

Central Auditory Damage Induced by Solvent Exposure

Adrian Fuente
Bradley McPherson

Centre for Communication Disorders, The University of Hong Kong

Different studies have demonstrated that solvents may induce auditory damage. It has been suggested that part of this damage may be localised in central auditory pathways. The present study aimed to investigate possible auditory processing disorders related to solvent exposure. Thirty solvent-exposed workers and 30 gender-, age- and educational level-matched control subjects were selected to participate in the study. To select participants, a questionnaire, otoscopy, pure-tone audiometry and tympanometry were carried out. Filtered speech (FS), random gap detection (RGD) and hearing-in-noise tests (HINT) were conducted in the selected participants. Both groups of workers presented as a mean normal hearing thresholds. However, significant differences between groups were observed for RGD, FS and HINT. It is concluded that a possible auditory processing disorder may be related to solvent exposure.

auditory processing auditory damage hearing solvent exposure speech discrimination

1. INTRODUCTION

It has been suggested that exposure to a mixture of solvents may induce hearing loss in humans [1], and that the effect of solvents at particular frequencies may damage the inner ear to a much greater extent than noise [2]. Hearing loss induced by solvents has been found in workers exposed to a mixture of solvents [1, 2]. Some studies have found solvent-related impairment of the central auditory nervous system in workers exposed to a mix of solvents [3, 4, 5, 6, 7, 8, 9, 10]. Interrupted speech discrimination and long latency evoked potentials have been found abnormal in workers exposed to solvents [6, 7]. In workers exposed to a mix of solvents abnormal results for filtered speech and long latency evoked potentials have been reported [3], as well as for dichotic listening [10]. Moen, Riise and Kyvik [4] examined the P300 component of the auditory event-related brain potential in a group of workers exposed to

low levels of organic solvents in a paint factory and in a control group of non-exposed workers. Results indicated that the P300 latency was prolonged among the exposed workers compared to the control group before the summer vacation, and also, in the exposed group the P300 latency was significantly longer before the summer vacation than after. Steinhauer, Morrow, Condray, et al. [11] obtained similar results: a prolongation of P300 latency in painters acutely exposed to solvents, and an enhanced N250 amplitude negativity in painters even during a period of 4 days free of solvent exposure. The results were statistically significant in comparison to a non-exposed control group. Taking into consideration that solvents may induce central auditory damage, the aim of the present study was to investigate a possible auditory processing disorder that solvent-exposed workers may acquire.

2. METHODS

2.1. Selection and Description of Participants

2.1.1. Study group

Thirty workers exposed to solvents were selected (mean age 39.5 years). Participants were recruited from a paint factory in Santiago, Chile. Personal information and type of job of each worker as well as environmental solvent concentrations and noise levels in the workplace were obtained from workers' files. Subjects between 18 and 55 years with a minimum of 2 years of solvent exposure and non-exposed to noise levels above 85 dBA were considered for pre-selection. A questionnaire was conducted to select the subjects. The questionnaire aimed to exclude those subjects with the presence of confounding factors in the genesis of solvent-induced auditory damage. The exclusion criteria were history of ear disease, treatment with ototoxic drugs, arterial hypertension, diabetes, head injury, metabolic disease, kidney dysfunction, alcohol abuse, recreational exposure to noise and acoustic trauma. Also, to select the participants, otoscopy, bilateral air and bone conduction pure-tone audiometry (250–8000 Hz) and tympanometry were carried out. For inclusion in the study group, subjects were required to have absence of visible pathologic alteration of the ear canal, audiometric patterns indicating either normal hearing or sensorineural hearing loss, and Jerger type A results in tympanometry [12].

2.1.2. Control group

Control-group subjects were selected according to the same criteria as the exposed group. The only difference was that this group of persons was not exposed to solvents or other chemicals. A total of 30 control-group subjects (mean age 38.6 years) were matched for gender, age and educational level with the study group.

The study was conducted in the School of Speech and Hearing Sciences, University of Chile. Appropriate approval was obtained prior to commencement of the study from the Ethics

Committee of the School of Speech and Hearing Sciences, University of Chile. All subjects provided signed informed consent forms.

2.2. Procedure

The sample selection and evaluation procedures were conducted in a double-walled, sound-treated booth. For pure-tone audiometry a clinical audiometer (Interacoustics AC33, Interacoustics, Denmark) was used with TDH-39P headphones (Telephonics, USA) and tympanometry was conducted with a middle-ear analyzer (Interacoustics AZ7, Interacoustics, Denmark). For central auditory tests a compact disc player (LG 7311N, LG, Korea) connected to the audiometer was utilised. A 1000-Hz calibration tone recorded in each compact disc was used to determine output intensity. This procedure was carried out each time that a compact disc was played. To assess speech discrimination the hearing-in-noise test (HINT) [13] (Maico Diagnostics, USA), with a Latin American Spanish sentence module, was used. The procedures carried out in both study and control groups are discussed in sections 2.2.1. and 2.2.2.

2.2.1. Auditory processing assessment

Random gap detection (RGD) was used in order to assess temporal resolution. At 50 dB HL, stimuli comprising two tones that differed in their onset time were presented binaurally. Subjects were asked to state whether they could hear one or two tones at each presentation. Thresholds for each frequency tested (500, 1000, 2000 and 4000 Hz) and for click stimuli were calculated.

Filtered speech (FS) was used in order to assess speech discrimination for degraded verbal material. Twenty-five low-pass filtered monosyllabic words were presented monaurally to each ear at 50 dB SL. Subjects were asked to repeat each word. The percentage of correct answers was calculated for each ear.

2.2.2. Speech discrimination assessment

HINT was used in order to assess speech discrimination in quiet and in noise. To calculate the speech reception threshold (SRT) a set of

sentences in quiet were presented binaurally (HINT SRT). Subjects were asked to repeat each sentence heard. Then, to assess speech discrimination in noise, signal-to-noise ratios (SNRs) for speech discrimination were calculated for different noise conditions. HINT uses three noise conditions: noise and sentences delivered from the same location (in front of the subject), i.e., no spatial separation between the noise and the sentences (HINT 1); noise delivered to the right ear (90° azimuth) and sentences delivered to the left ear (270° azimuth) (HINT 2); and noise delivered to the left ear (270° azimuth) and sentences delivered to the right ear (90° azimuth) (HINT 3). Finally, a composite score was calculated by combining the results of HINT 1, 2 and 3.

2.3. Statistics

Mann-Whitney tests were computed in order to explore significant differences for test scores (HINT, RGD and FS) between solvent-exposed and non-exposed subjects. All the analyses were performed using SPSS version 11.5.

3. RESULTS

3.1. Pure-Tone Audiometry

Means for pure-tone thresholds (250–8 000 Hz) for both groups were equal or better than 20 dB HL.

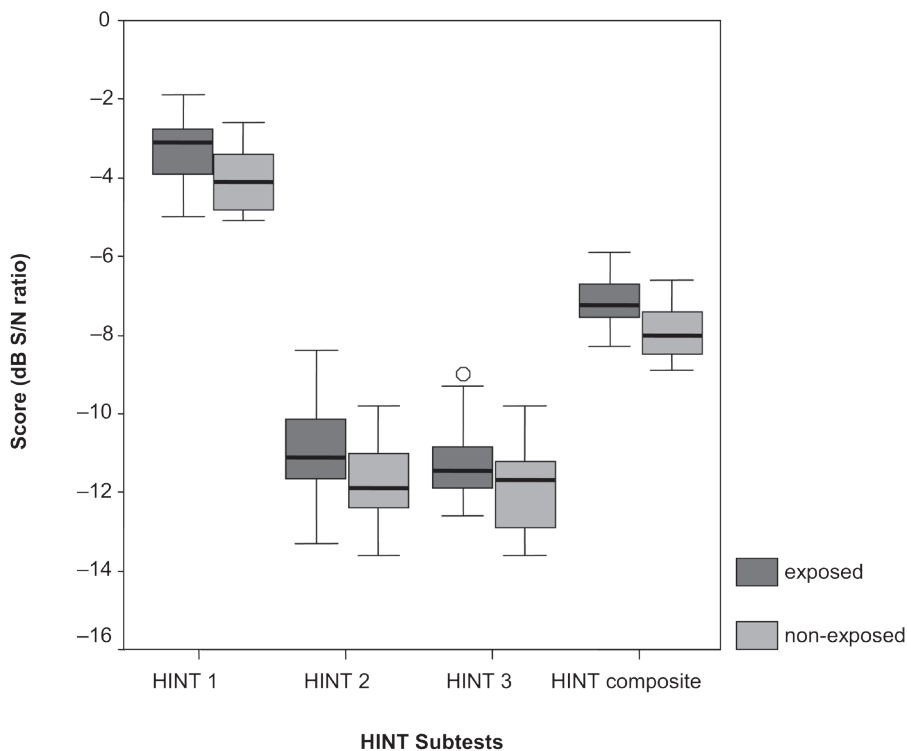


Figure 1. Boxplots of the scores of the study group ($n = 30$) and control group ($n = 30$) in hearing-in-noise (HINT) subtests. *Notes.* Scores are in dB signal-to-noise (S/N) ratio. HINT 1: noise and sentences delivered at 0° azimuth; HINT 2: noise delivered to the right ear (90° azimuth) and sentences delivered to the left ear (270° azimuth); HINT 3: noise delivered to the left ear (270° azimuth) and sentences delivered to the right ear (90° azimuth); HINT composite: score calculated combining the three HINT conditions. The boxes represent scores of 50% of cases. The line across the inside of the box represents the median value. The whiskers protruding from the box go out to the smallest and largest score values. The outlier (circle) represents values between 1.5 and 3 box-lengths from the edge of the box.

3.2. HINT Test

Mann-Whitney tests were computed for each condition measured. Statistically significant differences were found between the control and study groups for HINT SRT, HINT 1, HINT 2, HINT 3 and HINT composite ($Z = -2.73, p < .01$; $Z = -3.41, p < .05$; $Z = -2.86, p < .01$; $Z = -2.08, p < .05$; $Z = -3.66, p < .01$, respectively). Control-group subjects showed better results (dB and SNRs) when compared to solvent-exposed subjects. Figure 1 shows score distribution for both groups for HINT 1, 2, 3 and HINT composite.

3.3. RGD Test

Mann-Whitney tests were computed for each RGD subtest. Significant differences between group scores were found for RGD 1 000, 2 000, 4 000 Hz, and clicks subtests ($Z = -3.60, p < .01$; $Z = -3.98, p < .01$; $Z = -3.93, p < .01$; $Z = -2.00, p < .05$, respectively). The control group obtained lower (better) gap detection thresholds than the group of workers exposed to solvents. No significant differences between group scores were found for RGD 500 Hz subtest ($Z = -1.84, p > .05$). Figure 2 shows score distribution for both groups for the all the RGD subtests.

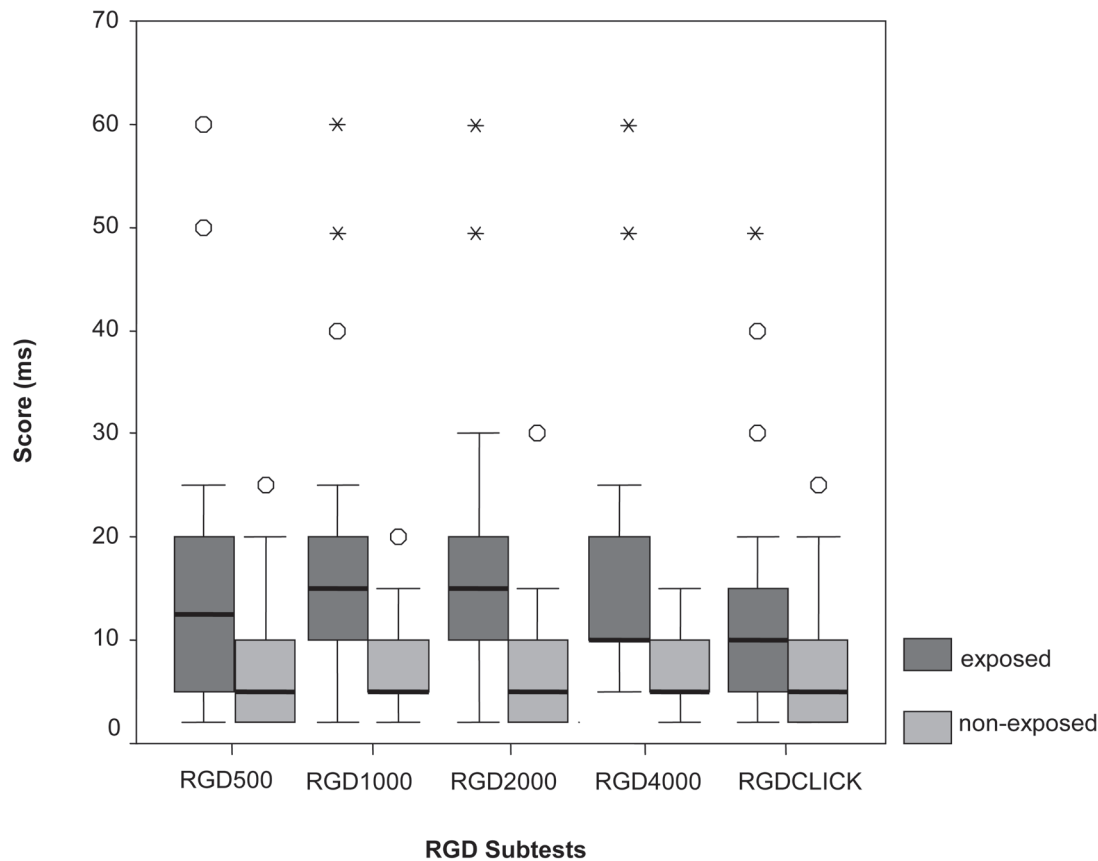


Figure 2. Boxplots of the scores of the study group ($n = 30$) and control group ($n = 30$) in the random gap detection (RGD) subtests. Notes. Scores are in milliseconds. RGD500: Subtest 500 Hz; RGD1000: Subtest 1 000 Hz; RGD2000: Subtest 2 000 Hz; RGD4000: Subtest 4 000 Hz; RGDCLICK: Subtest for clicks. The boxes represent scores of 50% of cases. The line across the inside of the box represents the median value. The whiskers protruding from the box go out to the smallest and largest score values. Outliers (circles) represent values between 1.5 and 3 box-lengths from the edge of the box. Extremes (asterisks) represent values more than 3 box-lengths from the edge of the box.

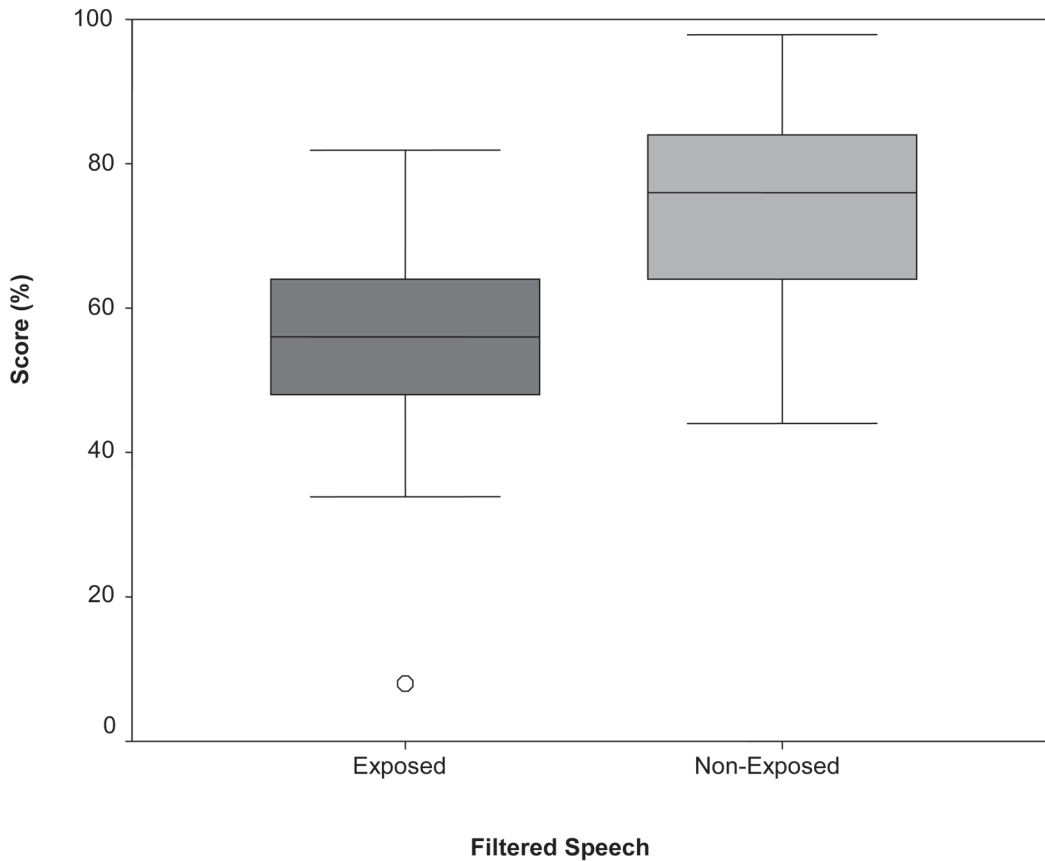


Figure 3. Boxplots of the scores of the study group ($n = 30$) and control group ($n = 30$) in the filtered speech test. *Notes.* Scores are in percentage of correct items. The boxes represent scores of 50% of cases. The line across the inside of the box represents the median value. The whiskers protruding from the box go out to the smallest and largest score values. The outlier (circle) represents values between 1.5 and 3 box-lengths from the edge of the box.

3.4. FS Test

Using Mann-Whitney test significant differences between group scores for FS were found ($Z = -4.28$, $p < .01$). Figure 3 shows score distribution for both groups for the FS test.

4. DISCUSSION

Both groups obtained mean hearing thresholds within normal ranges (equal to or better than 20 dB HL) for all of the frequencies tested for both ears. In spite of this finding, solvent-exposed subjects obtained lower scores for HINT, RGD and FS tests. HINT assesses speech discrimination abilities, thus solvent-exposed subjects showed to have difficulties to discriminate speech in the presence of background noise and in quiet. Both conditions (quiet and noise) are commonly

observed in daily life activities. Persons require to discriminate speech when being in a quiet environment (e.g., at home), and also when there is background noise such as on a bus, in church or in social gatherings. The FS test assesses the ability to discriminate degraded speech. This condition may be similar to a phone conversion (especially mobile phones when the quality of the processing voice is not optimal) or speech that is held in places with poor acoustics. For FS solvent-exposed subjects obtained lower results than non-exposed subjects. Finally, for most RGD subtests solvent-exposed subjects obtained lower (worse) scores than non-exposed subjects. The RGD test assesses temporal resolution abilities. Temporal resolution is closely related to some abilities of speech discrimination such as the perception of voice onset time.

Both FS and RGD tests assess the central auditory processing. Thus, due to the lower scores that solvent-exposed subjects obtained in these tests, it is plausible to argue that solvent exposure may be related to neurotoxicity of the central auditory pathways, and the hearing symptoms are related to a central auditory processing disorder. Central auditory damage due to solvent exposure has been already suggested [3, 4, 5, 6, 7, 8, 9, 10].

Solvents are not the only hazardous agent to hearing. In most factories where solvents or other chemicals are present, there is noise, too. An important fact that should be taken into consideration is that noise in conjunction with solvents may have a synergistic effect on hearing thresholds [14, 15, 16, 17, 18, 19]. The group of solvent-exposed workers investigated in the present research was not exposed to noise levels above 85 dBA. Thus, synergism between solvents and noise was not possible to be studied. However, according to the results, solvents alone may be inducing auditory damage, as observed in auditory processing test results. Auditory damage induced by solvent exposure may have a deleterious impact on subjects' quality of life. As observed in the present research, tests that are similar to real-life listening situations (HINT and FS) appeared to be poorer in solvent-exposed subjects than in non-exposed subjects. Much attention should be paid to workers' hearing health when solvent and especially solvents plus noise are present in workers' working environment.

REFERENCES

1. Morata TC, Engel T, Durao A, Costa TRS, Krieg EF, Dunn DE, et al. Hearing loss from combined exposures among petroleum refinery workers. *Scand Audiol.* 1997;26: 141–9.
2. Śliwińska-Kowalska M, Zmysłowska-Szmytko E, Kotyło P, Wesołowski W, Dudarewicz A, Fiszer M, et al. Assessment of hearing impairment in workers exposed to mixtures of organic solvents in the paint and lacquer industry. *Med Pr.* 2000;51:1–10. In Polish, with an abstract in English.
3. Laukli E, Hansen PW. An audiometric test battery for the evaluation of occupational exposure to industrial solvents. *Acta Otolaryngol.* 1995;115:162–4.
4. Moen BE, Riise T, Kyvik KR. P300 brain potential among workers exposed to organic solvents. *Norsk Epidemiologi.* 1999;9:27–31.
5. Niklasson M, Arlinger S, Ledin T, Moller C, Odkvist LM, Flodin U, et al. Audiological disturbances caused by long-term exposure to industrial solvents. Relation to the diagnosis of toxic encephalopathy. *Scand Audiol.* 1998;27:131–6.
6. Moller C, Odkvist LM, Thell J, Larsby B, Hyden D, Bergholtz LM, et al. Otoneurological findings in psycho-organic syndrome caused by industrial solvent exposure. *Acta Otolaryngol.* 1989;107: 5–12.
7. Odkvist LM, Arlinger SD, Edling C, Larsby B, Bergholtz LM. Audiological and vestibule-oculomotor findings in workers exposed to solvents and jet fuel. *Scand Audiol.* 1987;16:75–81.
8. Odkvist LM, Moller C, Thuomas KA. Otoneurologic disturbances caused by solvent pollution. *Otolaryngol Head Neck Surg.* 1992;106:687–92.
9. Pollastrini L, Abramo A, Cristalli G, Baretta F, Greco A. Early signs of occupational ototoxicity caused by inhalation of benzene derivative industrial solvents. *Acta Otorhinolaryngol Ital.* 1994; 14:503–12. In Italian.
10. Varney NR, Kubu CS, Morrow LA. Dichotic listening performances of patients with chronic exposure to organic solvents. *Clin Neuropsychol.* 1998;12:107–12.
11. Steinhauer SR, Morrow LA, Condray R, Dougherty GG Jr. Event-related potentials in workers with ongoing occupational exposure. *Biol Psychiatry.* 1997; 42:854–8.
12. Jerger J. Clinical experience with impedance audiometry. *Arch Otolaryngol.* 1970; 92:311–24.
13. Nilsson M, Soli SD, Sullivan JA. Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise. *J Acoust Soc Am.* 1994;95:1085–99.

14. Brandt-Lassen R, Lund SP, Jepsen GB. Rats exposed to toluene and noise may develop loss of auditory sensitivity due to synergistic interaction. *Noise Health*. 2000;3:33–44.
15. Lataye R, Campo P. Combined effects of a simultaneous exposure to noise and toluene on hearing function. *Neurotoxicol Teratol*. 1997;19:373–82.
16. Lataye R, Campo P, Loquet G. Combined effects of noise and styrene exposure on hearing function in the rat. *Hear Res*. 2000;139:86–96.
17. Makitie AA, Pirvola U, Pyykko I, Sakakibara H, Riihimäki V, Ylikoski J. The ototoxic interaction of styrene and noise. *Hear Res*. 2003;179:9–20.
18. Morata TC, Dunn D, Kretschmer LW, Lemasters GK, Keith RW. Effects of occupational exposure to organic solvents and noise on hearing. *Scand J Work Environ Health*. 1993;19:245–54.
19. Morata TC, Lemasters GK. Epidemiologic considerations in the evaluation of occupational hearing loss. *Occup Med (Lond)*. 1995;10:641–56.