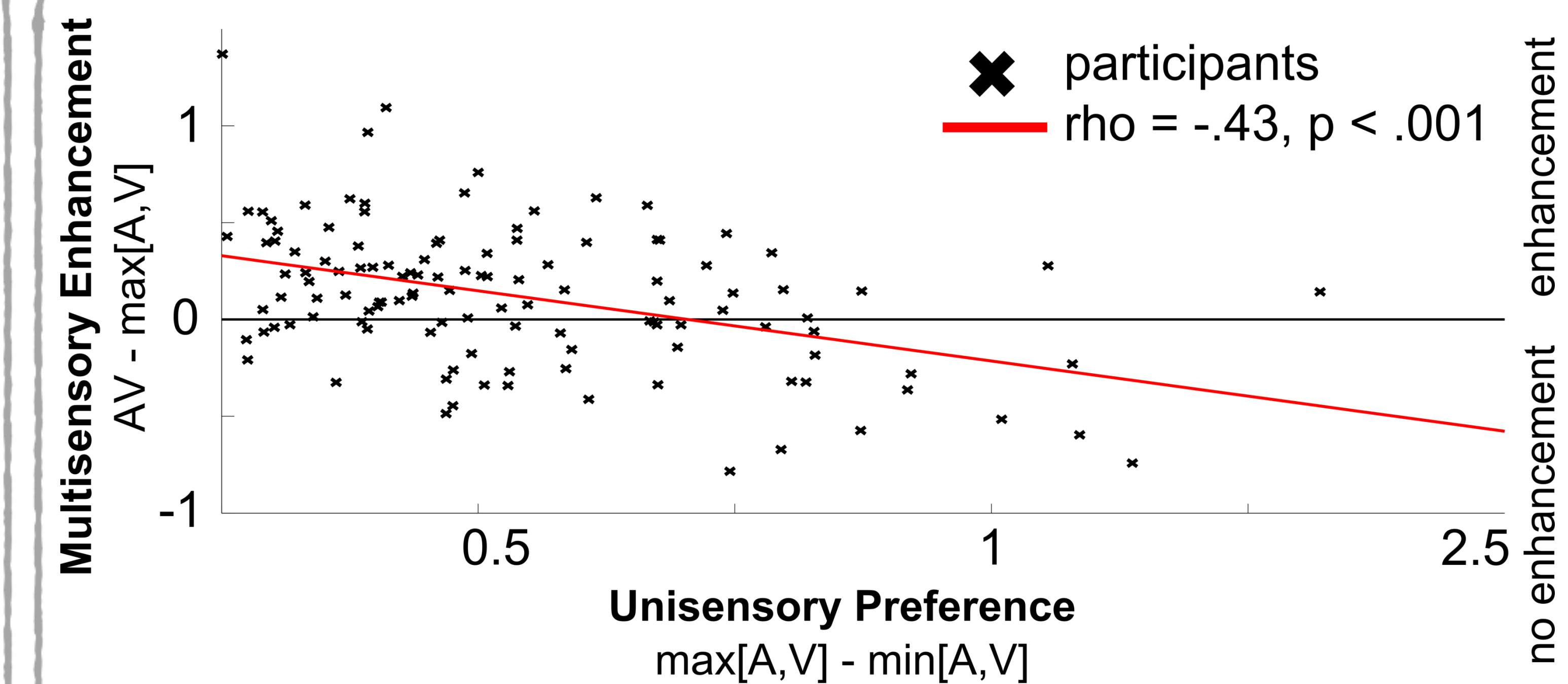### Results MSI & TE

d-prime

■ expected
■ unexpected

AV   Max[A,V]

Multisensory performance enhancement interacts with perfomance enhancement by temporal expectation ($F_{(1,116)} = 4.246$, $p = .042$).
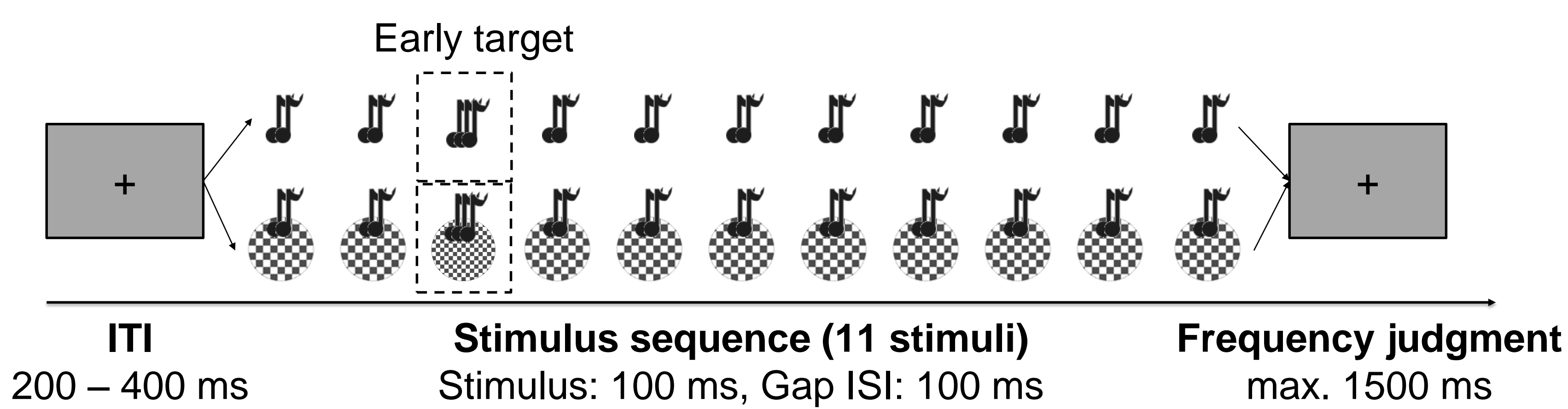
Trial-by-trial extraction of temporal information? (n = 120)

Quantifying trial-by-trial performance

Match vs. mismatch between target expectations in current (N) and previous trial (N-1)

N-1 Mismatch   **N-1 Match**

☐ Unexpected (early) target
■ Expected (late) target

Trials

Results trial-by-trial TE

d-prime

■ n-1 match
■ n-1 mismatch

AV   Max[A,V]

Benefit of multisensory interplay for extraction of temporal regularities is already present on a trial by trial level. Whenever successive trials match in their expectation level, performance increases for multisensory stimuli ($F_{(1,116)} = 5.047$, $p = .027$).

References

1. **Driver J, Noesselt T. (2008).** „Multisensory interplay reveals crossmodal influences on 'sensory-specific' brain regions, neural responses, and judgments." Neuron. 57(1):11-23.
2. **Noesselt T, Tyll S, Boehler CN, Budinger E, Heinze HJ, Driver J. (2010).** „Sound-induced enhancement of low-intensity vision: multisensory influences on human sensory-specific cortices and thalamic bodies relate to perceptual enhancement of visual detection sensitivity." J Neurosci. 30(41):13609-23.
3. **Van der Burg E, Olivers CN, Bronkhorst AW, Theeuwes J. (2008).** „Pip and pop: nonspatial auditory signals improve visual search." J Exp Psychol Hum Percept Perform. 34(5):1053-65.
4. **Meredith MA, Stein BE (1983).** "Interactions among converging sensory inputs in the superior colliculus". Science 221 (4608): 389–91.
5. **Nobre, A. C. K., & Rohenkohl, G. (2014).** "Time for the fourth dimension in attention." In The Oxford handbook of attention.

Prediction of MSI? (n = 120)

Multisensory Enhancement
AV - max[A,V]

enhancement
no enhancement

✖ participants
— rho = -.43, p < .001

Unisensory Preference
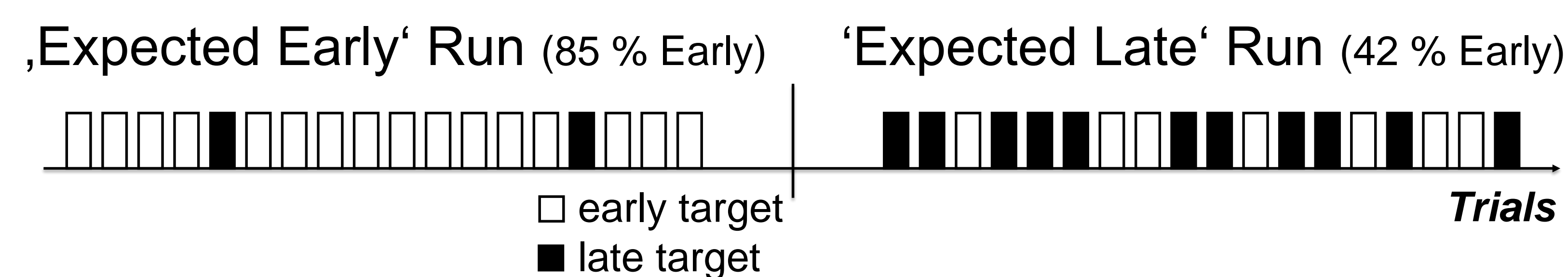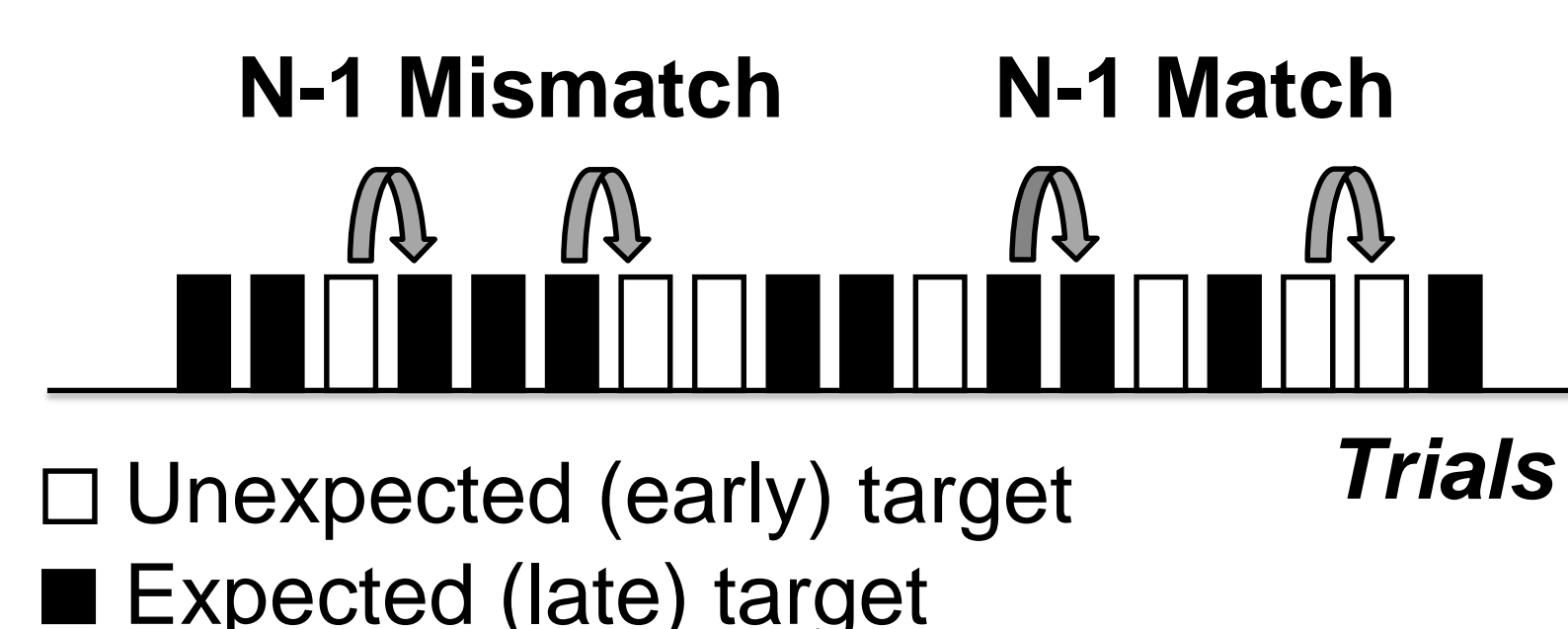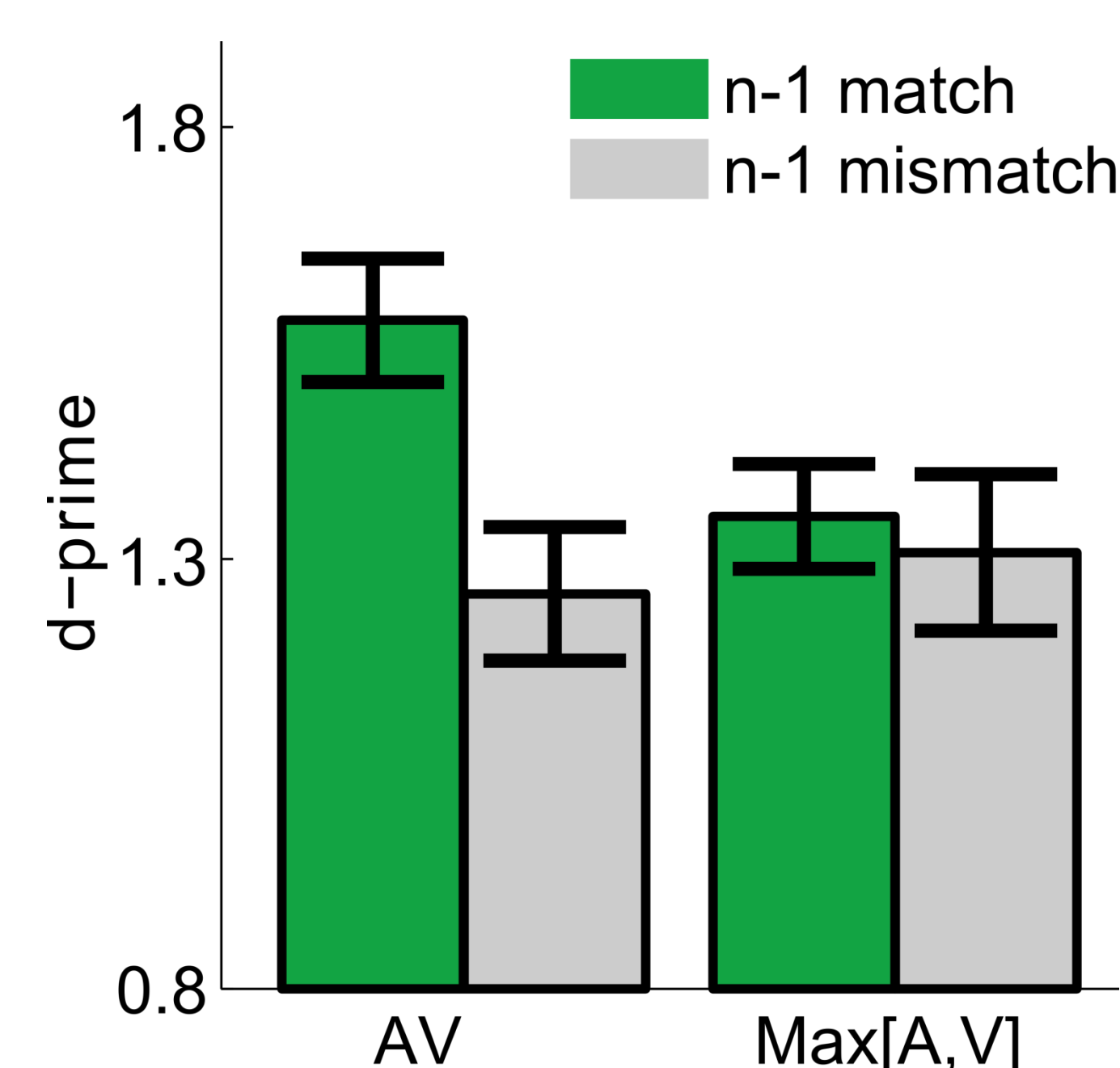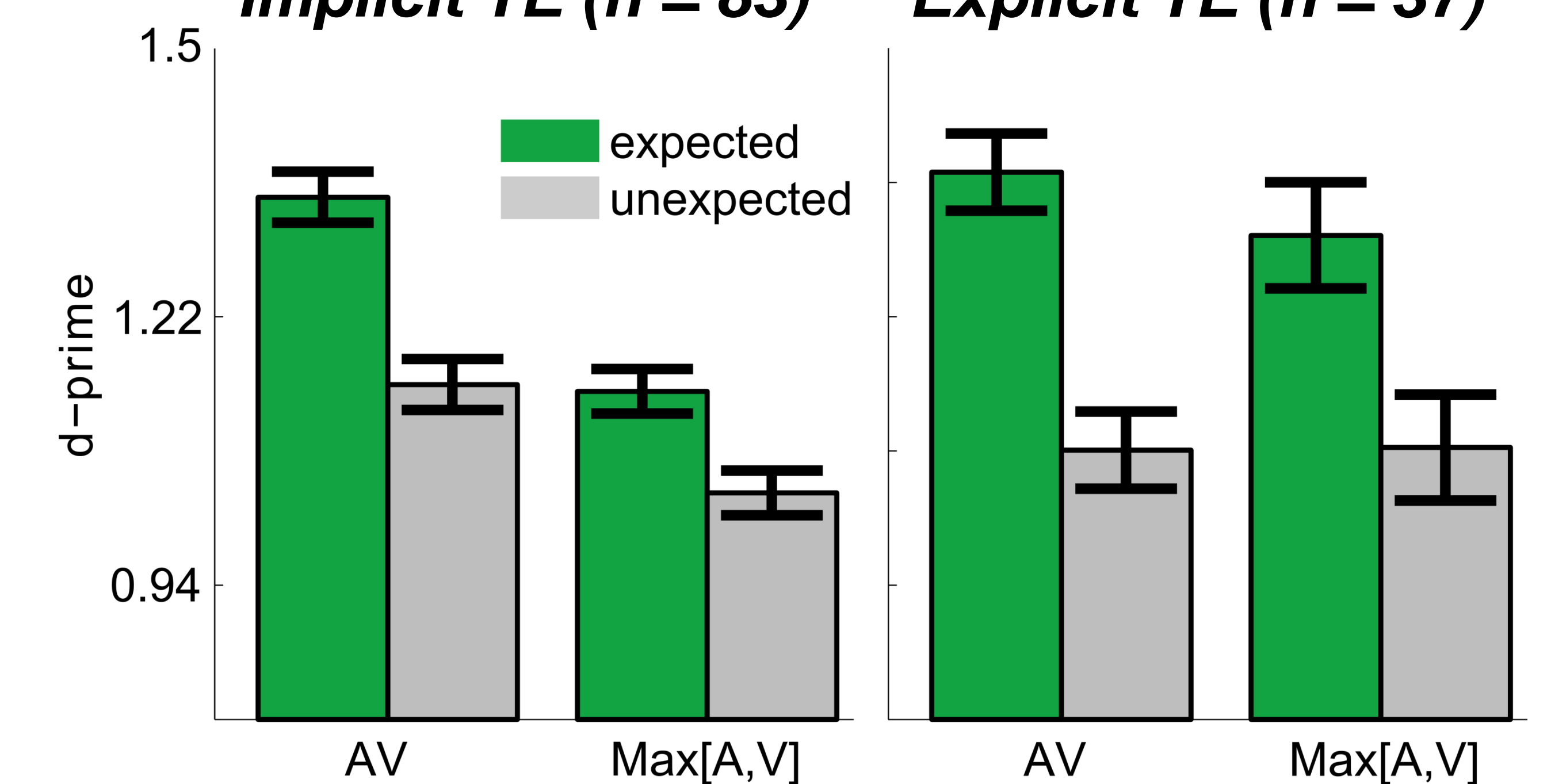max[A,V] - min[A,V]

MSI enhancement is predicted by individual modality-specific preferences (difference between best [e.g. auditory] and worst [e.g. visual] unisensory performance).

Dependency on knowledge type?

Implicit TE (n = 83)   *Explicit TE (n = 37)*

d-prime

■ expected
■ unexpected

AV   Max[A,V]   AV   Max[A,V]

Interaction of TE and MSI does not depend on explicit knowledge of temporal regularities ($F_{(1,118)}=.54$, $p =.816$, BF = .216).

Summary and Conclusion

- *TE effects enhanced for multisensory relative to unisensory stimulation*
- *MSI interacts with TE trial-by-trial.*
- *Effects are independent of explicit temporal knowledge.*

Together, the pattern of results indicates that multisensory stimulation has a protective and enhancing effect on the generation and usage of temporal expectations, highlighting the need for multisensory paradigms in future studies investigating temporal expectations.