Int J Biometeorol (1990) 34:35–41

International Journal of Biometeorology IJB

Differential negative air ion effects on learning disabled and normal-achieving children

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Received October 17, 1988; revised September 26, 1989 / Accepted September 26, 1989

Abstract. Forty normal-achieving and 33 learning disabled (LD) children were assigned randomly to either a negative ion or placebo test condition. On a dichotic listening task using consonant-vowel (CV) combinations, both groups showed an ion-induced increase in the normal right ear advantage (REA). However, the mechanisms for this effect were different for each group. The LDs showed the effect at the right ear/left hemisphere (enhancement). The normal achievers showed the effect at the left ear/right hemisphere (inhibition). The results are consistent with an activation-inhibition model of cerebral function and suggest a functional relationship between arousal, interhemispheric activation-inhibition, and learning disabilities. The LDs may have an interhemispheric dysfunction. Both groups showed superior right ear report and the normal achievers showed overall superiority. Normal achievers showed higher consonant intrusion scores, probably due to a greater cognitive capacity. Age was a significant covariate reflecting developmental capacity changes. Negative air ions are seen to be a tool with potential theoretical and remedial applications.

Key words: Negative air ions – Learning – Cerebral function – Children – Learning disabled children

Introduction

Negative air ions have been shown to have positive effects on a variety of biological subsystems (Kotaka 1978). Such findings, though often controversial, remain intriguing. Of interest for the present study is the supposed serotonin (5-hydroxytryptamine, 5-HT) reduction following exposure to negative air ionization (Diamond et al. 1980; Gilbert 1973; Krueger et al. 1963; Krueger and Kotaka 1969) perhaps due to a negative ion-induced increase in oxidative deamination (Krueger and Smith 1960).

The serotonin reduction may lead to beneficial effects on information processing. There is a literature base showing that high levels of serotonin can interfere with learning, and presumed reductions in serotonin (drug-induced or ion-induced) may facilitate learning.

Firstly, high levels of central serotonin have been shown to interfere with memory consolidation and protein synthesis in the synaptosome fraction in mice (Essman 1973, 1974). Also, serotonin appears to inhibit neural firing at the level of the diencephalon, inhibiting the flow of information to higher cortical levels in rats (Rogawski and Aghajanian 1980). Furthermore, some descriptive studies have linked high blood platelet levels of serotonin with such learning problems as mental retardation (Hanley et al. 1981; Oikawa et al. 1979; Pare et al. 1960; Schain and Freedman 1961) and attention disorders (Goldman et al. 1979; Irwin et al. 1981). Thus high levels of serotonin could be viewed as detrimental so far as learning is concerned.

Secondly, there is evidence that the serotonin-reducing drug, fenfluramine, benefits some learning impaired (autistic) children. When autistic children were given fenfluramine they showed IQ score gains and improved behavior concurrent with the serotonin reduction (Geller et al. 1982). Generally, high levels of serotonin appear detrimental, whereas, reduction in serotonin appears to be potentially beneficial. Similarly, the hypothesized ion-induced serotonin reduction would be consistent with favorable learning effects. In animal studies, learning (maze learning time and error rates) seems to be enhanced for older male rats under negative air

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ionization (Jordan and Sokoloff 1959), and positive and negative air ionization (Duffee and Koontz 1965).

Although air ion studies of human responses tend to explore physiological effects (Kotaka 1978; Sulman et al. 1978) and mood effects (Hawkins 1981), two previous studies (Morton and Kershner 1984, 1987) have noted intriguing effects on human memory and attention. Morton and Kershner (1984) noted (i) enhanced incidental recognition memory for three groups of subjects (normal-achieving, learning disabled, and educable retarded children); (ii) normalization of the right ear advantage (REA) on a dichotic listening task for the learning impaired subjects; and (iii) a counter-priming effect on the dichotic listening task, also for the learning impaired subjects. The learning impaired subjects manifested, under placebo, the typical dichotic REA when directed to attend right first, similar to the normal achievers. Yet, when they were directed to attend to the left ear first they did not show the REA, whereas, the normal-achievers did. The negative ions produced a normalization effect in the impaired subjects, when directed left first. There was now a REA which tended to off-set at least one aspect of the attentional difficulties they were showing in dichotic performance under placebo. In addition, there was a counter-priming effect when directed right first. Being directed right first tended to enhance subsequent left ear performance.

The second study (Morton and Kershner 1987) was conducted with a group of trainable retarded subjects and similar dichotic effects were noted. There was a normalization of the REA in several test conditions under negative ions which was not evident under placebo. Although the effects were not viewed as necessarily favorable in this study, they did suggest ion-induced alterations in information processing.

Limitations in the previous studies (i.e., small sample size, and inadequate control groups) were addressed in the present study. In addition we utilized a different type of dichotic stimuli (i.e., consonant-vowel combinations). On the basis of the two previous dichotic studies and the rationale developed, it was predicted that the negative air ionization would improve information processing (i.e., normalize the REA) in those subjects with learning problems.

Methods

Subjects. The sample, drawn from six urban and rural schools, was comprised of 33 learning disabled children (28 males and 5 females; mean age = 12.32 years, SD = 1.39) who had been placed in special education classes. The control group of 40 comprised randomly selected normal-achieving children within the same age range, and with a roughly similar sex distribution (29 males and 11 females; mean age = 11.91 years, SD = 1.06). Routine pure-tone, audiometric screening indicated that none of the subjects had abnormal hearing.

Intelligence was assumed to be average for normal-achieving students. Test scores (WISC-R) on the learning disabled placed them within the lower end of the average range (Full Scale mean = 86.0, SD = 12.14; Verbal Scale mean = 82.37, SD = 14.14; Performance Scale mean = 92.29, SD = 12.65), with a large spread between verbal and performance scales (mean = 13.18, SD = 10.65). These low scores and the spread between verbal and performance scores are not unusual in the learning disabled population.

Handedness was determined by self-report and observation. Nine learning disabled and three normal-achieving subjects indicated left-handedness. Statistical comparisons between left- and right-handed subjects, on all dependent variables, revealed no significant differences between these groups.

The children were assigned randomly to either a negative ion group ($n = 35$), or an unmodified classroom-air placebo control group ($n = 38$).

Apparatus. Negative ions were generated by corona discharge using a Biotech, Bionaire 2000 generator. The manufacturer reports the negative ion mobility at the source as 2.1×10^{-4} m^2/V-s. The generator was tested by UL and CSA for ozone generation which was found to be at trace background levels (less than 0.04 ppm). Furthermore, the manufacturer reports (personal communication) that organizations that monitor standards (Underwriters Laboratories (UL), Canadian Standards Association (CSA), and Verband Deutscher Elektrotechniker (VDE) of Germany) do not consider nitrate generation to be a relevant hazard with this generator since hardened stainless steel emitter points are used.

Ion density was measured with a Biotech electroscope, BT400. According to the manufacturer (personal communication) each unit is calibrated by current injection and the correlation between ion density and current was determined empirically using the aspiration-type ion counter (Medion Type 134A) with limiting mobility 0.05 cm^2/s per V.

The dichotic tape consisted of 30 trials of six different consonant-vowel (CV) combinations (baw, caw, daw, gaw, paw, taw). The stimuli were presented in a random order at 5.5-s intervals on a TEAC 160 Stereo (dual channel) Cassette Deck C47 through Realistic NOVA 40 headphones connected in series to permit group testing. The averge signal amplitude for each channel was set at approximately 65 dB.

Procedure. Subjects were tested in groups of four under single-blind conditions in various small rooms. The generator was set approximately 2 m from the subjects who were exposed to either negative air ions or unmodified classroom air. Subjects were not intentionally grounded since our purpose was to explore practical effects in a normal environment as in previous studies (Morton and Kershner 1984, 1987). Measurements of negative ion densities were made about 20 cm from the subject's face and typically ranged from 1000 to 10000 small negative ions per cubic centimeter of air when the generator was on. The fluctuations appeared to be due to movement-induced air currents in the room. When the 'fan-only' was on we were unable to detect any negative air ions within the room, which may reflect the limitations of the electroscope used for measurement.

In view of the reported decrement in alpha frequency after approximately 6 min exposure to increased levels of negative ions (Silverman and Kornblueh 1957) subjects were allowed 5 to 6 min to acclimatize. Although we were not convinced of the reliability of the Silverman and Kornblueh (1957) finding, the brief acclimatization period was consistent with previous research (Morton and Kershner 1984, 1987). During this time the children filled out answer forms indicating name, age, etc. and were given a brief explanation of the task.

The children were provided with a sheet of paper containing 30 lines of the six different CV combinations and told that these were made-up words which rhymed. They were asked to read each "word" after the experimenter had first read the list. One subject was excluded since he was unable to pronounce clearly all six sounds. The subjects were then told they would hear one of these words in one ear and another word in the other ear. In the free-report condition they were to circle the CV heard after each trial. In the directed-report condition they were to attend to one ear on one-half of the trials (30 trials) and report (i.e., circle) the CV heard with that ear. Then they were required to switch to the other ear for the remaining trials (30 trials) and report the CV heard with that ear. Headsets were reversed between left and right attending conditions to offset any signal-to-noise ratio differences. One-half of the subjects were directed to attend to the left ear first while the other half were directed to attend to the right ear first.

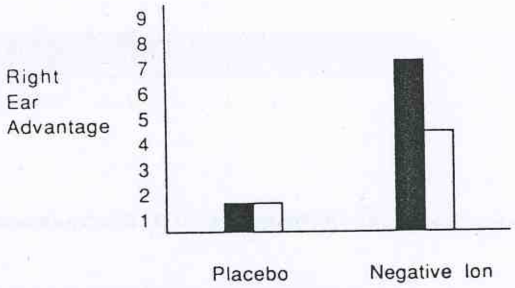

Fig. 1. The right ear advantage (REA) scores (R – L) when directed right fist for learning disabled and normal-achieving children under placebo and negative ions, showing the increase in REA for both groups under negative ions. ■ Learning disabled; □ normal achieving

Results

The dichotic data were considered in terms of total report in both free-report and directed-report conditions, and intrusions from the nonattended ear in the directed-report condition. Preliminary analyses indicated no differences between groupings based on sex or handedness. Age was a significant covariate for one analysis and therefore was included in the analyses of covariance (ANCOVA).

First, a three-way ANCOVA, using age as the covariate, with Group (learning disabled, normal-achieving), Ion Condition (negative ion, placebo), and Ear (left, right) as the independent variables, was computed for the free-report data. There was a main effect for Group [$F(1, 68)=14.79$, $P<0.0001$], due to normal achievers reporting more CVs (mean = 10.24) than the learning disabled (mean = 8.75), and a main effect for Ear [$F(1,69)=37.92$, $P<0.0001$], due to superior right ear report (mean = 11.27) compared to left ear report (mean = 7.72). Also, there was a significant Ion Condition by Ear interaction [$F(1, 69)=7.21$, $P<0.01$], due to superior right ear report under negative ions with a concurrent depression of left ear report (see Table 1). The covariate (Age) was nonsignificant ($F<1$).

In the directed-report condition a four-way ANCOVA (Group by Ion Condition by Ear Attended First by Ear), using Age as the covariate, was computed on the correct CVs reported. There was a main effect for Group [$F(1,64)=14.72$, $P<0.001$], with normal achievers reporting more CVs (mean = 11.26) than the learning disabled (mean = 9.2), a main effect for Ear [$F(1,65)=39.62$, $P<0.0001$], due to superior right ear report (mean = 12.08) compared to left ear report (mean = 8.37), and a main effect for the covariate [$F(1,64)=4.18$, $P<0.05$]. Also, there was a significant Group by Ear Attended First interaction [$F(1,64)=6.33$, $P<0.01$], and a significant Ear by Ear Attended First by Ion Condition interaction [$F(1,65)=5.45$, $P<0.05$].

To explain these interactions, tests for simple main effects were computed. These tests revealed that the learning disabled showed increased right ear report under negative ions but only when directed to attend right first [$t(14)=2.30$, $P<0.05$]. The normal achievers showed a reduced left ear report under negative ions when directed right first [$t(19)=3.76$, $P<0.01$], (an enhanced right ear priming effect). Thus, there is an increase in the REA under negative ions (see Fig. 1) but the mechanism is different for learning disabled (see Fig. 2a) and normal-achieving subjects (see Fig. 2b). The learning disabled show an ion-induced increase in reporting right ear CVs, when directed to attend right first. The normal achieving show an ion-induced reduction in left ear report when directed to attend right first.

A similar four-way ANCOVA (Group by Ion Condition by Ear Attended First by Ear) was computed on the CV intrusion data (i.e., CVs reported from the nonattended ear). There was a main effect for Group [$F(1,64)=10.29$, $P<0.002$], due to normal achievers reporting more intrusions (mean = 10.57) than the learning disabled (mean = 8.88), and a main effect for Ear [$F(1,65)=37.64$, $P<0.0001$], due to more intrusions when directed left (mean = 11.54) than when directed right (mean = 7.90). Also, there was a significant Group by Ear Attended First by Ion Condition interaction [$F(1,64)=3.85$, $P<0.05$]. Subsequent tests for sim-

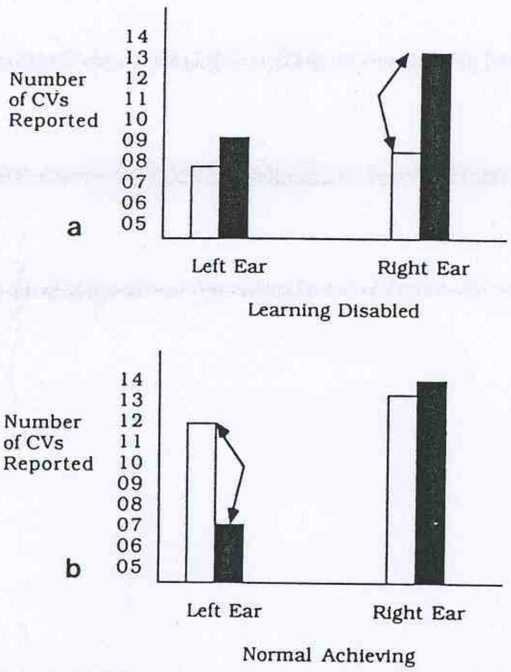

Fig. 2a, b. The mean number of consonant-vowel (CV) combinations reported for the left and right ears under placebo and negative ions when directed right first for **a** the learning disabled and **b** the normal achieving. Note the negative ion-induced increase in right ear report for the learning disabled (**a**) and the negative ion-induced decrease in left ear report for the normal achieving (**b**). ■ Negative ion; □ placebo

Table 1. Mean number of correct consonants from each ear on the free-report dichotic listening task

Ear reported	Learning disabled		Normal achievers	
	Mean	SD	Mean	SD
Left ear				
Negative ion	7.13	2.16	7.00	2.90
Placebo	7.55	2.79	9.20	2.19
Right Ear				
Negative ion	10.73	2.69	13.60	3.79
Placebo	9.61	3.24	11.15	3.34

Maximum score per ear = 30

Table 2. Mean number of correct consonants from the attended ear on the directed-report dichotic listening task

Ear reported	Learning disabled		Normal achievers	
	Mean	SD	Mean	SD
Attending left:				
Directed left first				
Negative ion	7.33	2.50	9.36	3.35
Placebo	6.13	1.73	9.25	3.11
Directed right first				
Negative ion	8.83	5.15	6.67	3.08
Placebo	7.50	3.34	11.92	3.23
Attending right:				
Directed left first				
Negative ion	10.33	4.80	13.55	3.30
Placebo	11.88	3.87	12.50	3.25
Directed right first				
Negative ion	13.17	4.62	13.67	4.18
Placebo	8.40	3.63	13.17	3.16

Maximum score per ear = 30

Table 3. Mean number of consonant intrusions from the nonattended ear on the directed-report dichotic listening task

Ear reported	Learning disabled		Normal achievers	
	Mean	SD	Mean	SD
Attending left:				
Directed left first				
Negative ion	9.00	2.65	13.09	3.53
Placebo	11.75	4.23	11.00	5.35
Directed right first				
Negative ion	11.50	5.54	13.89	2.80
Placebo	9.70	3.83	12.42	3.50
Attending right:				
Directed left first				
Negative ion	6.55	1.13	9.00	3.58
Placebo	8.63	2.83	8.00	3.38
Directed right first				
Negative ion	5.83	2.14	7.22	1.86
Placebo	8.10	2.28	9.92	3.06

Maximum score per ear = 30

ple main effects revealed that the interaction was due to a reduction in intrusions from the left ear for the normal achieving, under negative ions, when directed right first [$t(19) = 2.33$, $P < 0.05$]. This is consistent with a strengthened right ear report and a left ear/right hemisphere depression in this group. The covariate Age was nonsignificant ($F < 1$). Tables 1–3 present the means and standard deviations for the CV data.

In summary the data indicate, first, that both groups of subjects show a preference for right ear reporting, and thus, would be considered left hemisphere dominant for language. Secondly, the learning disabled show generally inferior performance when compared to normal subjects. Thirdly, negative ions enhance the REA for both the normal achievers and the learning disabled. However, the mechanism for enhancing the REA is different for the two groups.

The covariate (Age) is significant in the directed-report condition for correctly reported CVs. Presumably, this reflects changes in developmental capacity under the more stringent directed-report conditions.

Discussion

Negative air ionization is seen to affect dichotic processing. For the free-report data there was an ion-induced increase in right ear report and a decrease in left ear report. Differential effects were seen for the two groups from the directed-report data. The hypothesis predicting an ion-induced increase in the REA for the learning disabled was supported. In fact, the negative ions were seen to enhance the REA of both the learning disabled and the normal achievers. However, there were different mechanisms for achieving this effect in each group. When directed right first, the negative ions increased the right ear report of the learning disabled but decreased the left ear report of normal achievers.

This differential effect suggests interhemispheric processing differences for learning disabled and normal-achieving children. Apparently, the normal achieving have a fully active left hemisphere for processing CVs and the only interhemispheric effect is inhibition of the right hemisphere. The learning disabled may not have a fully active left hemisphere since exposure to negative ions increases left hemisphere processing efficiency. This may indicate a left hemisphere dysfunction in the learning disabled which is responsive to negative air ions.

In addition, the learning disabled may be showing a right hemisphere dysfunction. When attending left, but directed to attend right first, the normal achievers showed a left ear/right hemisphere depression (a right ear/left hemisphere priming effect). The learning disabled did not show this inhibitory effect which may indicate a less responsive right hemisphere (Hynd et al. 1987; Obrzut et al. 1981).

The predictable right ear/left hemisphere priming effect for digits (Hiscock and Kinsbourne 1980; Hiscock et al. 1979) has not been found previously for CVs (Hiscock and Stewart 1984). However, the previous CV study was limited to adult subjects. Thus, the priming effect noted here is novel and indicates that negative ions facilitate priming effects with CVs in normal-achieving children. Thus age, arousal and interhemispheric relations may be important variables for priming effects and should be considered along with stimulus differences.

The priming effect is noticeably missing in the learning disabled. In fact, the means suggest an ion-induced counter-priming effect in this group. A right ear counter-priming effect under negative ions was evident in previous studies (Morton and Kershner 1984, 1987); thus, the absence of a priming effect is not surprising. The absence of the priming effect for the learning disabled in the present study is consistent with an interhemispheric imbalance – a dysfunctional right hemisphere which could obscure the observation of a right ear (left hemisphere) priming effect inhibiting the right hemisphere.

Moreover, when normal achievers were directed right first there was an ion-induced decrease in intrusions from the nonattended left ear. This also reflects a left ear/right hemisphere depression only in response to negative air ionization. The learning disabled on the other hand showed low right hemisphere (left ear) responses in both placebo and negative ion conditions (see Fig. 2a). The right hemisphere of the learning disabled does not show the same interhemispheric interplay as in normal-achieving children.

Assuming the effects are due to ion-induced arousal, the findings indicate a differential response to increased arousal for normal-achieving and learning disabled children. The learning disabled show enhanced left hemisphere processing but they appear to lack normal right hemisphere effects. This is evident from the data showing that normal achievers show ion-induced left ear/right hemisphere suppression in (1) a right ear priming effect and (2) a reduction in left ear consonant intrusions when directed right first. The normal achievers seem to manifest a right hemisphere inhibition as a result of the increased ion-induced arousal.

The learning disabled do not show right hemisphere fluctuations or increased right hemisphere proficiency. This finding conflicts with a series of studies conducted by Obrzut and his associates (Obrzut et al. 1981, 1983, 1985), in which the learning disabled showed higher than normal left ear report of CVs indicating a failure to inhibit the right hemisphere. In the present study the learning disabled showed a somewhat lower left ear report, consistent with studies noting low left ear scores and low right hemisphere activity in the learning disabled (Cooke 1986; Hynd et al. 1987; Shucard et al. 1984).

Interpreting these effects within the framework of an activation-inhibition model of cerebral asymmetry (Denenberg 1984) would suggest that the learning disabled are unable to achieve interhemispheric balance in a manner comparable to normal achievers. Presumably, the negative ions are increasing the general cerebral arousal level which facilitates left hemisphere processing only for the learning disabled group. Thus, one aspect of the learning difficulties of the learning disabled may be an underaroused left hemisphere (Witelson 1977).

The positive enhancement of the REA (the right ear preference for verbal stimuli) for the learning disabled and the normal achievers under negative ions is encouraging even though it is achieved via different routes for the two groups. A right ear advantage, or preference, is expected from most normal subjects and is often absent in the abnormal (Kimura 1967; Pipe and Beale 1983; Obrzut et al. 1981). The learning disabled show enhanced left hemisphere processing. The normals show stable left hemisphere processing concurrent with right hemisphere inhibition. Both effects are neuropsychologically positive.

Differences between this study and the two previous studies may be related to a number of methodological changes. First, different dichotic stimuli were used. The first two studies used digit triads only, and a warning stimulus was used prior to each trial which could have facilitated the orienting/attending response. Secondly, the response requirements were different. A graphic response (i.e., circling the correct answer) was required in the present study, whereas an oral/verbal response was required in the previous studies. Thirdly, subjects were group tested in the presence of their peers, whereas subjects were tested individually in the first two studies. Nevertheless, the predicted enhancement for the REA was demonstrated.

The superior performance of the normal achievers, the superior right ear report for both groups, and the significance of the covariate, Age, are standard and predictable effects. Although the normal achievers showed more intrusions, this appears to be due to a general capacity advantage, as is evident from the overall total report.

In view of the fact that anomalous ear advantage scores are often associated with learning problems (Kershner 1985; Obrzut et al. 1981; Pipe and Beale 1983; Zekulin-Hartley 1981) a therapy that seems to enhance the REA could prove significant for both theoretical development and remedial applications. Moreover, ion-induced differences between normal achievers and exceptional students may contribute to an understanding of the attentional mechanisms involved and their dysfunction. Considering our results as a furtherance of previous research (Morton and Kershner 1984, 1987) on the negative ion effect, these positive effects would seem to achieve some credibility. Although it would be premature to recommend negative ion generators for educational environments, there seems to be converging evidence suggesting that the research focus should include both remedial and theoretical areas.

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