To Repeat or Not to Repeat? Redesigning Repeating Auditory Alarms Based on EEG Analysis

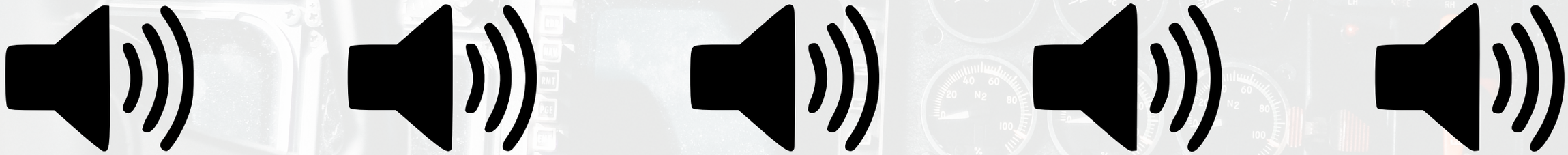
Yi-Chen Lee, **Fu-Yin Cherng**, Jung-Tai King, Wen-Chieh Lin

Dept. of Computer Science, Brain Research Center,

National Chiao Tung University, Taiwan

Better designs to increase usability

[Brewster, 1995; Garzonis 2009;
liljedahl, 2010; Setlur, 2014]



- Monitor contextual information & alert to unusual events
- Alarms will ring **repeatedly** to attract attention

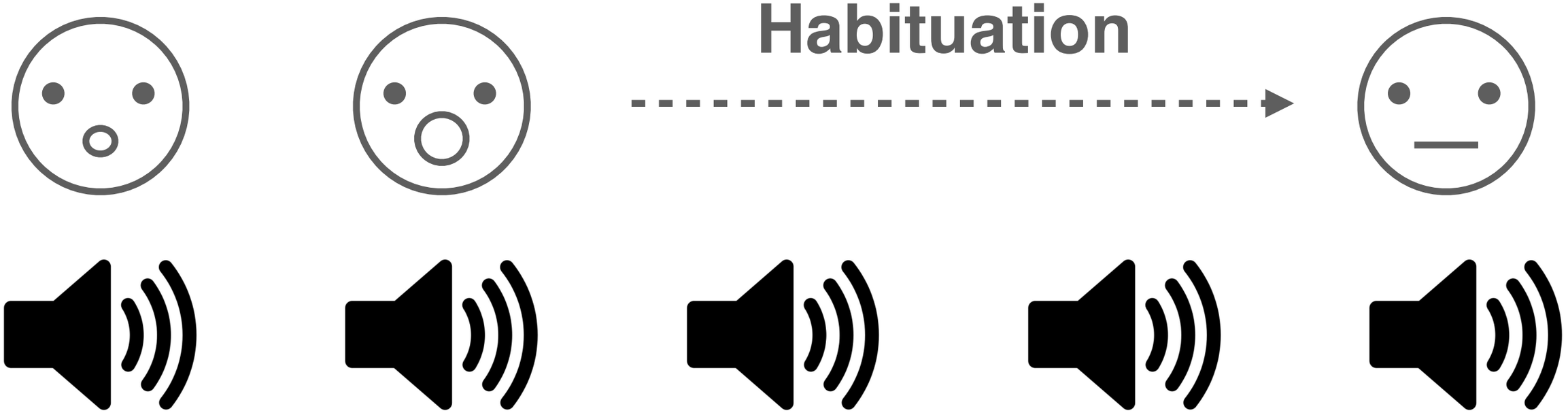
[Patterson, 1990; Edworthy, 2006; Waltrip, 2018]

Photo by Leonel Fernandez on Unsplash

Study an alarm as an **independent** stimulus,
without considering the **repeating situation**

[Bravo-Lillo, 2013, 2014; Anderson, 2015]

Habituation



Repetition **S**uppression

[Sams, 1984; Müller, 2005; Karmer, 2010]

Repetition **S**uppression

Habituation

- Less awareness & can’t attract enough attention
- Dangerous in information-dense environments

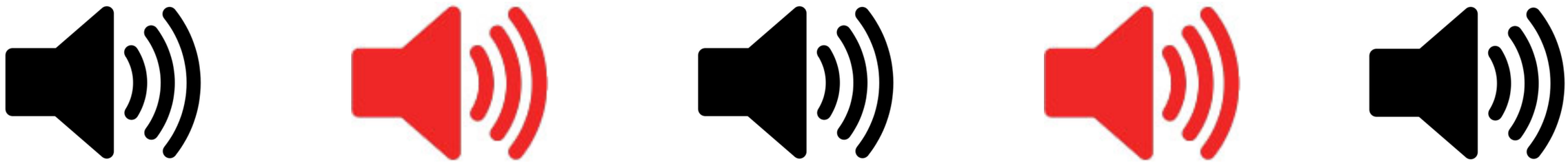
[Patterson, 1990; Edworthy, 2006; Waltrip, 2018]

Goal

To reduce RS,

Goal

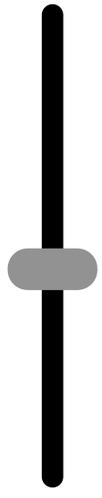
To reduce RS, we propose method of inserting **modulated alarms** into a series of identical ones



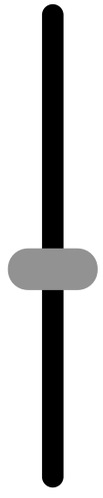
No extra effort to memorize new alarm

Goal

To reduce RS, we propose method of inserting **modulated alarms** into a series of identical ones



Pitch modulation

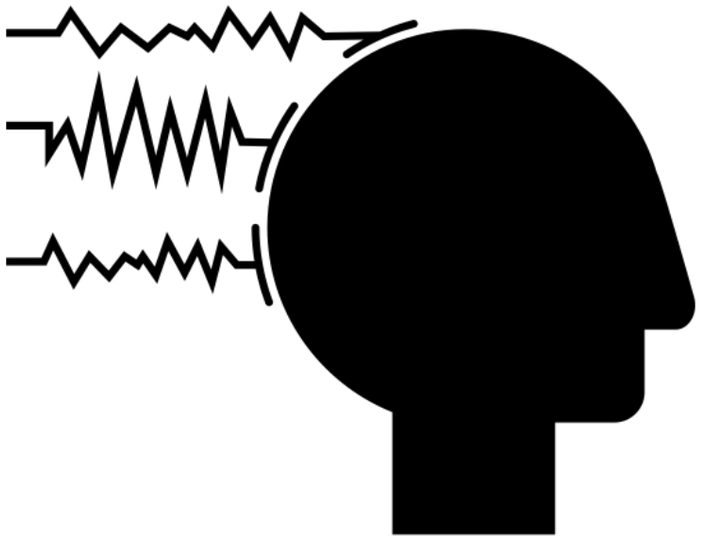


Intensity modulation

Cognitive Measures

Electroencephalography

Conducted **EEG** experiment to examine effects of our modulations on repetition suppression

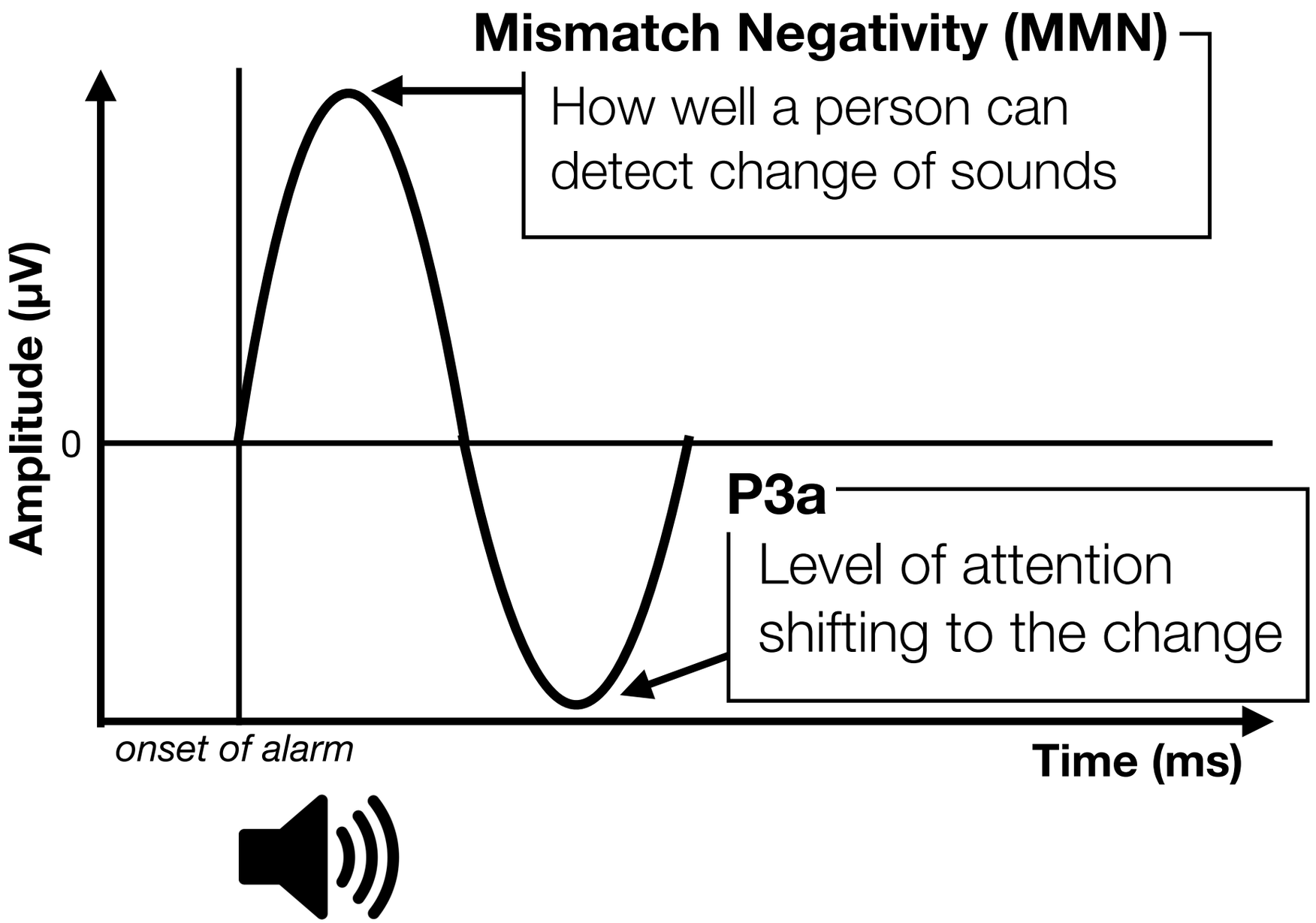


- Direct information to cognitive functions
- Use to study RS

[Sams, 1984; Müller, 2005; Rosburg, 2018]

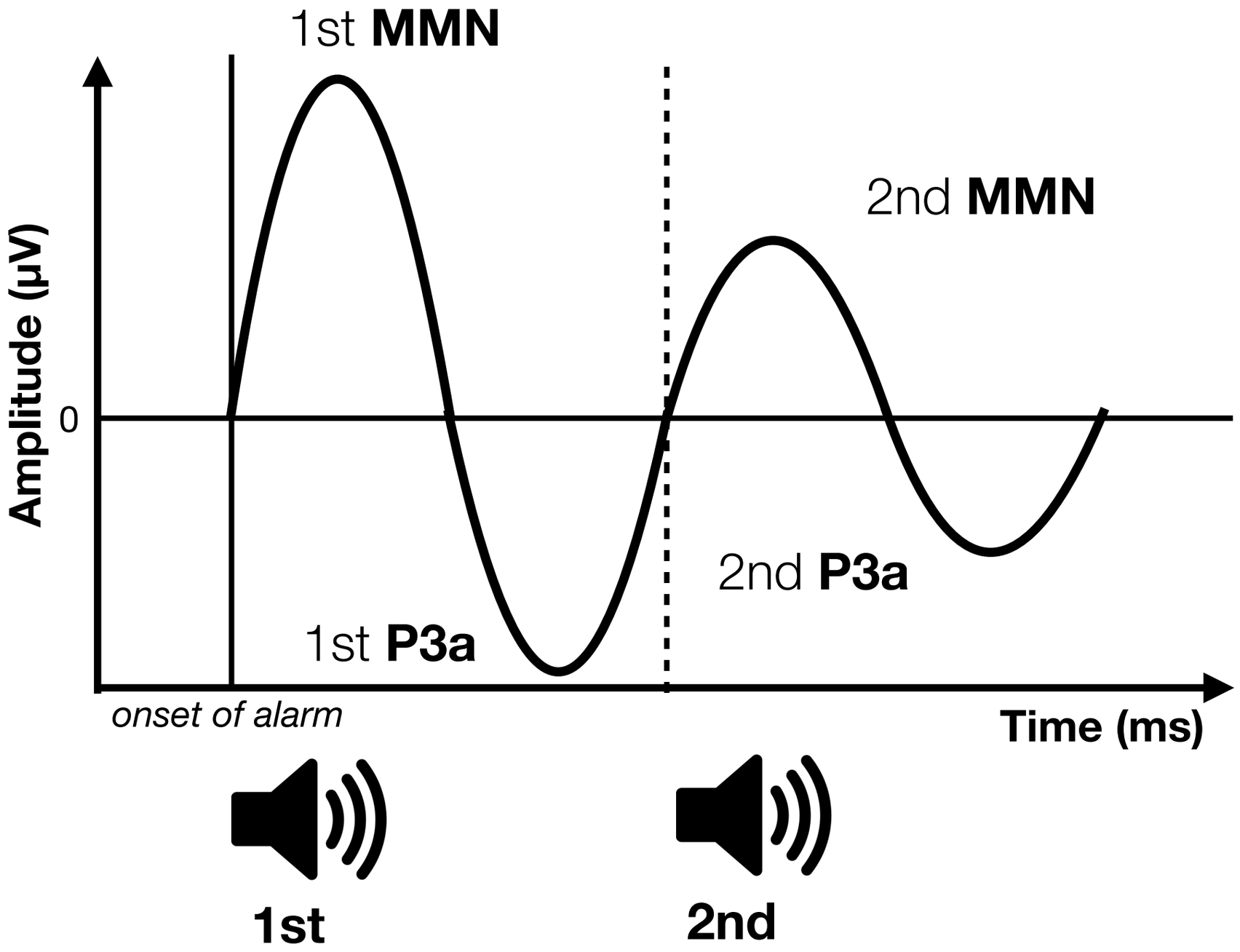
Created by Aenne Brielmann
from Noun Project

Metric for RS



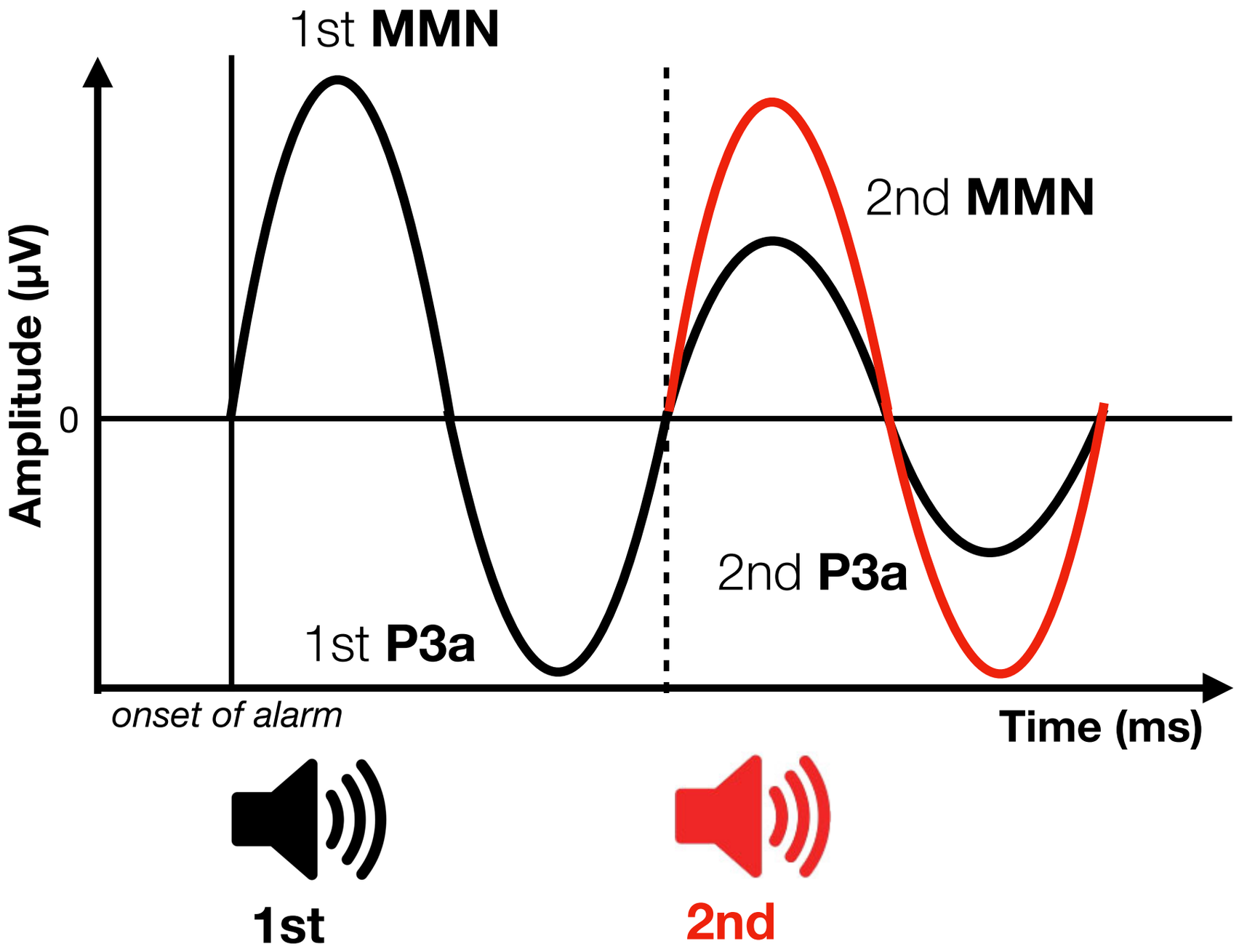
[Sams, 1984; Müller, 2005; Rosburg, 2018]

RS on MMN & P3a



[Sams, 1984; Müller, 2005; Rosburg, 2018]

Change Features of Sound can Reduce RS



[Sams, 1984; Müller, 2005; Rosburg, 2018]

Prior studies used **single tones** as background and repeated alarm **twice**

[Sams, 1984; Müller, 2005; Rosburg, 2018]

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[Sams, 1984; Müller, 2005; Rosburg, 2018]

We used **real-life** ambient sound as background and repeated alarm **five** times

Research Question 1

Whether we can observe RS in a more realistic setting compared to prior studies?

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Whether we can observe RS in a more realistic setting compared to prior studies?

Research Question 2

Can the proposed modulations reduce RS?

Experiment Setting

Auditory Stimuli

14 Participants
(8 males; 21-26 years old)

Auditory Stimuli

A: basic alarm (sine wave; 1000 Hz, 70 dB SPL)
P: pitch-modulated alarm (**1500 Hz**, 70 dB SPL)
I : intensity-modulated alarm (1000 Hz, **79 dB SPL**)

Dev 1	**A**	**A**	**A**	**A**	**A**
Dev 2	**A**	**P**	**A**	**P**	**A**
Dev 3	**A**	**I**	**A**	**I**	**A**

Isolated Session

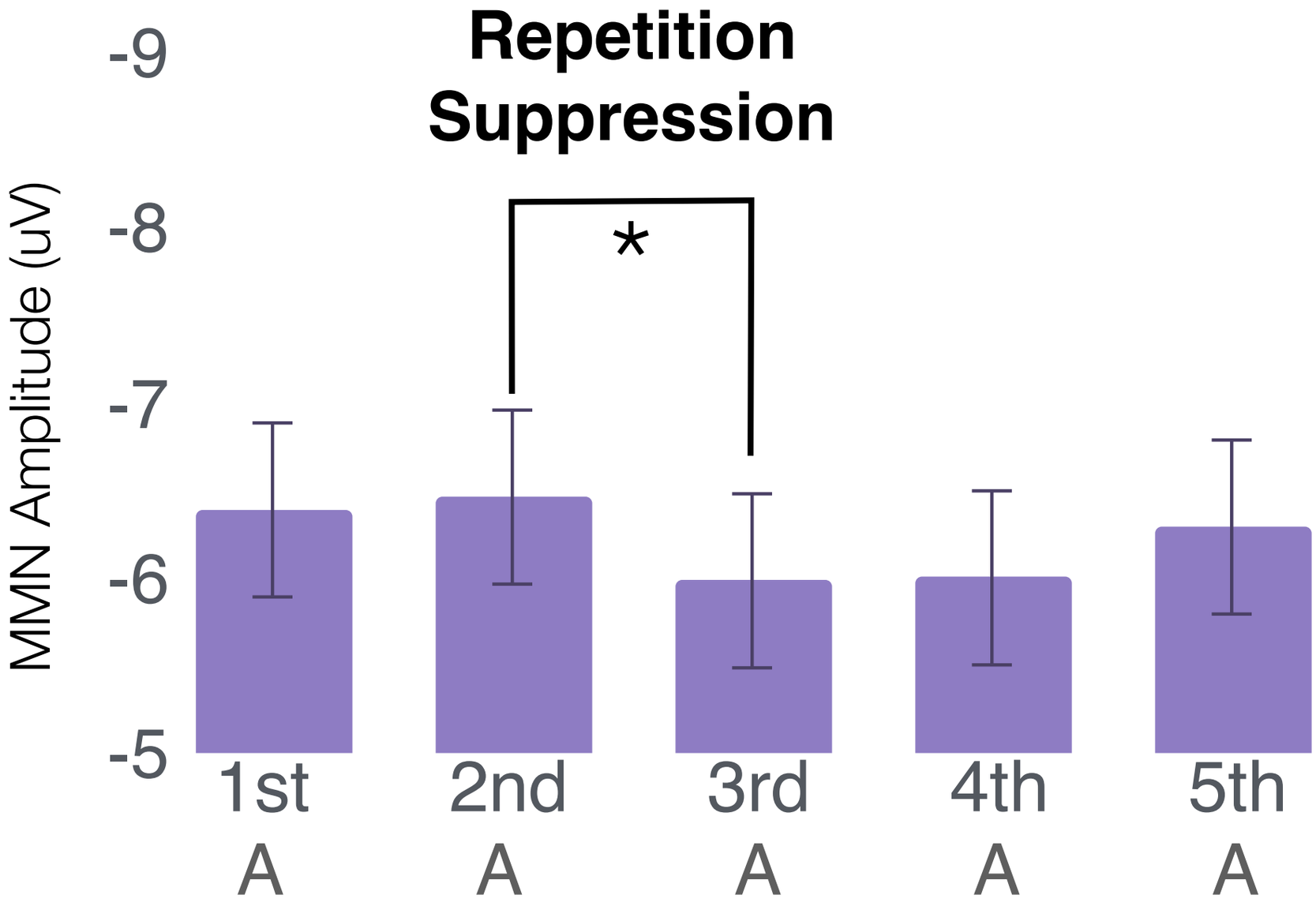
- **Dev 1 (AAAAA)** and ambient sound (70 dB)
- **RQ 1.** Whether we can observe RS?

Mixed Session

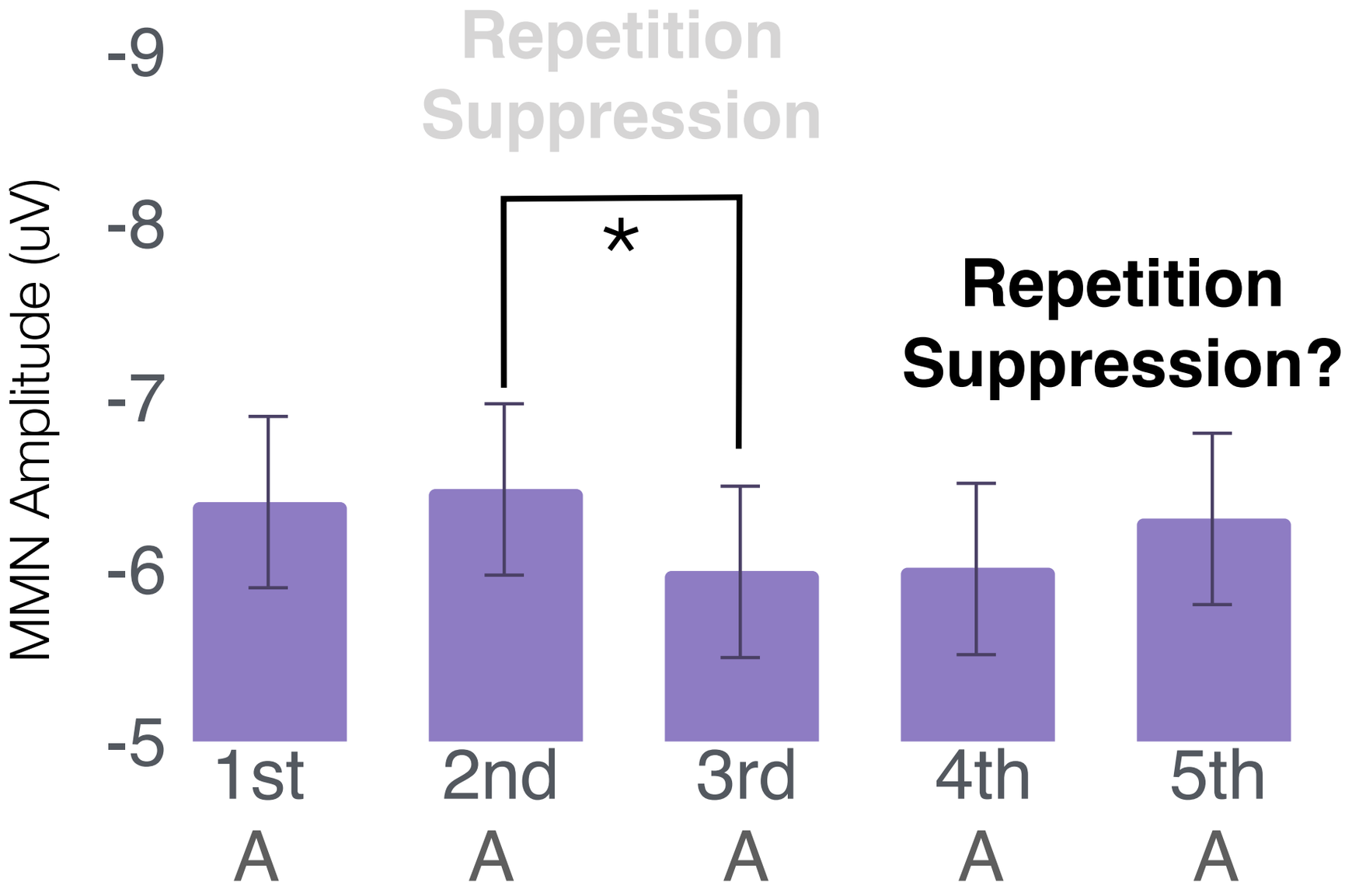
- **Dev 1**, **Dev 2** and **Dev 3** randomly appeared
- **RQ 2.** Can our modulations reduce RS?

Result

Observe Repetition Suppression in Isolated Session

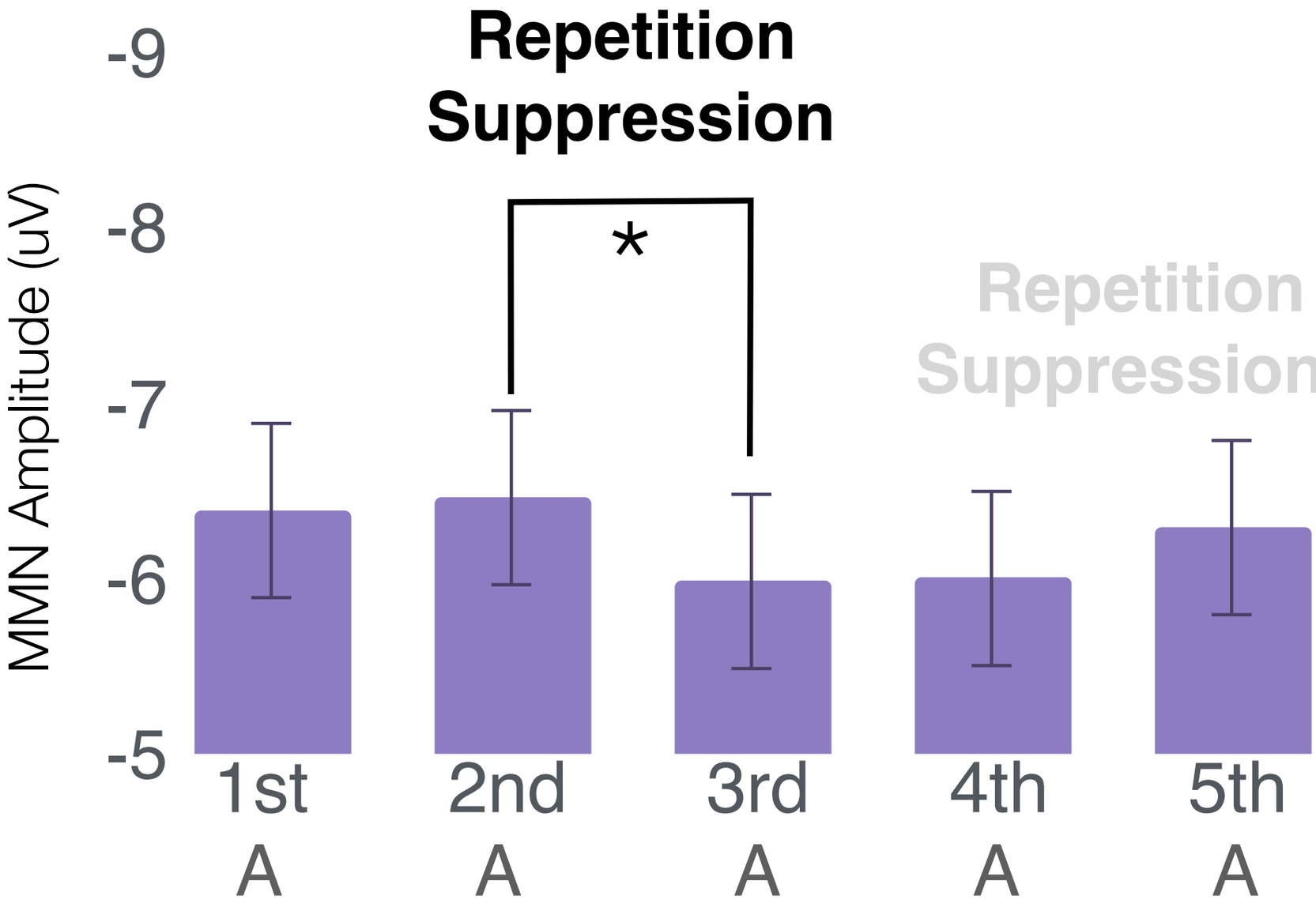


Auditory detection **decreased** in 3rd repetition



RS has **attention**-dependent & **attention**-independent processes

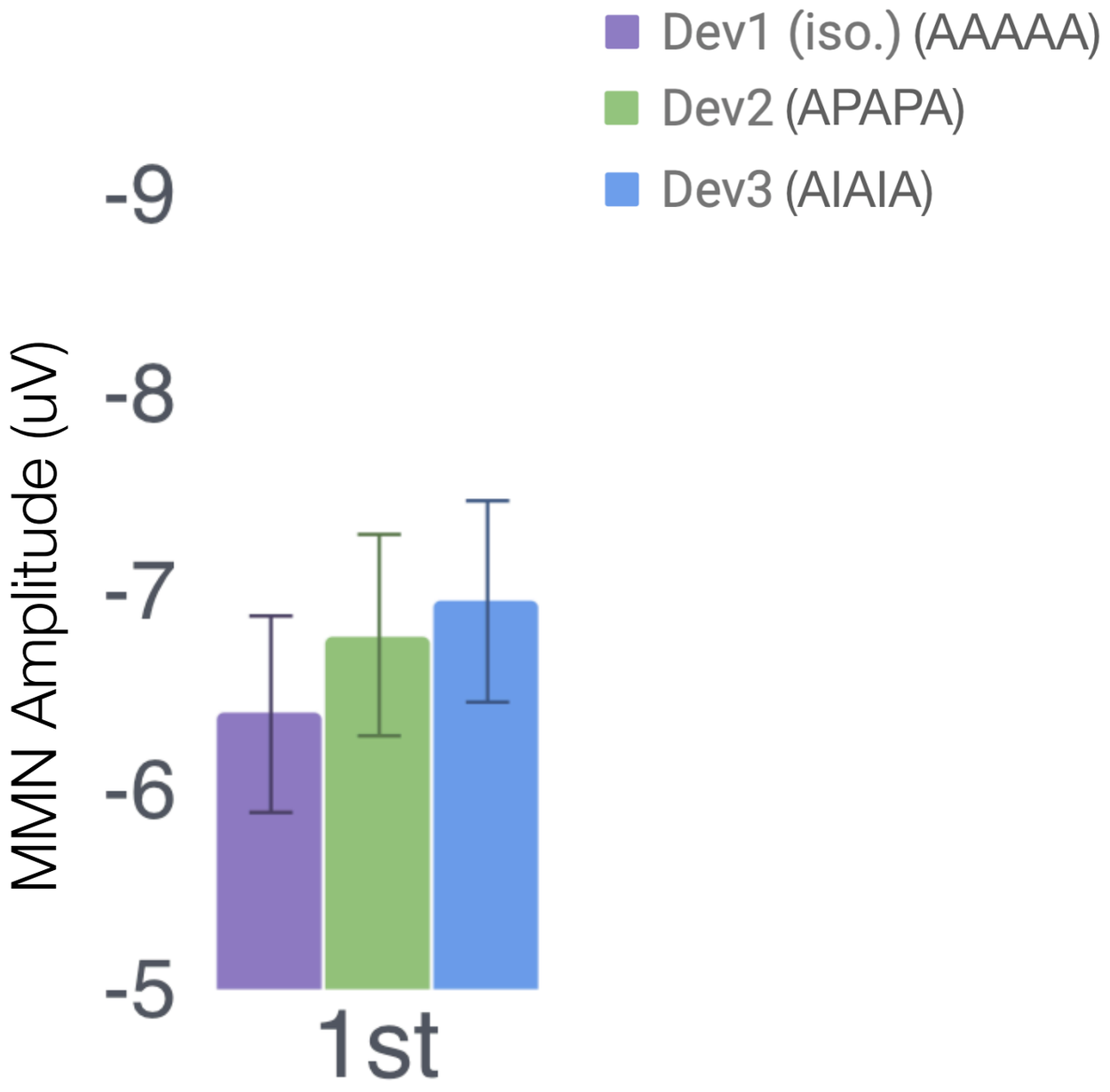
[Hsu, 2014; Grotheer, 2016]



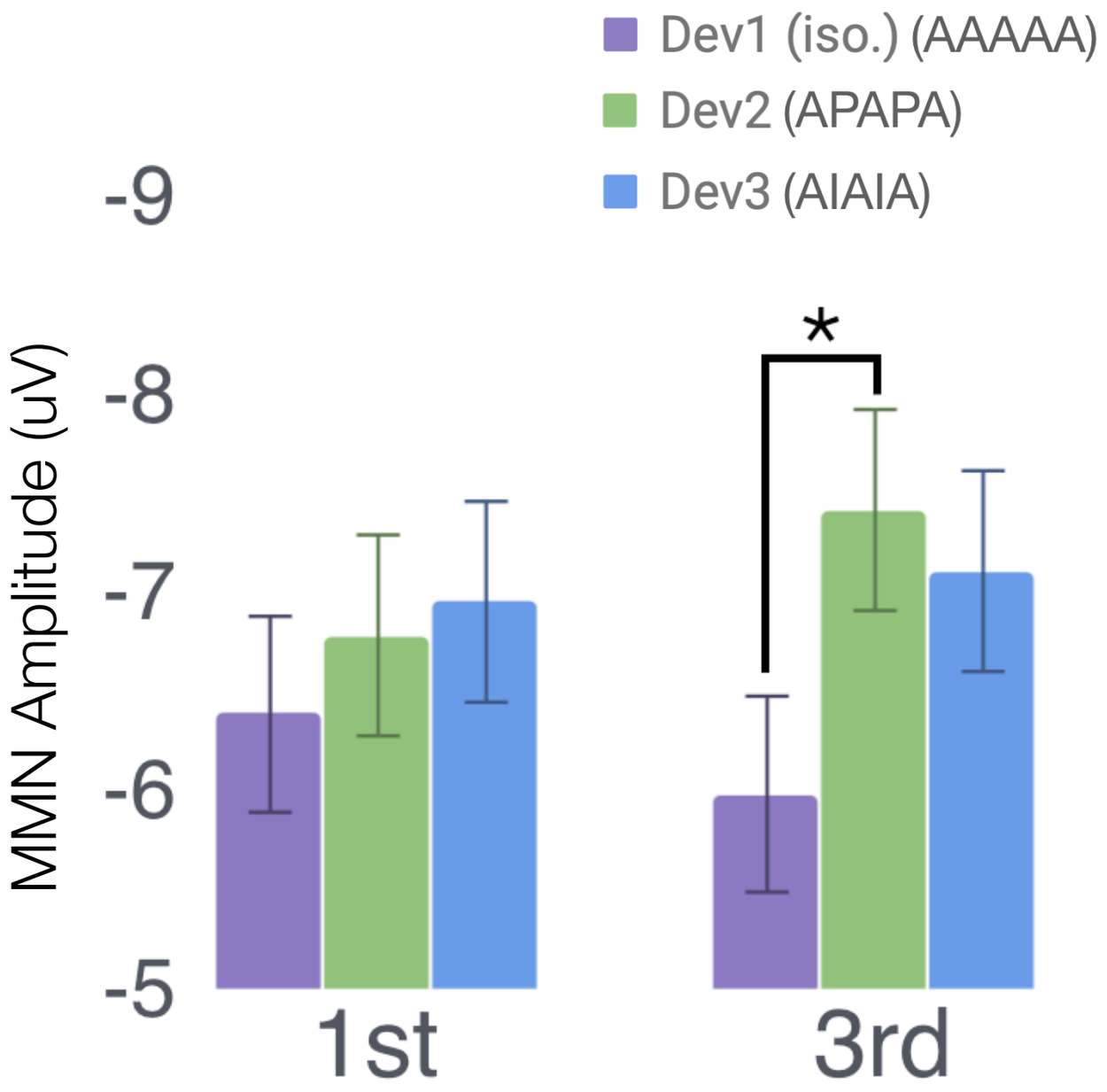
RS happens in the 3rd repetition

Result

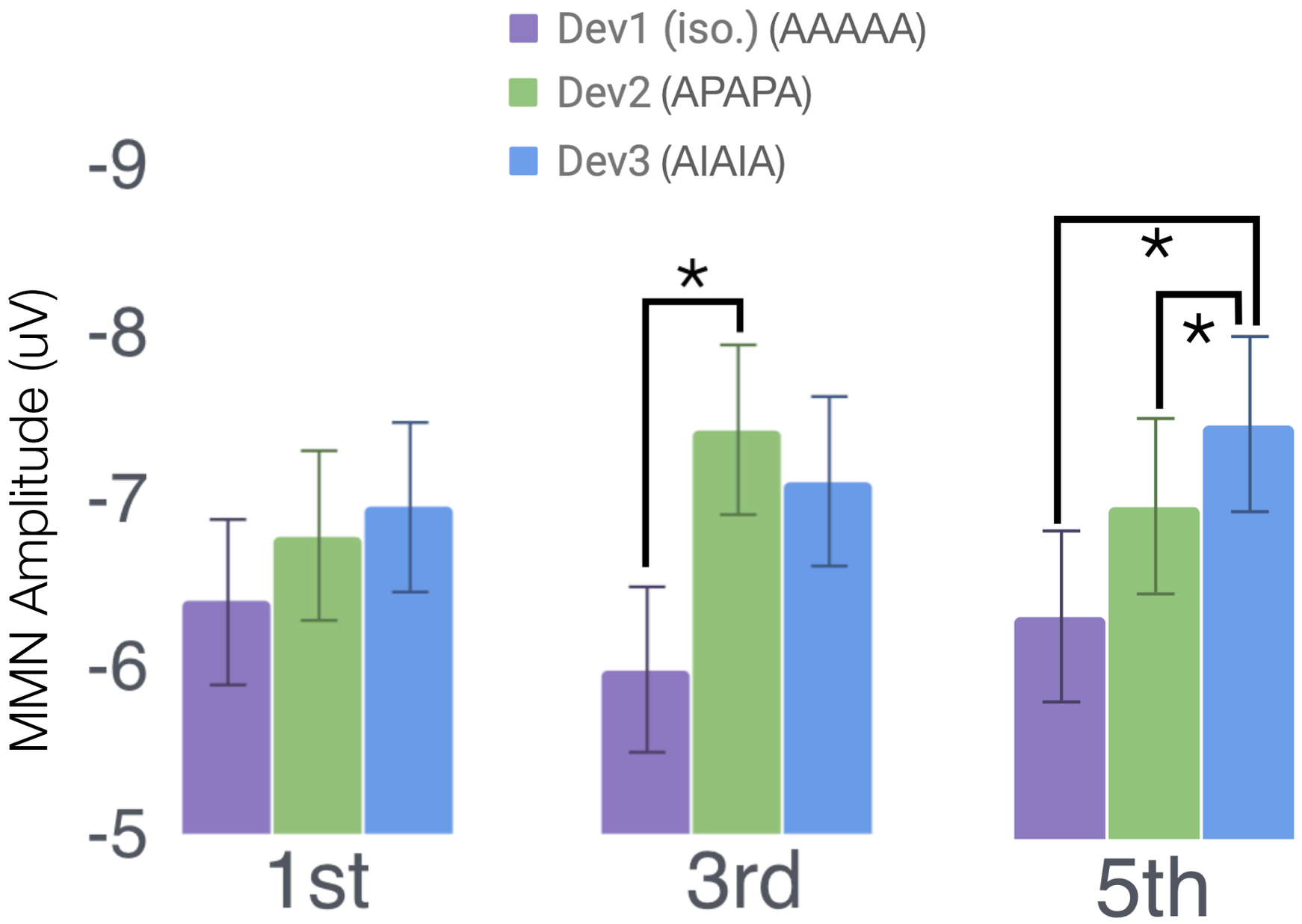
Modulations Reduce RS



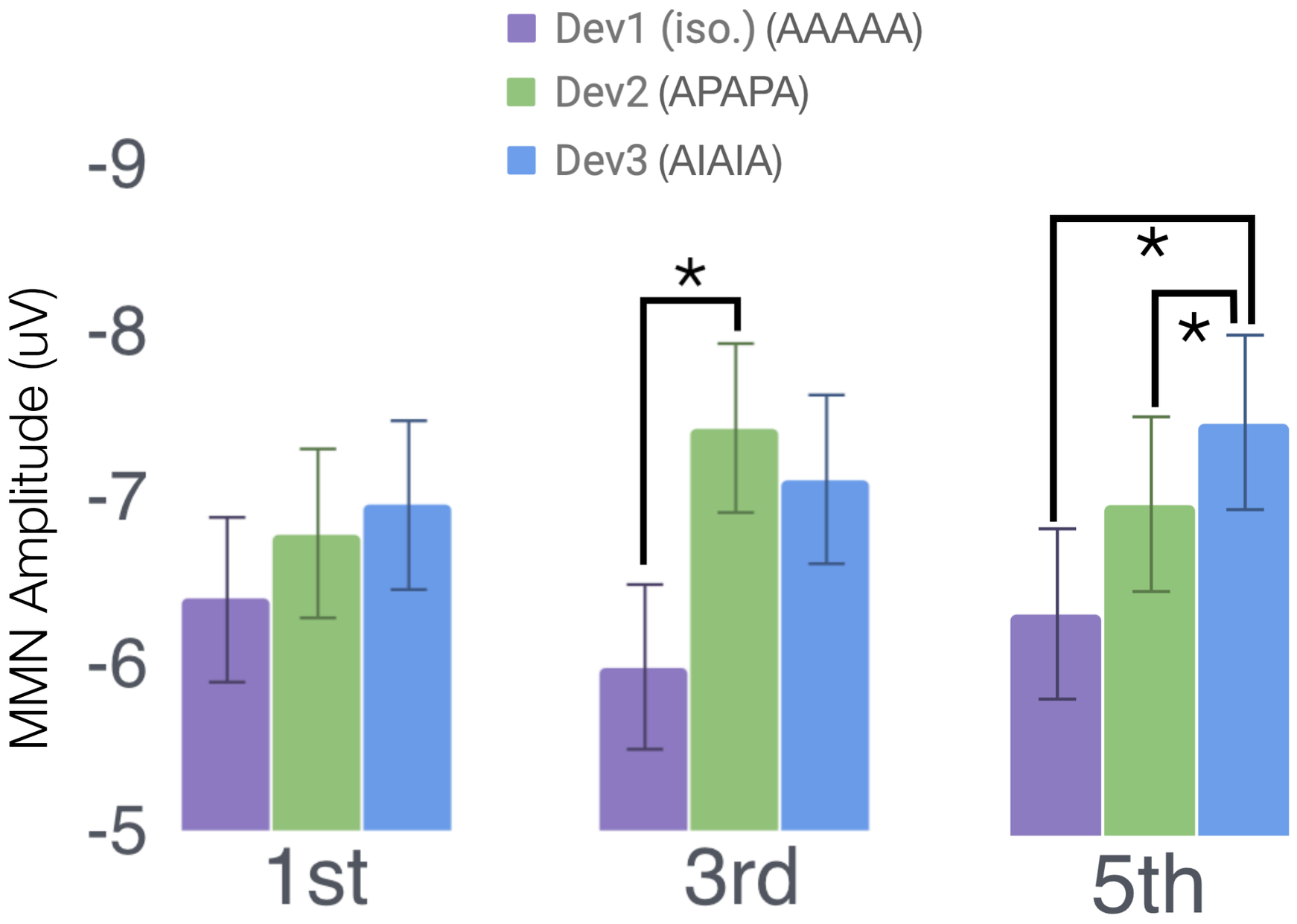
Dev 1 (iso.)	**A**
Dev 2	**A**
Dev 3	**A**



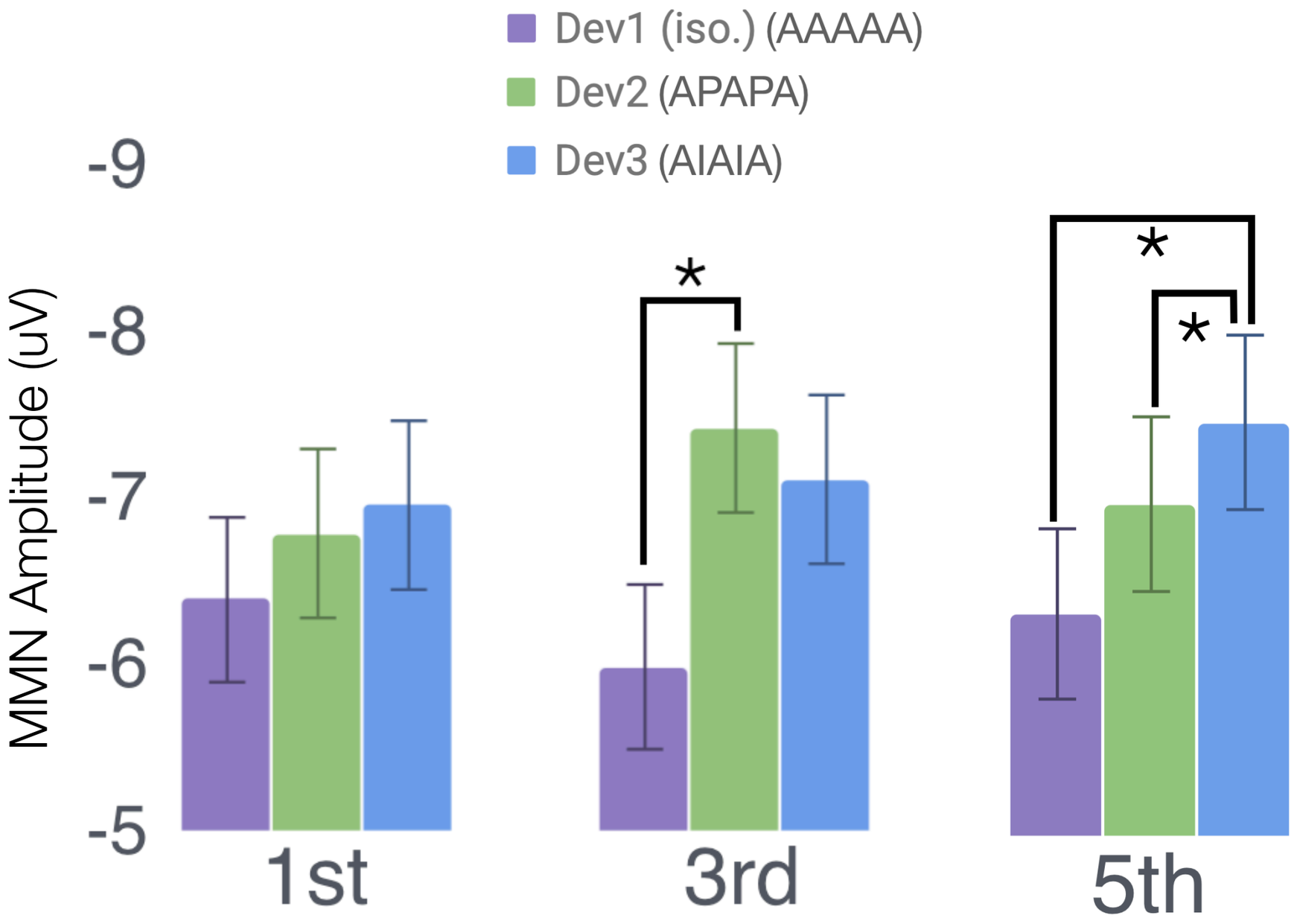
Dev 1 (iso.)	**A**	**A**	**A**
Dev 2	**A**	**P**	**A**
Dev 3	**A**	**I**	**A**



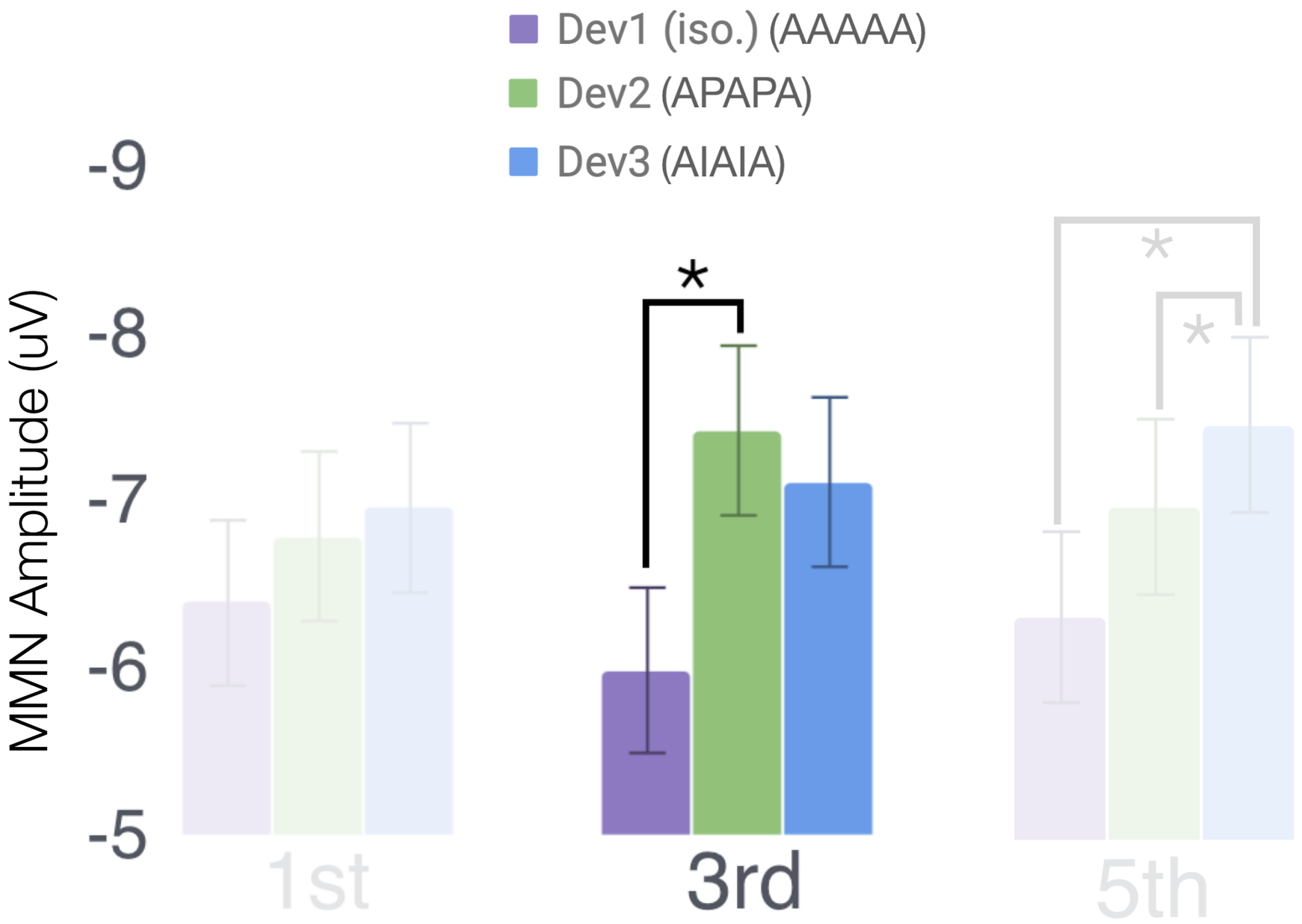
Dev 1 (iso.)	**A**	**A**	**A**	**A**	**A**
Dev 2	**A**	**P**	**A**	**P**	**A**
Dev 3	**A**	**I**	**A**	**I**	**A**



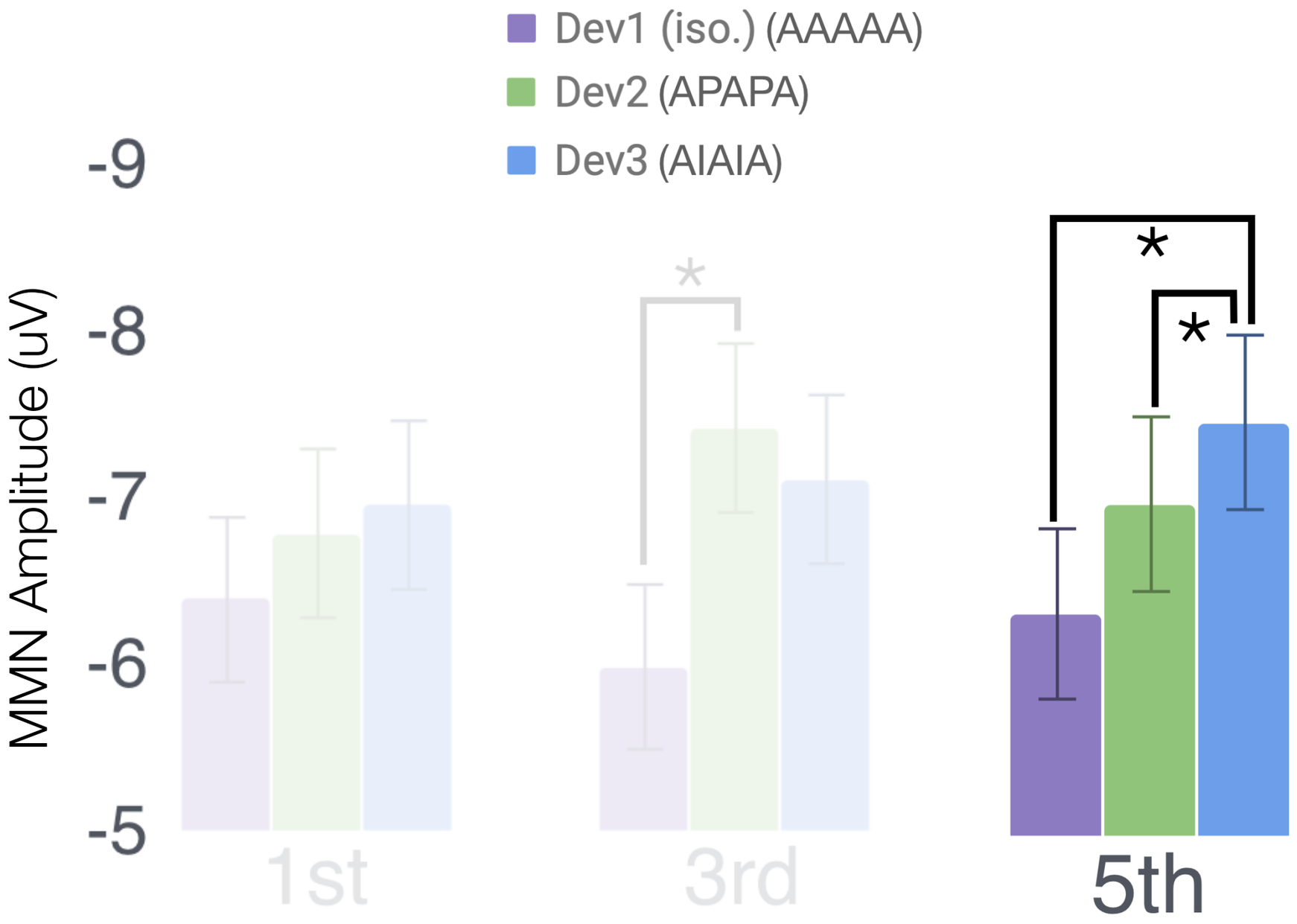
Modulations **reduce RS** by evoking higher MMN amplitude



Pitch & **intensity** modulation reduce RS differently



Pitch modulation reduces RS in **3rd** repetition



Intensity modulation reduces RS only in **5th** repetition but has **stronger** effect

Study **R**epetition **S**uppression in a more realistic setting

- Use real-life ambient sound & more repetition
- When design **repeating alarm**, should take **RS** into account
- Adopt the **modulation** methods to reduce RS

Pitch & **Intensity** Modulations Reduce RS Differently

- **Pitch modulation** reduces RS **earlier**
  - Good for time-sensitive situations
- **Intensity modulation** reduces RS **later** but **stronger**
  - Good for situations when quick response isn't crucial

Acknowledgement

Anonymous Reviewers

For insightful comments

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Former director of Brain Research Center

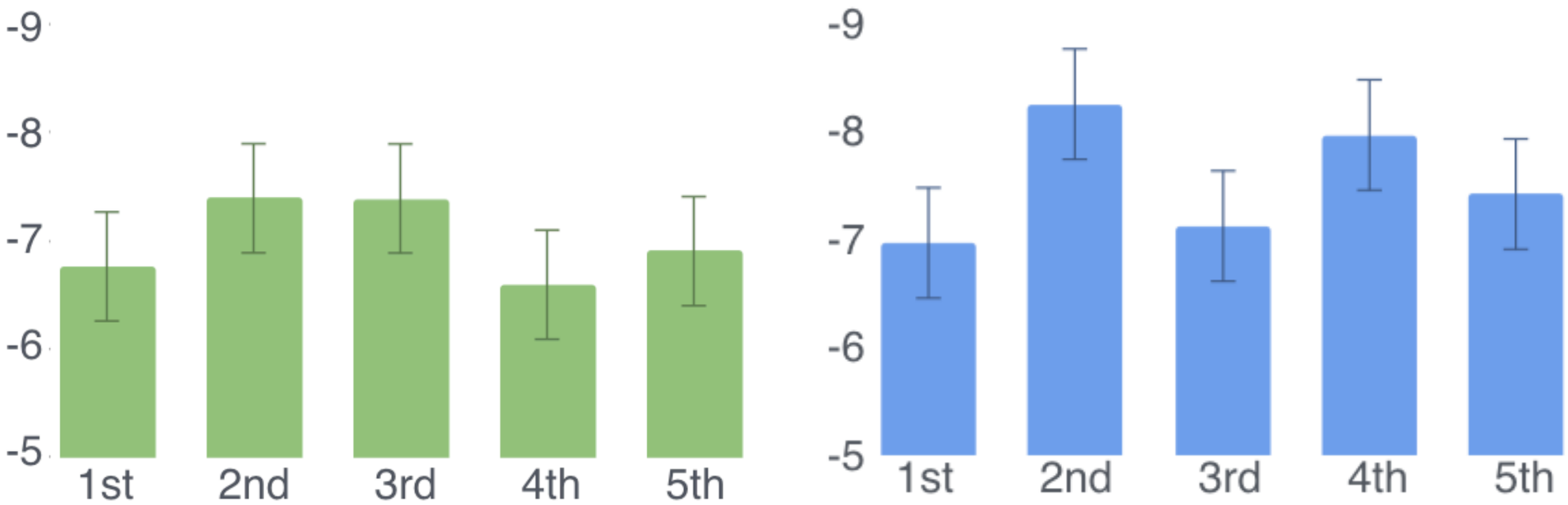
Taiwan Ministry of Science and Technology (MOST)

104-2628-E-009-001-MY3, 105-2221-E-009-095-MY3, and 107-2218-E-009-053-.

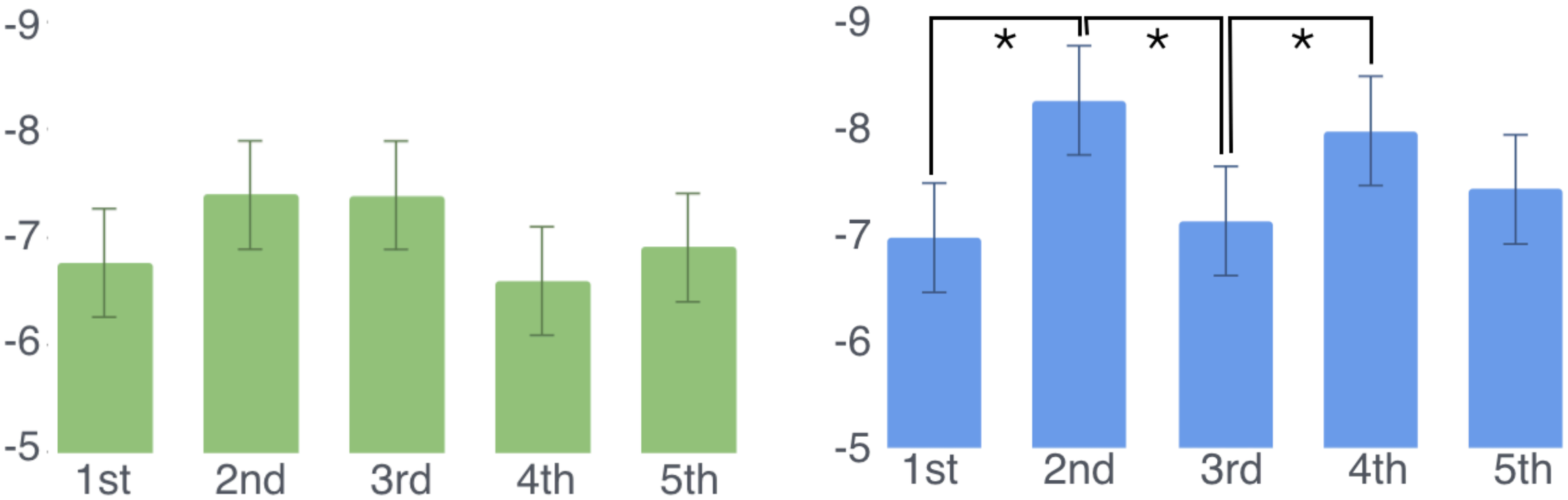
Appendix

Future Works

- More participants (N=14)
- More modulation method (source location, tempo)
- More repetition patterns (AAPAA, APAIA)
- Different ambient sounds



There is no RS effect for modulated alarms on pre-attentive auditory detection



Intensity-modulated alarms are more easily to be detected than the unmodulated alarms