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# NEMA: An Ecologically Valid Tool for Assessing Hearing Devices, Advanced Algorithms, and Communication in Diverse Listening Environments

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## Abstract

Ecological Momentary Assessment (EMA) is valuable research method for evaluating the real-world performance of novel computational algorithms and device technologies, addressing the shortcomings of objective metrics and laboratory assessments. Our customisable, cloud-connected smartphone app, NEMA, gathers repeated self-reports and related acoustic features in users' natural environments, providing personalised insights on how specific technologies impact daily activities. NEMA has proven effective in assessing the real-world performance of novel hearing aid algorithms and features, while also improving our understanding of the challenges faced by those with hearing loss which drive new developments. This paper outlines NEMA's innovative features designed to facilitate efficient data collection and presents findings from a recent clinical trial where NEMA played a key role in providing real-world evidence of user benefits for a medical device seeking FDA approval.

**Index Terms**: ecological momentary assessment (EMA), ecological validity, real-world evaluation, hearing research

## 1. Introduction

As hearing assistive technology continues to evolve, it is crucial to assess the real-world benefits experienced by users. Understanding the impact of these innovations on everyday lives ensures they address communication needs and enhance listening experiences. Existing assessment methods, such as objective predictive metrics, retrospective self-reports and controlled laboratory tests, have limitations. They may not fully capture the varied and dynamic real-world listening conditions that users encounter, suffer from recall bias, or fail to account for factors like fatigue, stress, and visual or contextual cues, which influence communication.

Ecological Momentary Assessment (EMA) addresses these limitations by collecting data in users' natural environments during, or shortly after, an experience. EMA provides real-world evidence of the effectiveness of interventions, complementing laboratory tests [1]**Error! Reference source not found.**[3].

The National Acoustics Laboratories' EMA (NEMA) smartphone app, utilised in over ten hearing research studies, has proven effective in understanding the behaviour of people with hearing difficulties, and the benefits of advanced hearing device features in various listening situations. NEMA is a customisable, remotely distributable tool that enables efficient data collection in daily life. Researchers can visualise, monitor, and analyse data to derive individual or group insights. Available on both iPhone and Android smartphones, with remote research features, NEMA enables inclusivity and access to a diverse research population. This approach results in larger data sets and efficient, timely data collection, ultimately providing a more comprehensive assessment.

## 2. Key features

NEMA can be remotely distributed to participants, who receive a unique code to access the relevant study materials. It collects self-report and objective data to capture "snapshots" of real-world experiences. By linking self-reports to specific contexts that are familiar to individuals, NEMA provides valuable insights into real-life user experiences.

### 2.1. Self-report survey

NEMA collects subjective data from participants, such as speech understanding, listening effort, emotions, or preferences for specific device settings, as they naturally engage with various acoustic environments NEMA's adaptable architecture allows for easy customisation of survey questions and flow to address study-specific research objectives. Questions are carefully designed to be straightforward, unambiguous, and quick to answer, maximising participant compliance and data validity. Participants may be prompted to complete surveys at redetermined time periods or intervals, or they may be instructed to initiate a survey when encountering in a particular situation. Example NEMA app screens are shown in Figure 1.

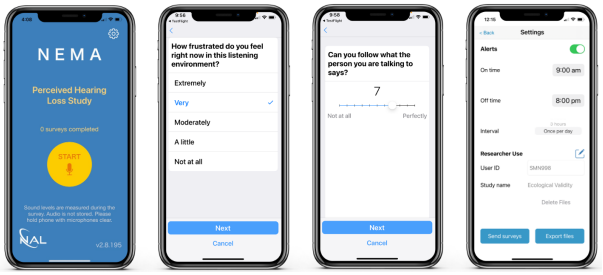


Figure 1: *NEMA app screenshots.*

### 2.2. Objective acoustic features

While surveys are completed, NEMA measures acoustic characteristics of participants' environments, providing additional context for understanding their real-world experiences. To ensure broad accessibility, smartphone microphones are utilised. Features include sound level (A-weighted and unweighted), zero crossing rate, power spectrum, spectral fine structure (pitch during voiced speech), spectral flatness, entropy, and spectral-temporal envelope modulation

which characterises reverberation. Privacy is maintained by calculating these temporal and spectral features on-the-fly, and no audio is stored.

Calibrated sound level measurements are achievable with iPhones and select Android models. For other Android models, laboratory calibration is performed by playing diffuse noise at a known level while NEMA calculates the sound level. Adjustment factors are applied to ensure accurate measurements and are added to a continuously expanding calibration library that reduces the need for individual calibration of later phones of the same model.

### 2.3. Real-time data analysis

NEMA transfers collected data to the cloud, enabling researchers to gain immediate insights into user experiences. Researchers can analyse and visualise real-time data through a secure web-based dashboard, and data handling tools help ensure participant compliance and error-free data collection. Automated notifications keep researchers informed, ensuring studies stay on track and allowing for timely intervention when necessary. EMA studies typically produce large datasets, allowing for analysis of intra-subject and inter-subject variability, mixed or random effects modelling, or machine learning predictive analysis.

## 3. Case study: Nuheara self-fitting hearing aid clinical trial

This case study investigates the real-world effectiveness of Nuheara HP Hearing PRO self-fitting hearing aids using the NEMA app. The device's performance, and in particular the Focus directionality feature, was assessed in terms of speech understanding, naturalness and sound quality in noisy environments.

### 3.1. Study design and NEMA integration

Standard audiological assessments were conducted, including speech tests, patient-reported outcome questionnaires and real-world measures. The study population included 43 adults with varying degrees of hearing loss who consistently reported difficulties understanding speech in noise.

Ecological Momentary Assessment (EMA) using the NEMA app was conducted during a 2-4 week field trial. During this time, participants responded to a total of 772 NEMA surveys. To understand the nature of the aided benefit, the EMA data was analysed using a generalised linear model with logistic kernel distribution to find associations between outcome measures and other factors such as type of environments' background noise level and hearing aid settings.

### 3.2. Key findings

Clinical assessment demonstrated a 30% speech understanding improvement in speech babble noise when aided with Focus on, compared to unaided listening and aided with Focus off. The data showed statistically significant improvements in ease of listening, reduced annoyance of noise and background sounds, and overall preference for Focus. The perceived naturalness and sound quality of sound were not degraded.

Real-world data collected by NEMA supported the clinical findings. Participants reported a statistically high number of everyday listening situations where they experienced improvements when using Focus. The data revealed that participants were most commonly unaided in lower background noise levels, without Focus activated in mid-range sound levels, and with Focus activated in high background noise levels. Directional processing improved communication at moderate noise levels, however the improvement decreased at the extreme highest noise levels. Figure 2 shows the Focus feature was most effective in environments with background noise from 80-90 dBA. However, it was less utilised in quiet settings and had limited impact in extremely noisy (90-100 dB) environments.

These results demonstrate the benefits of Nuheara HP Hearing PRO hearing aids with Focus in enhancing communication in everyday noisy situations. This clinical validation was instrumental in obtaining the first FDA clearance for a self-fitting and over-the-counter hearing aid [4].

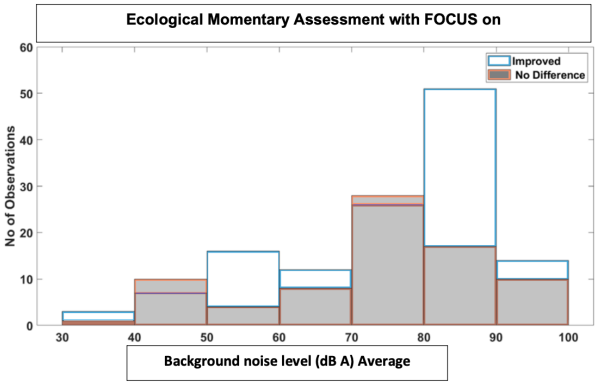


Figure 2: *Effectiveness of the Focus feature in various background noise levels, measured by NEMA.*

## 4. Conclusions

The NEMA smartphone app is a powerful tool that addresses the limitations of traditional objective metrics and laboratory assessments by providing real-world insights. By integrating ecologically valid measures into the analysis, researchers can better understand the impact of new algorithms or technologies on users' communication and listening experiences. Hence, the use of NEMA underscores the importance of integrating ecologically valid assessment methods to complement laboratory measures and enrich research findings to give a more comprehensive assessment and real-world evidence base.

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