Effect of modulated masking on electrophysiological and behavioral measures

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INTRODUCTION

The use of Long Latency Auditory Evoked Potentials (LLAEP), particularly the Cortical Auditory Evoked Potential (CAEP), has become increasingly important in clinical audiology for diagnosis and follow-up, as well as in research on Central Auditory Processing (CAP)[1]. CAEP provides valuable insights into auditory processing by measuring neuroelectric activity in the auditory cortex, and it's convenient because it doesn't rely on the patient's active participation[2].

One key area that can be explored with CAEP is Temporal Auditory Processing (TAP), essential for communication, especially for understanding speech. TAP helps the brain process small changes in sound over time, allowing us to pick up on subtle differences in timing, frequency, and intensity[3].

Modulation Masking Release (MMR) is a phenomenon closely linked to TAP. It refers to how the brain detects speech in fluctuating noise, where these fluctuations make it easier to hear the target sound, improving speech recognition[4,5]. More recent studies have turned to electrophysiological methods like CAEP to better understand MMR. These methods are particularly useful for individuals who can't provide reliable behavioral responses and could help predict auditory performance in noisy environments[6].

The aim of this study was to analyze the Benefit of Modulated Masking (BMM) in electrophysiological and behavioral measurements in young and adult normal-hearing individuals

METHODS

Inclusion and Exclusion Criteria

This study initially included 22 young adults aged 18 to 30 years and 23 adults aged 31 to 50 years, recruited from the university campus through electronic advertisements. All participants were informed about the study's purpose and procedures and signed an informed consent form. Inclusion criteria required participants to be between 18 and 50 years old with normal hearing. Exclusion criteria included neurological or psychiatric conditions, cognitive deficits, or malformations of the outer ear or auditory canal.

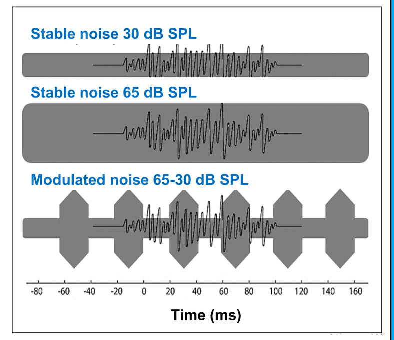
Main Pre-Exams

Participants underwent health screenings, basic audiological exams, and a cognitive test (MoCA) to ensure eligibility. After these screenings, 40 participants were selected for behavioral and electrophysiological evaluations to study Modulation Masking Release (MMR).

Modulation Masking Release protocol

In this study, both behavioral and electrophysiological assessments were used to investigate the effects of Modulation Masking Release (MMR). The behavioral component focused on sentence recognition in stable and modulated noise, while the electrophysiological component measured cortical auditory evoked potentials (CAEP) using the synthetic speech stimulus /ba/ under different noise conditions. Below is a summary of the key methodological points for each assessment.

Aspect	Behavioral Assessment	Electrophysiological Assessment
Test Type	Sentence recognition with stable and modulated noise	Cortical Auditory Evoked Potentials (CAEP)
Stimulus	12 HINT-Brazil lists (20 sentences each)	Synthetic speech stimulus /ba/
Noise Conditions	Stable noise at 65 dB SPL and modulated noise at 65-30 dB SPL	Stable (weak and strong) and modulated noise (30 and 65 dB SPL)
Test Environment	Participants seated in a soundproof booth	Participants seated in a soundproof booth watching a silent video
Equipment	Supra-aural headphones (Sennheiser HD580)	Insert earphones (ER2)
Outcome Measures	Sentence Recognition Threshold (SRT)	Cortical responses (P1, N1, P2) measured in latency and amplitude



RESULTS

Participants

The final sample consisted of 40 participants with normal hearing as per the pre-established criteria. The participants were divided into two groups based on age: the "Young Adult" group (18-30 years) and the "Adult" group (31-50 years). The Young Adult group comprised 20 participants (15 women and 5 men), with an average age of 22.8 (±5.5) years, while the Adult group included 20 participants (10 women and 10 men), with an average age of 37.7 (±6.7) years.

Electrophysiological assessment

Young-adult

Latency (ms)	Soft stable noise Mean ± SD (CI 95%)	Loud stable noise Mean ± SD (CI 95%)	Modulated noise Mean ± SD (CI 95%)	ANOVA Post-hoc (Bonferroni)
Component P1	56.3 ± 11.5 (50.8 - 61.7)	68.9 ± 20.1 (59.4 - 78.3)	51.9 ± 8.0 (48.1 - 55.6)	**p 0.016 (a) *** p 0.896 (b) **p 0.003 (c) ***
Component N1	109.6 ± 10.0 (104.9 - 114.3)	118.7 ± 23.2 (107.8 - 129.6)	116.6 ± 12.3 (110.8 - 122.4)	p 0.328 (a) p 0.059 (b) p 1.000 (c)
Component P2	165.9 ± 16.1 (158.3 - 173.4)	174.9 ± 24.2 (163.1 - 186.2)	168.3 ± 12.9 (162.2 - 174.4)	p 0.521 (a) p 1.000 (b) p 0.488 (c)

Amplitude (µV)	Soft stable noise Mean ± SD (CI 95%)	Loud stable noise Mean ± SD (CI 95%)	Modulated noise Mean ± SD (CI 95%)	ANOVA Post-hoc (Bonferroni)
Component P1	5.7 ± 1.9 (4.8 - 6.6)	5.2 ± 1.9 (4.3 - 6.1)	5.8 ± 1.6 (5.0 - 6.6)	p 0.565 (a) p 1.000 (b) p 0.373 (c)
Component N1	5.1 ± 3.1 (3.6 - 6.6)	4.2 ± 3.2 (2.6 - 5.7)	4.4 ± 2.4 (3.2 - 5.5)	p 0.123 (a) p 0.370 (b) p 1.000 (c)
Component P2	5.0 ± 4.1 (3.0 - 6.9)	3.3 ± 2.5 (2.1 - 4.5)	5.4 ± 2.4 (4.2 - 6.5)	**p 0.027 (a) *** p 1.000 (b) **p 0.001 (c) ***

Adult

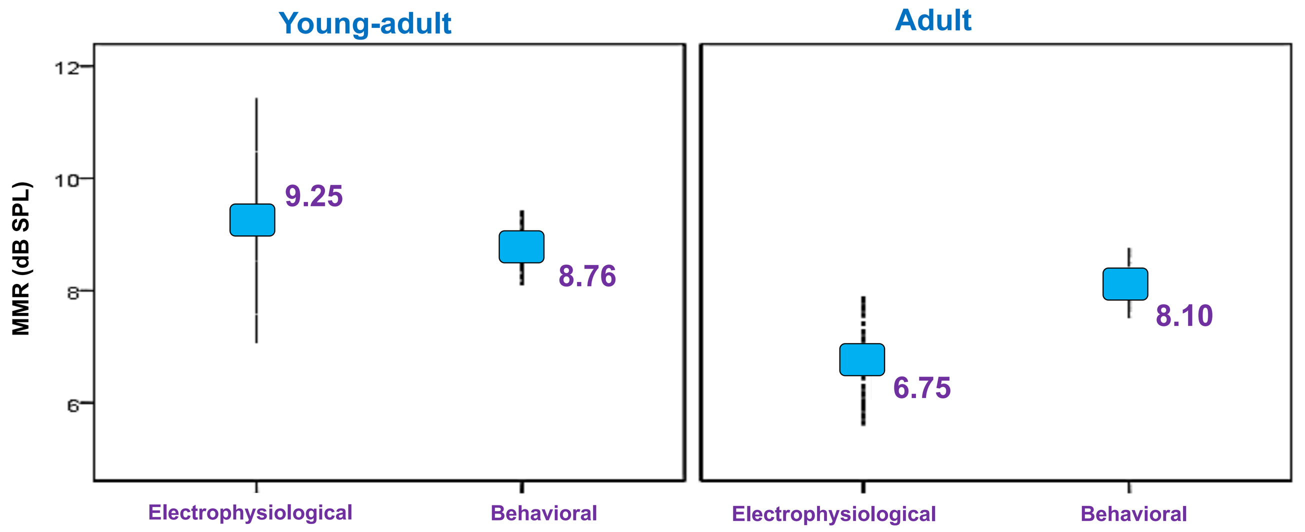
Latency (ms)	Soft stable noise Mean ± SD (CI 95%)	Loud stable noise Mean ± SD (CI 95%)	Modulated noise Mean ± SD (CI 95%)	ANOVA Post-hoc (Bonferroni)
Component P1	56.4 ± 9.3 (52.1 - 60.8)	65.6 ± 10.3 (60.7 - 70.5)	54.8 ± 7.5 (51.3 - 58.4)	**p 0.024 (a) *** p 1.000 (b) **p 0.002 (c) ***
Component N1	104.6 ± 7.7 (100.9 - 108.2)	119.9 ± 21.5 (109.8 - 129.9)	116.7 ± 15.1 (109.6 - 123.8)	p 0.022 (a) p 0.008 (b) p 1.000 (c)
Component P2	163.8 ± 13.7 (157.4 - 170.3)	178.7 ± 27.4 (165.9 - 191.6)	173.2 ± 22.0 (162.8 - 183.4)	p 0.108 (a) p 0.204 (b) p 0.793 (c)

Amplitude (µV)	Soft stable noise Mean ± SD (CI 95%)	Loud stable noise Mean ± SD (CI 95%)	Modulated noise Mean ± SD (CI 95%)	ANOVA Post-hoc (Bonferroni)
Component P1	5.3 ± 1.8 (4.4 - 6.2)	5.4 ± 2.0 (4.4 - 6.3)	5.4 ± 1.7 (4.6 - 6.3)	p 1.000 (b) p 1.000 (b) p 1.000 (b)
Component N1	5.4 ± 2.3 (4.3 - 6.5)	4.1 ± 3.1 (2.6 - 5.6)	4.8 ± 2.4 (3.6 - 5.9)	p 0.055 (a) p 0.368 (b) p 0.690 (c)
Component P2	4.9 ± 2.6 (3.6 - 6.1)	3.4 ± 2.0 (2.5 - 4.4)	5.2 ± 1.8 (4.4 - 6.1)	p 0.084 (a) p 1.000 (b) **p 0.006 (c) ***

*SD – Standard Deviation; CI – 95% Confidence Interval; (a) comparison of means between weak stable noise and strong stable noise; (b) comparison of means between weak stable noise and modulated noise; (c) comparison of means between strong stable noise and modulated noise. * statistically significant difference.*

Electrophysiological x Behavioral threshold

(dB SPL)	Stable noise Mean ± SD (CI 95%)	Modulated noise Mean ± SD (CI 95%)	Difference (MMR) Mean ± SD (CI 95%)	T test p - valor
Young-adult				
Electrophysiological threshold	49.7 ± 6.3 (46.7 - 52.7)	41.2 ± 5.3 (38.7 - 43.7)	9.5 ± 4.6 (7.0 - 11.4)	**p 0.000 ***
Behavioral threshold	59.1 ± 1.0 (58.6 - 59.6)	50.3 ± 1.8 (49.4 - 51.2)	8.7 ± 1.4 (8.1 - 9.4)	**p 0.000 ***
Adult				
Electrophysiological threshold	52.5 ± 4.1 (50.5 - 54.4)	45.5 ± 3.5 (43.8 - 47.1)	6.7 ± 2.4 (5.6 - 7.9)	**p 0.000 ***
Behavioral threshold	59.2 ± 1.0 (58.7 - 59.6)	51.0 ± 1.6 (50.2 - 51.8)	8.1 ± 1.3 (7.5 - 8.7)	**p 0.000 ***



DISCUSSION

This study explores how modulated noise influences speech detection using Cortical Auditory Evoked Potentials (CAEP), offering an objective view of the benefits of noise modulation on temporal auditory processing. We examined the effects of noise modulation on speech stimuli in both the electrophysiological and behavioral domains in young and adult normal-hearing participants. The P1-N1-P2 complex, evoked by the /ba/ speech sound masked by stable and modulated noise, confirmed the value of CAEP for understanding modulation masking release (BMM), showing how our brains process these sounds in different noise conditions[7].

The results from latency and amplitude measurements revealed how noise impacts neural encoding of speech. Strong stable noise caused greater disruption, leading to delayed latencies. In contrast, modulated noise had a milder effect, allowing faster neural synchronization, particularly for the P1 component. This suggests that modulated noise is less intrusive on the brain's ability to process speech[8].

In terms of amplitude, we saw similar results: modulated noise produced less interference compared to strong stable noise, resulting in larger amplitudes, especially for the P2 component. This indicates that modulation helps the brain more easily discriminate speech sounds, despite the presence of noise, allowing for clearer neural responses[9].

Finally, the comparison between electrophysiological and behavioral thresholds aligned with what has been reported in the literature. Stable noise led to higher detection thresholds than modulated noise in both domains, with CAEP thresholds slightly lower than behavioral ones. The difference between these two thresholds was less than 10 dB, supporting previous findings that suggest CAEP can reliably predict behavioral performance in detecting speech in noisy environments[10, 11].

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