Validating a Quick Spectral Modulation Detection Task

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Objectives: The Quick Spectral Modulation Detection (QSMD) test provides a quick and clinically implementable spectral resolution estimate for cochlear implant (CI) users. However, the original QSMD software (QSMD(MySound)) has technical and usability limitations that prevent widespread distribution and implementation. In this article, we introduce a new software package EasyQSMD, which is freely available software with the goal of both simplifying and standardizing spectral resolution measurements.

Design: QSMD was measured for 20 CI users using both software packages.

Results: No differences between the two software packages were detected, and based on the 95% confidence interval of the difference between tests, the difference between the tests is expected to be <2% points. The average test duration was under 4 minutes.

Conclusions: EasyQSMD is considered functionally equivalent to QSMD(MySound) providing a clinically feasible and quick estimate of spectral resolution for CI users.

Key words: Cochlear Implant, Spectral resolution, Spectral modulation detection

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INTRODUCTION

Spectral resolution is typically assessed by asking a listener to resolve a broadband stimulus with modulations applied in the spectral domain (i.e., a spectral ripple). There are many variations on this task including (1) spectral-phase discrimination between spectrally modulated stimuli at the same ripple frequency, but 180° out of phase (e.g., Supin et al. 1994; Henry et al. 2005; Won et al. 2007), (2) spectral ripple discrimination between different spectral ripple frequencies (e.g., Aronoff & Landsberger, 2013; Landsberger et al. (2019)), and (3) spectral modulation detection (SMD) which requires discrimination between spectrally flat and spectrally modulated/rippled stimuli (e.g., Litvak et al. 2007; Saoji et al. 2009). These measures correlate with speech recognition and therefore may be clinically useful (e.g., Henry et al. 2005; Won et al. 2007, Saoji et al. 2009; Holden et al. 2016). Furthermore, they may provide information about performance before the listener acclimates to a new fitting (e.g., Zhou 2017).

Most spectral ripple tests are limited by a lack of standardization and administration time limiting clinical feasibility. To address these limitations, the Quick Spectral Modulation Detection (QSMD) task was designed to provide a quick and clinically feasible variation of the SMD task (e.g., Litvak et al. 2007; Saoji et al. 2009) expressing performance in percent correct for cochlear implant (CI) listeners. Using a method of constant stimuli to reduce the test to 60 trials, QSMD results were highly correlated with an adaptive and time-intensive SMD threshold task. QSMD has been used in multiple studies (e.g., Noble et al. 2014; Dwyer et al. 2016; Gifford et al. 2018; Holder et al. 2018) and in the clinical battery at Vanderbilt University Medical Center. To this date, no other clinical tests have been released that measure SMD. However, other clinically oriented tests based on other spectral ripple variants have been released (e.g., Aronoff & Landsberger, 2013; Drennan et al. 2014; Landsberger et al. 2019).

Widespread use of QSMD has been limited primarily by software implementation. The original software runs on a platform called MySound and will henceforth be called QSMD(MySound). MySound requires Microsoft Access and a license from Advanced Bionics that requires periodic renewal. Therefore, QSMD(MySound) can be difficult to install and maintain. The patient interface is suboptimal with small response buttons that are closely spaced occupying a small window on the screen. Furthermore, after task completion, the results must be calculated by extracting responses from the log file.

To address the limitations of QSMD(MySound), the EasyQSMD was developed. EasyQSMD is easily setup and does not require additional software or a license. EasyQSMD is available for free download at www.ear-lab.org/easyqsmd.html. The interface, which is based on the Spectral temporally Modulated Ripple Test (Aronoff & Landsberger, 2013), displays a large response window occupying the full computer screen. The response buttons are large, horizontally arranged, light up with the corresponding stimulus and are easily clicked with a mouse or a finger if a touch screen is used. Alternatively, responses can be made using a keyboard which allows usage of custom response boxes or interfaces supporting keyboard drivers. Upon completion of the task, EasyQSMD provides overall and modulation rate- and depth-dependent scores.

It is hoped that the efficiency of the QSMD test combined with the easy-to-use and easy-to-acquire EasyQSMD will allow more researchers and clinicians to measure SMD in CI users. Furthermore, data collected across groups can be directly compared as EasyQSMD ensures standardization of stimuli and protocol. While EasyQSMD is new software, the original sound files from QSMD(MySound) are used to provide consistency across the two tests. Therefore, our hypothesis was that there would be no clinically relevant difference in outcomes obtained via QSMD(MySound) and EasyQSMD. However, before replacing QSMD(MySound) with EasyQSMD, it was important to verify that the tests are functionally equivalent as there are factors that could theoretically cause the tests to produce different results, including interface improvements (e.g., larger buttons that light up) and fewer on-screen distractions that could affect listener attention and cognitive load. In this study, SMD via QSMD(MySound) and EasyQSMD was measured to evaluate differences between the two tests.

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MATERIALS AND METHODS

QSMD Task

QSMD is a 3-Interval Forced-Choice task in which a target interval contains a spectrally modulated noise. The remaining intervals contain unmodulated noise (125 to 5600 Hz) separated by a 400-msec interstimulus interval. Target interval modulations contain one of five modulation depths (10, 11, 13, 14, and 16 dB) and two modulation rates (0.5 and 1.0 cyc/oct). Figure 1 of Gifford et al. (2014) illustrates the QSMD stimuli spectrum. Six trials are presented for each modulation depth and rate combination, totaling 60 trials. Listeners reported which sound was different by selecting the corresponding button on a computer screen.

QSMD modulation rates were chosen based on previous studies demonstrating that spectral modulation rates of 0.5 and 1.0 cyc/oct are highly correlated with consonant, vowel, and phonemic recognition (Litvak et al. 2007; Saoji et al. 2009) and are thus thought to reflect peripheral spatial selectivity rather than central auditory mechanisms. Low spectral modulation rates and larger depths were chosen specifically for the target population: CI users. Higher spectral modulation rates were not chosen as the limited number of electrodes in a CI prevents adequate spectral sampling. Lower spectral modulation rates were not chosen as they likely tax spectral profile analysis rather than peripheral spatial selectivity (e.g., Anderson et al. 2011, 2012). The modulation depths were selected based on pilot experimentation with CI recipients to represent above-chance to below-ceiling SMD (Gifford et al. 2014).

Subjects

Twenty subjects with CIs participated in this experiment. Ten were tested at the New York University School of Medicine and 10 at Vanderbilt University Medical Center. Subjects were evaluated in their every-day listening condition. All subjects gave informed consent as approved by the corresponding institutional review board.

Protocol

SMD was measured using both QSMD(MySound) and EasyQSMD. The testing software alternated after every run. The first software used by a subject was randomly selected. This was repeated until at least 3 measures were made using both software packages for each subject. Measurements were made in sound-treated booth with the listener facing a speaker 1 m away at 60 dB SPL.

RESULTS

Figure 1 displays SMD averaged across all trials, modulation rates, and depths in percent correct. The *x* axis represents average QSMD(MySound) score and the *y* axis represents the corresponding EasyQSMD score. Performance on the two tests was significantly correlated ($r = 0.965$, $n = 20$, $p < 0.001$). A paired *t* test failed to find a difference between the two tests ($t(19) = 0.549$, $p = 0.590$). Because a failure to detect a difference between groups does not mean that there is no difference between the groups, the 95% confidence interval of the difference between the groups (−1.229 to 2.101) was calculated.

The standard deviations (SDs) for each subject using the QSMD(MySound) and EasyQSMD software were calculated.

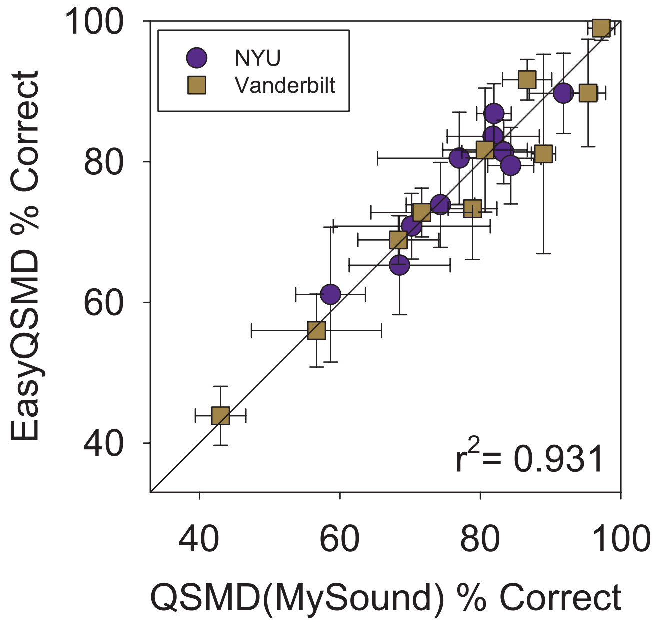

Fig. 1. Scatter plot of performance on the Quick Spectral Modulation Detection (QSMD) test measured with QSMD(MySound) and EasyQSMD software. Purple circles represent data collected at the New York University (NYU) Medical Center, while gold squares represent data collected at Vanderbilt University Medical Center. Error bars indicate ±1 SD. The black diagonal line indicates identity between QSMD(MySound) and EasyQSMD data.

No differences between the SDs for the two software packages were detected ($t(19) = 0.363$, $p = 0.721$). The absolute values of average differences observed between the two software were smaller than the SD for both QSMD(MySound) ($t(19) = 2.668$, $p = 0.0152$) and EasyQSMD ($t(19) = 26.357$, $p < 0.001$). These remain significant after Bonferroni error correction.

EasyQSMD records the duration of each run. The average duration for an EasyQSMD run was 3:47 (SD = 40 sec). Gifford et al. (2014) reported a 5- to 6-minute duration for QSMD(MySound) which included experimental setup and task description; EasyQSMD durations only measured the time spent collecting data. Because QSMD(MySound) does not record the testing duration, there were no QSMD(MySound) duration estimates for the current experiment. However, it is expected that the testing duration for QSMD(MySound) would be similar to that of EasyQSMD.

DISCUSSION

The results produced by the QSMD(MySound) and EasyQSMD software were functionally equivalent, consistent with our hypothesis. The tests produced highly correlated results, and no significant differences between the two were detected. While it is difficult to demonstrate statistically that two manipulations are identical, the 95% confidence interval for the difference between the two tests suggests that the absolute value of the true difference between the tests (if there is one) is most likely <2.1% points. Furthermore, the absolute value of the true difference is smaller than the measurement SD for each subject. Therefore, any potential differences between the tests would be difficult to detect above measurement variability with either test. Consequently, we feel comfortable recommending the EasyQSMD as a substitute for QSMD(MySound). Furthermore, direct comparison of data collected with the EasyQSMD and QSMD(MySound) can also be conducted. Although it has not been measured with the EasyQSMD, one would expect that the correlations between EasyQSMD and SMD thresholds would be similar to the ones observed in Figure 2 of Gifford et al. (2014) between QSMD(MySound) and SMD thresholds.

EasyQSMD provides a free, standardized, and easy-to-use tool to estimate SMD in CI users that allow SMD measurements to be directly compared across experiments and groups. It is hoped that EasyQSMD will be a useful tool for the CI research community and perhaps even the CI clinical community as a nonlinguistic measure of CI outcomes.

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The authors have no conflicts of interest to disclose.

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