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Handedness Effects on Transient Evoked Otoacoustic Emissions in Schoolchildren

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Abstract

Handedness, as a potentially influencing, nonpathologic factor, has not been investigated in relation to transient evoked otoacoustic emissions (TEOAEs). The present study aimed to examine the effects of handedness on the TEOAE spectrum in entry-level schoolchildren, with attention also to possible ear asymmetry. A total of 228 subjects (114 males, 114 females, mean age = 6.3 years) were tested using the ILO292 Otodynamics Analyzer (Quickscreen mode) in quiet rooms in 22 schools. For statistical analysis, subjects were matched for factors such as handedness, gender, age, and history of recent ear infection. The results from subjects with passing TEOAE, pure-tone screening, and tympanometry revealed no significant handedness effect overall, although a significant ear asymmetry effect on the measurement parameters of AB difference, noise level, response level, whole-wave reproducibility, band reproducibility, and signal-to-noise ratios was found.

Key Words: Ear asymmetry, handedness, schoolchildren, transient evoked otoacoustic emissions

Abbreviations: ABDIFF = AB difference; NOISE = noise level; REPRO = band reproducibility; REPRWH = whole-wave reproducibility; RESPON = response level; SNR = signal-to-noise ratio; TEOAEs = transient evoked otoacoustic emissions; TREPRO = transformed band reproducibility; TREPRWH = transformed whole-wave reproducibility

Sumario

La lateralidad, como un factor no patológico, potencialmente influyente, no ha sido investigada en relación a las emisiones otoacústicas evocadas por transientes (TEOAE). El presente estudio buscó examinar los efectos de la lateralidad en el espectro de las TEOAE en niños escolares de primer ingreso, atendiendo también a posibles asimetrías auditivas. Un total de 228 sujetos (114 niñas; 114 niños, con un edad media de 6.3 años) fueron evaluados utilizando el Analizador Acústico ILO292 (modo Quickscreen) en salones silenciosos de 22 escuelas. Para el análisis estadístico, los sujetos fueron agrupados con base en factores tales como lateralidad, género, edad e historia de infección reciente de oído. Los resultados en sujetos que pasaban la prueba de TEOAE, el tamizaje tonal puro y la timpanometría no revelaron un efecto global significativo de la lateralidad, aunque se encontró un efecto significativo de la asimetría auditiva en los parámetros de medición en cuanto a diferencia aéreo-ósea, nivel de ruido, nivel de respuesta, reproductividad de la onda total, reproductividad de banda y tasas de señal/ruido.

Palabras Clave: Asimetría auditiva, lateralidad, niños escolares, emisiones otoacústicas evocadas por transientes

Abreviaturas: ABDIFF = diferencia aéreo-ósea; NOISE = nivel de ruido; REPRO = reproductividad de banda; REPRWH = reproductividad de banda total; RESPON = nivel de respuesta; SNR = tasa de señal/ruido; TEOAE = emisiones otoacústicas evocadas por transientes; TREPRO = reproductividad de banda transformada; TREPRWH = reproductividad de onda total transformada

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To interpret audiologic test results accurately, it is essential that adequate investigation be made of any possible nonpathologic, influencing factors. Various effects on transient evoked otoacoustic emissions (TEOAEs), such as age, gender, and ear asymmetry, have received widespread examination and general acceptance (Kemp et al, 1990; Norton and Widen, 1990; Aidan et al, 1997; Kei et al, 1997; Newmark et al, 1997; Driscoll et al, 1999). However, to date, the factor of handedness has not been addressed in relation to TEOAEs.

Pirila and colleagues (1991) were unable to find any evidence of a handedness effect (left- versus right-handed) on hearing threshold asymmetry. Additionally, Keogh and colleagues (2001) found no significant evidence of a handedness effect on mean signal-to-noise ratios (SNRs) of distortion-product otoacoustic emissions. Handedness, however, has been associated with various behavioral asymmetries, including ear dominance (Emmerich et al, 1988; Pirila et al, 1991). Such studies involving auditory tasks such as dichotic listening have shown that right ear advantage is reversed or reduced in left-handed persons. Significant effects of handedness and ear asymmetry on the auditory P300 response have also been established (Alexander and Polich, 1997; Polich and Hoffman, 1998).

The present examination aimed to investigate the effect of handedness on TEOAE recordings obtained from schoolchildren, with attention also given to the factor of ear asymmetry.

MATERIAL AND METHODS

Data from the current study were obtained from larger, previously published investigations by the present authors (see Driscoll et al, 2000 and 2001). These studies examined gender, ear asymmetry, and history of ear infection effects on the TEOAE spectrum, along with the performance measures of TEOAE testing versus pure-tone screening with tympanometry. A total of 940 subjects were recruited from among Year 1 children who attended 22 primary schools in Brisbane, Australia. No selection criteria were used to restrict participation, which was on a voluntary basis. Full written consent was obtained from caregivers, along with a brief history of middle ear infections over the prior 2-year period (one or more episodes indicating a positive history). Children who wrote on the day of testing with their left hand were classified as left-handers, whereas those who wrote with their right hand were recorded as right-handers. In Australia, pressures against use of the left hand are restricted to small cultural minorities. The choice of left hand for writing as recorded in the present study should therefore provide a stable indicator of true bias toward the left hand (Peters, 1995).

Tympanometry and pure-tone screening were also conducted in the Driscoll and colleagues (2001) study, and the results are used in the present investigation as a strict criterion for determining normal middle ear function and hearing sensitivity in schoolchildren. Tympanometry was conducted using a Madsen Zodiac 901 Middle Ear Analyzer. Failure of this test was defined as any result that could be classified as a type B or C_2 tympanogram using the modified Jerger (1970) system. Pure-tone screening was performed using a Madsen Micromate 304, fitted with noise-excluding headsets. Thresholds greater than 25 dB HL at any of the frequencies of 0.5, 1.0, 2.0, and 4.0 kHz indicated failure of pure-tone screening.

A detailed description of TEOAE test procedure may be viewed in Driscoll and colleagues (2000). In summary, the ILO292 Otodynamics Analyzer in Quickscreen mode was used for TEOAE testing and analysis. Testing was conducted in non–sound-proofed rooms within each school, where ambient noise levels (34 to 51 dBA) were consistent with those reported by McPherson and Smyth (1997) in Brisbane schools (38 to 52 dBA). Measurement parameters of interest included AB difference or the difference between averaged waveforms in memory buffers A and B (ABDIFF), noise level (NOISE), response level (RESPON), whole-wave reproducibility (REPRWH), band reproducibility (REPRO), and SNR at 2.4, 3.2, and 4.0 kHz. Using Kei and colleagues' (1997) criterion, TEOAE results were considered a "pass" if the TEOAE spectrum was recorded at least 3 dB above the noise floor (i.e., SNR $\geq$ 3 dB) and halfway across the frequency bands of 2.0 to 3.0 and 3.0 to 4.0 kHz (as spectrums consisting of sharp, isolated peaks of very narrow bandwidths may be associated with artifactual response). A "fail" was otherwise indicated. Such a criterion was selected in view of its widespread frequency in the literature and in clinical practice.

For the purpose of examining handedness effects on TEOAE measurement parameters, three main restrictions were applied to the original database. First, data from an equal number of left- and right-handers were compared. As 153 subjects of the original 940 subjects were designated as left-handers, 153 right-handed sub-

Table 1 Mean and SD Values for TEOAE Measurement Parameters (228 Subjects)

	Mean	SD	N	Mean	SD	N
Parameters	*Left Ear*			*Right Ear*		
ABDIFF (dB)	4.07	2.63	228	4.49	2.46	228
NOISE (dB)	37.22	2.60	228	37.65	2.45	228
RESPON (dB)	14.96	4.35	227	16.30	4.49	227
REPRWH (%)	88.61	11.20	228	90.36	10.19	228
REPRO2.4 (%)	95.29	7.86	228	96.45	4.57	228
REPRO3.2 (%)	95.44	7.74	228	96.41	4.47	228
REPRO4.0 (%)	95.79	4.72	228	95.74	5.12	228
SNR2.4 (dB)	16.67	5.48	228	18.26	5.53	228
SNR3.2 (dB)	17.32	6.00	228	18.83	6.30	228
SNR4.0 (dB)	17.44	6.01	228	17.84	6.59	228

jects were selected from among the same subject group. Second, in view of previously noted nonpathologic effects on the TEOAE spectrum (Driscoll et al, 2000), the right-handed subjects were chosen to match their left-handed peers for gender, history of ear infections (one or more episodes over the prior 2-year period indicating a positive history, no episodes indicating a negative history), and age (within 1 month). The total subject number for the current handedness investigation was therefore reduced to 306 (164 males and 142 females), with a mean age of 6.3 years (SD = 0.4). A positive history of ear infection was evident in 139 subjects, whereas a negative history was recorded for 167 subjects. Third, subjects who had failed the combined protocol of pure-tone screening and tympanometry in one or both ears (17.0% of 306 subjects) and/or had failed TEOAE testing in either ear (20.3% of 306 subjects) were excluded from statistical analysis. Refer to Driscoll and colleagues (2001) for further detail regarding middle ear pathology and hearing impairment in failing subjects. The resultant database for analysis in the current investigation was composed of 228 subjects (114 female, 114 male), with a mean age of 6.3 years (SD = 0.4). A total of 111 subjects were designated as left-handed, whereas 117 subjects were right-handed. A positive history of ear infection was reported for 90 subjects, a negative history being noted for the remaining 138 subjects.

In regard to TEOAE testing of the 228 subjects, the mean noise rejection level was 51.04 dB SPL (SD = 0.19), which produced a mean percentage of quiet responses of 80.61 (SD = 14.13). The stimulus was delivered to the test ear at an average level of 79.75 dB peak SPL (SD = 2.46). The mean number of quiet responses obtained was 259.58 (SD = 6.29). Mean stimulus stability for the test group was 91.62% (range = 40 to 98%, SD = 8.78). Average test time per ear was 1 minute, 44 seconds (SD = 29 seconds).

Owing to a lack of normalcy in the distribution of REPRWH and REPRO values for the subject group, these variables were statistically transformed: TREPRWH = log (100 – REPRWH value) and TREPRO = log (100 – REPRO value), respectively. A factorial model, which included two factors (ear [left/right] and handedness [left/right]) and all interactions, was applied to the data. The significance of any term was assessed using the analysis of variance (ANOVA) for each parameter measured. Significance was set at an alpha level of .05.

RESULTS

The results from the ANOVA revealed a significant difference in all TEOAE parameters across ear, with the right ear generally displaying higher mean values: ABDIFF ($F = 5.29$, $df = 1, 226$, $p = .022$), NOISE ($F = 5.644$, $df = 1, 226$, $p = .018$), RESPON ($F = 35.523$, $df = 1, 225$, $p = < .001$), TREPRWH ($F = 12.902$, $df = 1, 226$, $p = < .001$), TREPRO ($F = 13.677$, $df = 1, 226$, $p = < .001$), and SNR ($F = 17.057$, $df = 1, 226$, $p = < .001$). In addition, a significant ear × frequency interaction was obtained for TREPRO ($F = 4.08$, $df = 2, 225$, $p = .018$) and SNR ($F = 3.602$, $df = 2, 225$, $p = .029$). No significant handedness effects on ABDIFF, NOISE, RESPON, TREPRWH, TREPRO, and SNR at 2.4, 3.2, and 4.0 kHz were found. Further interactions between factors did not achieve significance. Table 1 displays the mean and standard deviation for each TEOAE parameter for both ears.

DISCUSSION

An ear asymmetry in the TEOAE results obtained from schoolchildren was clearly evident in the present investigation and in accordance with the findings of Driscoll and colleagues (2000). To summarize, the results suggest that the right ears of the test group displayed stronger and more robust emissions than the left ears. In essence, the results from the current investigation are in agreement with literature reports of general TEOAE right ear robusticity (Robinette, 1992; Glattke et al, 1995; Kei et al, 1997).

No significant handedness effects on the TEOAE results of schoolchildren were demonstrated in the present examination. Ultimately, it may not be suggested that right-handed schoolchildren produce stronger, more robust emissions than left-handed persons. Such findings concur with Keogh and colleagues' (2001) study of handedness and DPOAE SNRs in children of a similar age. Further examination of the influence of handedness on TEOAEs, although not urgently required, is still desirable as it is possible that additional effects and interactions may have been revealed had a larger sample size been available.

CONCLUSION

In the current investigation of TEOAEs in schoolchildren, a significant ear asymmetry effect was demonstrated for all measurement parameters, with right ears displaying larger values than left ears. Conversely, the factor of handedness was not shown to significantly affect the TEOAE spectrum. Thus, for the time being, it is feasible that this factor may be safely ignored from a clinical perspective.

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