Electro-encephalographic disturbances due to chronic toxin abuse in young people, with special reference to glue-sniffing

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Summary

A study was carried out in order to document any abnormalities in the electro-encephalogram (EEG) that might appear in young adolescents who have deliberately inhaled the range of volatile substances loosely referred to as 'glue'. The EEGs of a group of 'street children' being assisted in a Johannesburg shelter were examined. The records were analysed for any clinical abnormalities and also subjected to spectral analysis in order to examine the overall characteristics of frequency, power and spatial distribution. The EEGs clearly revealed that, although at the time of the examination the subjects were ostensibly abstinent, both clinical and normative evidence of continuing brain disturbance was present. It was concluded that glue sniffing is likely to have long term electrocerebral sequelae.

Inhalant abuse, an almost exclusively juvenile activity, refers to the deliberate inhalation of volatile substances. Glue sniffing is the common term used but it generally encompasses a variety of solvents or substances suitable for sniffing, including glue but also materials such as spray paint, thinners, nail-varnish remover, petrol, marking pens, and lighter fluids.

The inhaled vapours are drawn into the lungs and absorbed into the bloodstream. The effect is allegedly as rapid as an intravenous injection and depression of the central nervous system occurs quickly, producing the initial feelings of intoxication.

It is not the materials themselves that create these effects but compounds that are used in their preparation. Chemicals such as toluene and n-hexane are most frequently involved. The presence of each compound varies in proportion over a wide range of manufactured products. Manufacturers also vary the amounts of compounds used in a particular product or even substitute other substances, depending on shortages and supplies of different raw materials.

The compounds used in the manufacture of the substances sniffed are generally lipophilic, attaching to fats in the brain particularly, where they may be stored for long periods of time. The mechanisms by which these substances act on the body are not fully understood but kidney, liver, and brain dysfunctions have been reported. Although a fairly large number of studies have been carried out it is still unclear whether permanent damage occurs in persons exposed to solvents generally, or whether such effects have more often been highlighted in the context of habitual solvent abuse.

Studies on changes in the electro-encephalographic (EEG) activity of the brain after solvent abuse or exposure have yielded inconsistent results. In general, the recordings have been carried out at different stages of recovery after inhalation and some positive results reflect acute rather than permanent central nervous system disturbances. At least some studies suggest that despite a long exposure among printers and lacquers to mixed solvents or to toluene, no EEG abnormalities could be detected. More often, however, the EEG does seem to reflect some disturbance of central nervous system function.

Acute effects of benzene (a highly toxic aromatic hydrocarbon previously used in the manufacture of plastic cements and glues) and toluene on the EEG patterns of cats have been described. Contreras et al. reported that benzene inhalation produced generalised hypersynchronous rhythms, which were immediately followed by clonic-tonic seizures. Similarly, induced benzene or toluene intoxication has been shown to be capable of producing 3/5 spike-wave activity, similar to that seen in human solvent abusers.

Studies of brain function after acute solvent sniffing suggest that the effects may be transient. Brozovsky and Winkler found that 6 out of 10 hospitalised solvent-abusers had abnormal EEGs. Three cases showed spikes in the temporal area while another individual showed sharp waves in the left centrotemporal zone. However, after a 2-week follow-up period the EEGs were repeated and found to be normal. King et al. reported 3 cases of solvent abuse with abnormal EEG patterns showing diffuse slow-wave activity in 2 cases and unilateral slowing in the other. The EEGs were repeated after 3 weeks and found to be normal.

On the other hand, chronic exposure to solvents appears to lead to long-term if not permanent nervous system dysfunction. This frequently occurs in occupational contexts and Seppalanen has thoroughly reviewed a large number of studies in this regard. In one of her own investigations, where high concentrations of toluene were found in the work areas concerned, car painters showed a high incidence of abnormal EEG patterns. The recordings indicated localised and paroxysmal abnormalities. Although these findings were not interpreted as being conclusive (since similar patterns of abnormalities were found in a reference group of railroad engineers), another group of researchers have reported persistent EEG abnormalities in a group of Italian workers exposed in a shoe factory to high concentrations of solvents containing n-hexane.

The present enquiry was undertaken to examine possible EEG indicators of effects on central nervous system functioning after voluntary chronic but suspended volatile solvent inhalation by a group of adolescents.

Subjects and methods

The research was carried out in the course of work concerning the behaviour and family backgrounds of 97 'street children' in Johannesburg. This term has been used to describe the homeless, abandoned or runaway children who live and work
on the streets of our cities. Many of them fall prey, *inter alia*, to the sniffing of solvents in an attempt to cope with the hazards of their lifestyle.14 Twenty-two of the boys in this group were known solvent abusers. This was admitted by them and confirmed by at least three independent persons involved with the children as child care workers attached to the shelters caring for the boys. The length of time the boys had been involved in glue sniffing varied but was roughly linked to the time they had spent on the streets, which ranged between 6 months and 36 months (mean 16.89 months). During this time most of them had sniffed intermittently throughout the day, the majority reporting especially heavy night-time sniffing. Although some of the boys were vague when asked to estimate the amount of glue they had used, 10 of them reported having sniffed 7 containers (i.e. 1750 ml) per week and others about half that amount.

The boys involved in the study had entered the shelters, on average, 2.48 years before we examined them. According to our sources none of them had sniffed glue subsequently. Although the period of abstinence had therefore been relatively long for many of the boys, it was not statistically significantly different; however, for each of the other four assessments the sniffers were markedly different from the normal group, as reflected in statistically significant chi-square values. Forty-five per cent of the sniffers showed abnormal records in comparison with 9% of the normal group, and 27% of the boys who had sniffed glue had some form of paroxysmal discharge in their EEGs, compared with only 4% (that is, only 1 subject) in the normal group. In the latter case the paroxysmal activity took the form of generalised brief runs of high voltage theta activity. This form of activity was present in 14% and augmented by epiileptiform features in 5% of the sniffers. The abnormalities subsumed under the headings 'maturation' and 'nonspecific' mostly concerned excessive theta activity.

### Results

A comparison between the sniffers and the normal group was made in respect of their clinical EEG characteristics (Table 1). The interhemispheric synchrony shown by the two groups was not statistically significantly different; however, for each of the other four assessments the sniffers were markedly different from the normal group, as reflected in statistically significant chi-square values. Forty-five per cent of the sniffers showed abnormal records in comparison with 9% of the normal group, and 27% of the boys who had sniffed glue had some form of paroxysmal discharge in their EEGs, compared with only 4% (that is, only 1 subject) in the normal group. In the latter case the paroxysmal activity took the form of generalised brief runs of high voltage theta activity. This form of activity was present in 14% and augmented by epiileptiform features in 5% of the sniffers. The abnormalities subsumed under the headings 'maturation' and 'nonspecific' mostly concerned excessive theta activity.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sniffers (N = 22)</th>
<th>Non-sniffers (N = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interhemispheric synchrony</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent/poor</td>
<td>32</td>
<td>25</td>
</tr>
<tr>
<td>Good</td>
<td>63</td>
<td>75</td>
</tr>
<tr>
<td>Very good</td>
<td>5</td>
<td>0</td>
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<tr>
<td>Abnormality rating</td>
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<td></td>
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<tr>
<td>Normal/normal limits</td>
<td>54</td>
<td>67</td>
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<tr>
<td>Mild/moderate</td>
<td>27</td>
<td>8</td>
</tr>
<tr>
<td>Abnormal</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>Paroxysmal bursts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>27</td>
<td>16</td>
</tr>
<tr>
<td>Absent</td>
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<td>84</td>
</tr>
<tr>
<td>Abnormality location</td>
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<tr>
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<tr>
<td>Generalised</td>
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<td>0</td>
</tr>
<tr>
<td>Nonspecific</td>
<td>18</td>
<td>8</td>
</tr>
</tbody>
</table>

The clinical impression of a preponderance of theta activity was confirmed to some extent when the background EEG was examined in terms of spectral features. The spectral power across the 16 recording electrodes as a group was statistically assessed by using a multivariate analysis of variance when comparing the two groups of boys for the total EEG band and each of the traditional frequency bands separately. Further, the ratios between slow and fast activity, and between theta and alpha activity were calculated for each subject and the groups compared, for all electrode positions considered together, again using a multivariate analysis of variance. In no comparison could a statistically significant group effect be demonstrated.

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Nevertheless, Figs 1 - 3 reveal a consistent trend across the whole head for raised theta and lowered beta2-power for the glue-sniffers in comparison with the normal group.

![Graph 1](image1)

**Fig. 1.** Relative spectral values for theta band (Manova lambda = 0.567; F = 1,385; df = 16 and 29; P = 0.2).

![Graph 2](image2)

**Fig. 2.** Relative spectral values for beta band (Manova lambda = 0.722; F = 0.698; df = 16 and 29; P = 0.8).

![Graph 3](image3)

**Fig. 3.** Theta/alpha spectral power ratios (Manova lambda = 0.668; F = 0.901; df = 16 and 29; P = 0.6).

**Discussion**

The EEG abnormalities observed among the glue-sniffing boys correspond with those described in previous studies of workers who have been chronically exposed to solvent inhalation, namely increased slow activity and sometimes epileptiform features.10,15,17 Similarly, these phenomena shown by the boys in the present study were both generalised and localised, as was also found by other workers.17,18

The presence of epileptiform activity without the overt emergence of seizures is not unusual, both generally — since the subjects in the present study were not yet adult — and in the sense that the same phenomenon was found by Seppalainen17 among workers chronically exposed to solvent fumes. The lack of inhibitory cerebral mechanisms among young persons is sometimes reflected in theta bursts in this age group.19 What does seem noteworthy, however, was that this activity was more prevalent among the glue-sniffers than the normal group and that this raised incidence had persisted despite the boys having stopped their glue-sniffing activities for some time.

Several reports have appeared in which the disturbance of sub-cortical control mechanisms has been linked to solvent inhalation. This work was done with rats and rabbits and showed that toluene can change the nature of sleep EEG patterns, preventing or lessening slow-wave sleep, although prolonging, the onset of paradoxical sleep.20-23

The propensity of the glue-sniffers for showing more slow activity could not be supported statistically from the spectral analyses but an inspection of the data reveal that the tendency was very uniform across the head and held both for theta, and to a lesser extent, for delta activity. Similarly, alpha and beta activity in the various areas of the head tended more often to be curtailed by comparison with that shown in the normal boys.

The overall impression, therefore, is one of depressed electro-cerebral functioning, as reflected in increased slow activity in the EEG. Some workers have reported that the total spectral power of the EEG may as much as double following chronic toxic-solvent exposure and, although declining with time, it will remain above normal levels.24 Our results did not follow this trend, but it is possible that the chronicity of exposure and the specificity of the solvent involved in the present study may have influenced the results.

The finding of abnormal EEGs, despite the fact that the boys were no longer sniffing glue, is in accordance with similar reports in the occupational domain (for example, Passero et al.).12 Seppalainen and Anti-Poika25 reported that EEG abnormalities were still evident in about 50% of patients several years after exposure to solvent poisoning. It would be necessary to follow up the present subjects for some time to make exact comparisons, since the period of abstinence of the subjects in the present study was not constant nor, in some cases, extended. Nevertheless, over the time-span covered, the effects of the glue-sniffing appear to be persistent.

What is particularly disturbing about these results is that they suggest an interference, following inhalant abuse, during an important period of bodily growth in general and a possible 'spurt' in neurophysiological growth in particular.26 Excessive exposure to solvents during pubescence can possibly affect growing tissues even when concentrations of the substances are too low to have any effect on adult cells and tissues.27

In conclusion, it should be stressed that EEG phenomena cannot be seen in isolation, but that they are reflections of central nervous function at some level or another that inevitably have implications for the behaviour of the individual. Although Dodds and Santostefano28 were unable to show any effect of glue-sniffing on 'cognitive' test performance, the boys in the present study demonstrated multiple deficits on neuropsychological tasks, including visual-spatial difficulties, visual-scanning problems, language deficiencies, motor inco-ordination, memory deficits and attentional and concentration problems.29

These results were obtained with standard neuropsychological procedures including: the Token Test, Picture Completion,
Block Design, Visual-Motor Gestalt Test, Trail Making Test, Majovski's Screening Instrument, Rant Memory Test, Aptitude Test for School Beginners, the Jesness Inventory, Locus of Control, Lateralisation Procedures, a measure of grip strength using a hand dynamometer and a standard neurological screening.

Further studies of this kind would benefit from including not only detailed neuropsychological assessment but also evoked potential measures. Subjects exposed to n-hexane and other substances found in solvents reportedly show marked changes in their brain responses to discrete stimuli. Various other types of evoked electrophysiological activity, including nerve conduction velocities, are also promising avenues of research.

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REFERENCES