FOREWORD

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ABSTRACT

The performance effects of excesses of unipolar atmospheric ions were investigated. Seventy subjects were tested on a complex mental task, and an additional 70 were tested on a complex vigilance task. Seven ion concentrations were investigated with each task: high positive, high negative, medium positive, and medium negative; three control conditions were also used: high positive and negative combined, medium positive and negative combined, and a low ion condition. Although two of the three measures analyzed for the vigilance task showed significant ion effects, in both instances the unipolar ion groups were homogeneous, and the differences in question were entirely attributable to the difference between these groups and the low ion group. The most parsimonious interpretation of this finding is that it resulted from some uncontrolled factor in the selection and assignment of subjects or in the conduct of the experiment.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

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EFFECTS OF IONIZED AIR ON DECISION MAKING AND VIGILANCE PERFORMANCE

INTRODUCTION

In a previous study by Chiles, Cleveland, and Fox (ref. 2), ionized air had no effect on the performance of two different types of tasks. The first task required subjects to work very rapidly making decisions as to the numbers of symbol differences between successive pairs of displays. The second task, a modified version of the Clock Test (ref. 3), required relatively passive vigilance behavior. However, there were two deficiencies in the experimental design that suggested that a repetition of the experiment was in order. The first and most important deficiency was that the total exposure time was limited to 2 hours—1 hour acclimatization and 1 hour performance. Even though previous reports of positive effects suggested that, when present, the effects were manifested almost immediately, a longer period of performance during exposure to ions seemed desirable. Second, the design used required each subject to perform under each condition with a different group for each order of experiencing the treatments. In this first study, there were significant differences among order groups for all three criterion measures in the case of the complex mental task. Since inspection of the raw data revealed no systematic trend, we tentatively concluded that some uncontrolled factor had entered the situation. However, we again felt that a repetition was called for so that possible order effects could be eliminated.

Two other lesser considerations prompted the additional study: (a) higher ion concentrations would be desirable and (b) we wanted to include a mixed (both plus and minus ions) condition for approximate comparison with the zero condition. Therefore, a second study was initiated using the same Complex Mental Task and the Clock Test. A third portion of the first study, which attempted to assess attitude changes through use of an adjective check-list, was eliminated since it showed no promise of sensitivity to the test conditions.

METHOD

EXPERIMENT I: COMPLEX MENTAL TASK

Apparatus

This test may be described briefly as follows (ref. 1 gives a more detailed description): Symbol-bearing frames (1-inch by 1-3/8-inch) were irregularly spaced along an opaque film. Each frame contained 6 symbols; in the upper left corner either an "O" or a "/" appeared; in the upper right corner, either an "X" or a "V"; there was either a solid or a dashed horizontal midline, etc. Five pairs of frames were printed on the stationary board on either side of the film. The subject's task was to compare each of the moving frames with each of the stationary frames and report the number of differences; this was a number between 0 and 6. Since there

were 20 moving frames to be compared with each of 10 stationary frames, the total number of comparisons to be made was 200. The subject wrote his answer on a sheet of paper using a code system to identify the particular comparison being made. The film speed permitted an average of 6.6 seconds per comparison, and a complete session took approximately 22 minutes.

Procedure

The 70 subjects taking part in this test were paid male university students. After the subjects completed 2 one-hour training sessions, they were divided at random into 7 equal groups, each of which performed under only one ionic atmosphere. The 2-hour test period was divided into 5 approximately equal trials with a 25-second period between trials for recycling the stimulus materials. The subjects of a given group were tested individually. The records of a total of 15 subjects were discarded and new subjects tested; 9 were discarded because of collusion, 2 because of obvious lack of application to the task, and 4 because of faulty data recording on the subject's part.

Three criterion scores were analyzed: (a) number correct, (b) number of omissions, and (c) number of errors.

EXPERIMENT II: CLOCK TEST

Apparatus

This task employed a modification of the Mackworth Three-Clock Test (ref. 3). The subject's display consisted of three clock dials arranged in a triangular manner on a square black panel placed 6 feet away from the subject at the far end of a 6-foot table. Each clock had a single hand, which progressed by 11-degree jumps once a second. At random intervals, which ranged from 15 to 80 seconds, the hand on one of the clocks (also selected at random) made a double jump, i.e., the hand advanced 22 degrees. The subject was required to actuate the appropriate one of 3 response buttons whenever he thought that one of the clocks had made a double jump. The actual occurrence of the single and double jumps was preprogrammed using a standard, 5-channel Western Union tape transmitter. In the course of a 50-minute test, 84 double jumps occurred on all three clocks; the double jumps were distributed equally over the three clocks.

Procedure

Seventy male university students were paid to serve as subjects. They were assigned at random in equal numbers to 7 groups, each of which performed under only one ion condition. During the week prior to the experimental day, subjects were given a 1-hour training session. Subjects reported individually, in pairs, or in some cases three at a time for the test run; they acclimatized for 1 hour followed by 3 hours of performance divided into three 50-minute trials separated by 10-minute rest periods. For analysis purposes, each 50-minute period was subdivided into two 25-minute periods.

A total of 6 subjects were eliminated from the experiment and replaced with new subjects; 2 of these refused to perform further, 1 went to sleep, and 3 subjects were dropped because of equipment or procedural errors. Three criterion measures were analysed: (a) proportion correct (proportion of double jumps detected), (b) number of false responses (number of times subject signalled a double jump when none had occurred), and (c) total errors (number of double jumps missed plus false responses).

TEST CONDITIONS

The physical environment and the ion generating and measuring equipment were essentially identical to those used in the previous experiment (ref. 2) and will not be described here except to say that 2, rather than only 1, high-voltage generators were used in the present experiments.

Seven different ionic atmospheres were used: (a) high positive, (b) high negative, (c) high positive and negative, (d) medium positive, (e) medium negative, (f) medium positive and negative, and (g) "zero" (the lowest quantities of each sign obtainable with the filter system used). The previous study did not include the two mixed ion conditions. The orders of magnitude of the concentrations of both low and high mobility ions present under each of the seven conditions are shown in table 1. Apparently because of some uncontrolled factors in the experimental environment, the "zero" ion condition actually approximates many naturally occuring ion concentrations. Care was taken in both experiments to be sure that the experimenter who recorded the data did not know what ion condition was being studied on a given day, and the subjects were given no information about the nature of the experimental conditions.

TABLE 1

APPROXIMATE NUMBER OF IONS PER CUBIC CENTIMETER FOR EACH CONDITION

Condition	High +	High -	High +,-	Medium +	Medium -	Medium +,-	Zero
Positive ions of mobility - 0.007*	28,000		32,000	10,000	1,400	11,000	1,000
Negative ions of mobility - 0.007		25,000	32,000	300	11,000	11,000	1,300
Positive ions of mobility - 0.062	26,000		29,000	7,700	1,000	9,000	800
Negative ions of mobility - 0.062		21,000	30,000	100	8,700	9,000	800

*All of the mobility figures are in terms $cm^2/sec/volt$.

Note: Typical concentrations of ions ($ions/cm^3$) maintained under the various conditions of the experiment, derived from random sampling of the monitors' records.

RESULTS AND DISCUSSION

COMPLEX MENTAL TASK

The primary interest in the experiment was in the comparisons among the unipolar and zero ion conditions, and since the suggestive evidence available would predict that the mixed ion conditions would be similar to the zero conditions, inclusion of the mixed condition in the analyses would tend to decrease the sensitivity of the statistical tests. Therefore, analyses of variance were carried out using only the high (+), medium (+), zero, medium (-), and high (-) conditions. Since inspection of the raw data suggested the presence of heterogeneity of variance among the different treatment groups, Bartlett's test was applied to the mean score for the five trials for each subject. The number-correct data yielded a χ^2 of 10.79 ($p < .05$), but neither of the other two measures exhibited significant heterogeneity of variance.

With respect to variance differences, there appears to be only one straight forward prediction from the suggestive evidence in the literature. This prediction stems from the implication that whereas some people are affected by ions, others are not. Thus, in an experiment, such as those

reported here, we would, in effect, be adding a constant to the scores of those subjects in the unipolar groups who were sensitive to ion effects. Statistically, this means that we would predict that the variances of the unipolar groups would be larger than those of the control groups. Inspection of the variances shown in table 5 indicates that this prediction is not realized. However, although the pattern of these variance differences cannot in any reasonable way be construed as a product of the ion conditions, the obtained heterogeneity does suggest that caution should be exercised in the interpretation of any significant effects involving the number-correct measure.

Summaries of the analyses of variance applied to the three criterion measures are shown in tables 2, 3, and 4. The means and variances for each of the ion conditions analysed, as well as those for the mixed conditions, are shown in table 5. For the number correct and omissions measures, only the learning effect (time periods) was significant. For the error measure, none of the effects were significant. Thus, in this as well as the previous experiment (ref. 2) there is no evidence that ions affect the performance of this sort of task.

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE FOR NUMBER CORRECT ON COMPLEX MENTAL TASK

SOURCE	SS	df	ms	F
Time Periods (T)	4,159.62	4	1,039.91	8.59***
Ion Concentrations (I)	10,844.06	4	2,711.02	.59
IxT	2,385.62	16	149.10	1.23
Subjects within I	207,873.74	45	4,619.42	
SxT within I	20,179.56	180	121.09	
Total	245,442.60	249		

TABLE 3

SUMMARY OF ANALYSIS OF VARIANCE FOR NUMBER OF OMISSIONS ON COMPLEX MENTAL TASK

SOURCE	SS	df	ms	F
Time Periods (T)	4,376.10	4	1,094.03	10.92***
Ion Concentrations (I)	14,361.10	4	3,590.28	.71
IxT	2,047.10	16	127.94	1.28
Subjects within I	227,626.80	45	5,058.37	
SxT within I	18,033.60	180		
Total	266,444.70	249		

***Significant at .001 level.

TABLE 4

SUMMARY OF ANALYSIS OF VARIANCE FOR NUMBER OF ERRORS ON COMPLEX MENTAL TASK

SOURCE	SS	df	ms	F
Time Periods (T)	246.02	4	61.51	1.72
Ion Concentrations (I)	1,561.70	4	390.42	.65
IxT	624.78	16	39.05	1.09
Subjects within I	22,345.90	45	569.58	
SxT within I	6,444.40	180	35.80	
Total	31,222.80	249		

TABLE 5

MEANS AND VARIANCES ON COMPLEX MENTAL TASK

	O	+	-	++	--	+-	++--
Omissions							
(M)	51.00	44.82	59.54	52.30	69.46	54.56	57.0
(S^2)	1,148.	1,220.	1,360.	774.3	555.2	972.2	362.0
Errors							
(M)	13.90	14.48	7.40	11.92	12.10	8.62	9.26
(S^2)	179.30	118.7	47.04	103.5	48.04	25.12	46.30
Correct							
(M)	135.34	140.80	133.06	135.78	121.04	136.82	133.56
(S^2)	1,255.	953.3	529.0	576.3	528.4	1,004.	400.6

VIGILANCE TASK

Here, as was the case for the complex mental task, the statistical comparisons of interest are those among the four unipolar and the zero conditions. The raw data for this task suggested the likelihood of heterogeneity of variance, and this suggestion was borne out by the Bartlett's tests applied to the mean of the six scores per subject for the false-responses and total-errors measures ($p < .001$ in both cases) but not for the proportion-correct measure. The finding of heterogeneity of variance with this task has not been uncommon in previous vigilance experiments (ref. 3). There also appeared to be a correlation between the means and variances for the

false-response and for the total-errors measures. As was the case for the number-correct measure on the complex mental task, the variances for both of these measures (table 9) also do not fit the pattern predicted by the only reasonable rationale for expecting ions to affect the variances. The obtained heterogeneity suggests that the interpretation of the analyses of variance applied to the false-response and total-errors measures should be made with some caution if significant differences are found. Summaries of the analyses are presented in tables 6, 7, and 8, and the means for each measure for all 7 conditions are presented in table 9. The findings for the proportion-correct measure were negative for all variance components. In the case of the total-errors measures, the effect of ion conditions was significant at the .05 level. Because of the heterogeneous variances and correlated means and variances for this measure, a log transformation of the data was analyzed (table 10). However, the effect of ion conditions was still significant. Inspection of the means (table 9) suggested a strong possibility that the significance of the ion effect was primarily a product of the performance of the zero ions group. Therefore, using the raw scores, the degrees of freedom for ions were partitioned into 1 d.f. for zero vs the unipolar conditions and 3 d.f. for differences among the unipolar conditions. This analysis showed the effect of ions to be entirely attributable to the difference between the zero vs the combined unipolar conditions. (Zero vs unipolar $F = 13.536$ - $p < .001$; among unipolar conditions, $F < 1.0$.)

For the number of false responses, the ion effect again was significant at the .05 level. Since this measure contributes heavily to the total-errors measure, agreement between the two measures is not unexpected, and for this reason, the log transformation of these data was not carried out. Again the sum of squares for ion conditions was broken down into two components: zero vs unipolar and among unipolar conditions. And here again the apparent effect of ions is entirely attributable to the aberrancy of the zero group. (For zero vs unipolar, $F = 11.672$ - $p < .005$; for among unipolar, $F < 1.0$). To the extent that the suggestive evidence in the literature on ionized air permits predictive assertions, one would expect excesses of negative ions to have beneficial effects on performance and excesses of positive ions to have deleterious performance effects. There are essentially no clues available in the literature that offer possible explanations for the obtained similarities among the unipolar conditions and their in turn differing significantly from the zero condition. This is especially true in view of the fact that the zero concentration is approximately equivalent to frequently encountered natural ion concentrations. Again referring to table 9, the mixed ion conditions are seen to be between the zero and unipolar conditions, and, in terms of performance, the high mixed condition is closer to the zero than to the unipolar conditions. If the presence of excesses of ions, irrespective of sign, were to have an effect, we would expect the high mixed condition to approximate the unipolar rather than the zero condition. Because of these considerations and the fact that in the previous study, performance under the zero condition was arithmetically (though not statistically) superior to that under the unipolar conditions, the law of parsimony dictates that this finding be interpreted to result from some uncontrolled or chance factor in the selection and assignment of subjects to groups or in the conduct of the experiment.

In conclusion, regarding the effects of ionized air on behavior, these experiments and those in the previous study (ref. 2) are in basic agreement. Namely, there are no effects of ions on performance of the type of tasks used in these experiments even for as long as 3 to 4 hours of exposure to extreme concentrations of ions.

TABLE 6

SUMMARY OF ANALYSIS OF VARIANCE FOR PROPORTION CORRECT ON VIGILANCE TASK

SOURCE	SS	df	ms	F
Time Periods (T)	532.07	5	106.41	.56
Ion Conditions (I)	18,668.19	4	4,667.05	1.96
IxT	3,676.33	20	183.82	.97
Subjects within I	107,388.26	45	2,386.41	
SxT within I	42,742.94	225	189.97	
Total	173,007.79	299		

TABLE 7

SUMMARY OF ANALYSIS OF VARIANCE OF TOTAL ERRORS ON VIGILANCE TASK

SOURCE	SS	df	ms	F
Time Periods (T)	704.35	5	140.87	.27
Ion Conditions (I)	110,782.42	4	27,695.61	3.46*
IxT	4,331.82	20	216.59	.41
Subjects within I	360,196.21	45	8,004.36	
SxT within I	118,640.19	225	527.29	
Total	594,654.99	299		

*Significant at .05 level.

TABLE 8

SUMMARY OF ANALYSIS OF VARIANCE FOR FALSE RESPONSES ON VIGILANCE TASK

SOURCE	SS	df	ms	F
Time Periods (T)	684.44	5	136.89	.26
Ion Conditions (I)	108,898.17	4	27,224.54	3.00*
IxT	3,834.39	20	191.72	.36
Subjects within I	408,436.15	45	9,076.36	
SxT within I	119,162.85	225	529.61	
Total	641,016.00	299		

*Significant at .05 level.

TABLE 9

MEANS AND VARIANCES ON VIGILANCE TASK

	0	+	-	++	--	+-	++--
Proportion Correct							
(M)	.28	.43	.48	.51	.44	.38	.49
(S^2)	0.0361	0.0358	0.0320	0.0587	0.0244	0.0687	0.0885
False Responses							
(M)	78.5	35.9	26.4	33.0	30.4	41.6	62.5
(S^2)	4,144.	1,448.	818.0	1,303.	221.4	1,829.	8,160.
Total Errors							
(M)	103.0	60.8	52.5	57.0	53.6	69.7	86.3
(S^2)	3,675.	1,352.	294.3	1,080.	238.7	2,027.	6,976.

TABLE 10

SOURCE	SS	df	ms	F
Time Periods (T)	237.26	5	47.45	.42
Ion Conditions (I)	27,281.80	4	6,820.45	2.92*
IxT	1,438.96	20	71.95	.63
Subjects within I	104,930.65	45	2,331.79	
SxT within I	25,540.25	225	113.51	
Total	159,428.92	299		

* Significant at .05 level.

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