PHYSIOLOGICAL, BIOCHEMICAL, AND PSYCHOLOGICAL RESPONSES IN AIR TRAFFIC CONTROL PERSONNEL: COMPARISON OF THE 5-DAY AND 2-2-1 SHIFT ROTATION PATTERNS

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16. Abstract
Stress in controllers on the straight 5-day shift was determined at Houston Intercontinental Tower in 1970. In 1971 controllers on the 2-2-1 rotation were studied at the same tower. Controllers generally prefer the 2-2-1 to the straight 5-day schedule because of the long week end associated with the 2-2-1. Management is concerned that the "quick turnaround" on the 2-2-1 is a stressor that could compromise job performance. Physiological and psychological assessments showed no significant stress differences on the two schedules. On neither of the schedules did the controllers' stress levels differ from the general population. Urine and blood analysis showed that day work on the 5-day rotation was generally more stressful than was the 2-2-1. On the day shift on the 5-day rotation, controllers slept an average of 1 hour and 36 minutes longer per night than they did during a week on the 2-2-1. When on the mid shift on the 5-day, controllers slept an average of 1 hour and 2 minutes less per day than they did on the 2-2-1. Results of State-Trait Anxiety Index, Composite Mood Adjective Checklist, and Attitude and Shift Experience Questionnaire showed: (1) A-State $>$ A-Trait, (2) A-State $>$ after work, (3) mood index $\leq$ after work, (4) mood index $>$ for 5-day shift than for 2-2-1 day shifts, (5) mood index for mid shifts lower than for day shifts, (6) attitudes and satisfaction favor day work. Controllers find their work fatiguing, moderately anxiety arousing, and satisfying. It was concluded that the stress differences on the two rotation patterns were too slight to be of real significance and a choice between them would have to rest on managerial considerations rather than biomedical ones.

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PHYSIOLOGICAL, BIOCHEMICAL, AND PSYCHOLOGICAL RESPONSES IN AIR TRAFFIC CONTROL PERSONNEL: COMPARISON OF THE 5-DAY AND 2-2-1 SHIFT ROTATION PATTERNS

I. Introduction.

Many shift rotation patterns are in effect at ATC facilities around the country; however, most are variations of the 2-2-1 (2 evening shifts, 2 day shifts, 1 mid shift) or the straight 5-day (5 consecutive days on the same shift) rotations. When facility work load and staffing level permit, controllers will usually opt for the 2-2-1 rotation in order to obtain the long weekend that goes with it. The extended time between work weeks results, obviously, from "bunching up" work periods during the week, thus causing briefer periods (quick turnarounds) between shifts than would otherwise occur (Fig. 1). When the straight 5-day pattern is employed, controllers work the same 8-hour shift and have 16 hours off duty for 5 days; they then have 2 days off. On the 2-2-1 rotation, the controllers normally work a different shift every day. At Houston the work week consisted of the 1600–2400 shift on day 1, 1400–2200 on day 2, 0800–1600 on day 3, 0700–1500 on day 4, and 2400–0800 on day 5. Figure 1 shows that the time between shifts on the 2-2-1 pattern ranges from 9 to 15 hours, for an average of 12 hours; thus a controller can put in a 40-hour week in 88 hours, leaving an 80-hour weekend. On the straight 5-day rotation, 104 hours are required to accomplish 40 hours of work. The weekend on the 5-day rotation may be as long as 72 hours if a controller coming off a day shift returns to an evening shift, or as short as 56 hours if he comes back on a mid shift (Fig. 1).

The desirability of the 2-2-1 rotation is obvious: the weekend is about 48% of the 7-day (168-hour) week; the controller on the 5-day rotation has a weekend that varies from 33% to 43% of the 7-day week.

Management generally does not favor the [illegible]n, alleging that the quick turnaround does not allow time for sufficient rest between shifts. Certainly, 9 hours between shifts does not allow for 8 hours of bed rest when time for travel and meals is considered. Controllers say that the long weekend contributes to a better life and that they return to work more relaxed and refreshed than they do on the straight 5-day rotation. Most controllers also prefer the single mid shift feature of the 2-2-1 to the five consecutive mid shifts on the 5-day rotation. That contention is supported by data obtained in earlier studies[1,3] that showed five days of shift work to be not long enough for complete adaptation to night work but too long because of the accumulation of fatigue resulting from poor quality daytime sleep.

A study of stress in air traffic control specialists at Houston Intercontinental Tower was carried out in July and August 1970.[4] At that time the 5-day rotation pattern was in use. Later that year the shift pattern was changed to the 2-2-1 rotation, thus affording an opportunity for study of substantially the same group of controllers on both rotations. The present study was carried out in July and August of 1971. The purpose of the experiment was to compare the levels of various stress indicators on the two shift rotation patterns.

II. Methods.

Nineteen controllers volunteered to participate in the study: twelve were journeymen, five were supervisors, and two were trainees; twelve of them had served as subjects on the previous project. The techniques employed were the same as those used on the 1970 project and described in an earlier report.[4] Briefly, the electrocardiogram was recorded continuously on tape throughout every work period. Urine was collected by each subject when he arose each morning (speci-

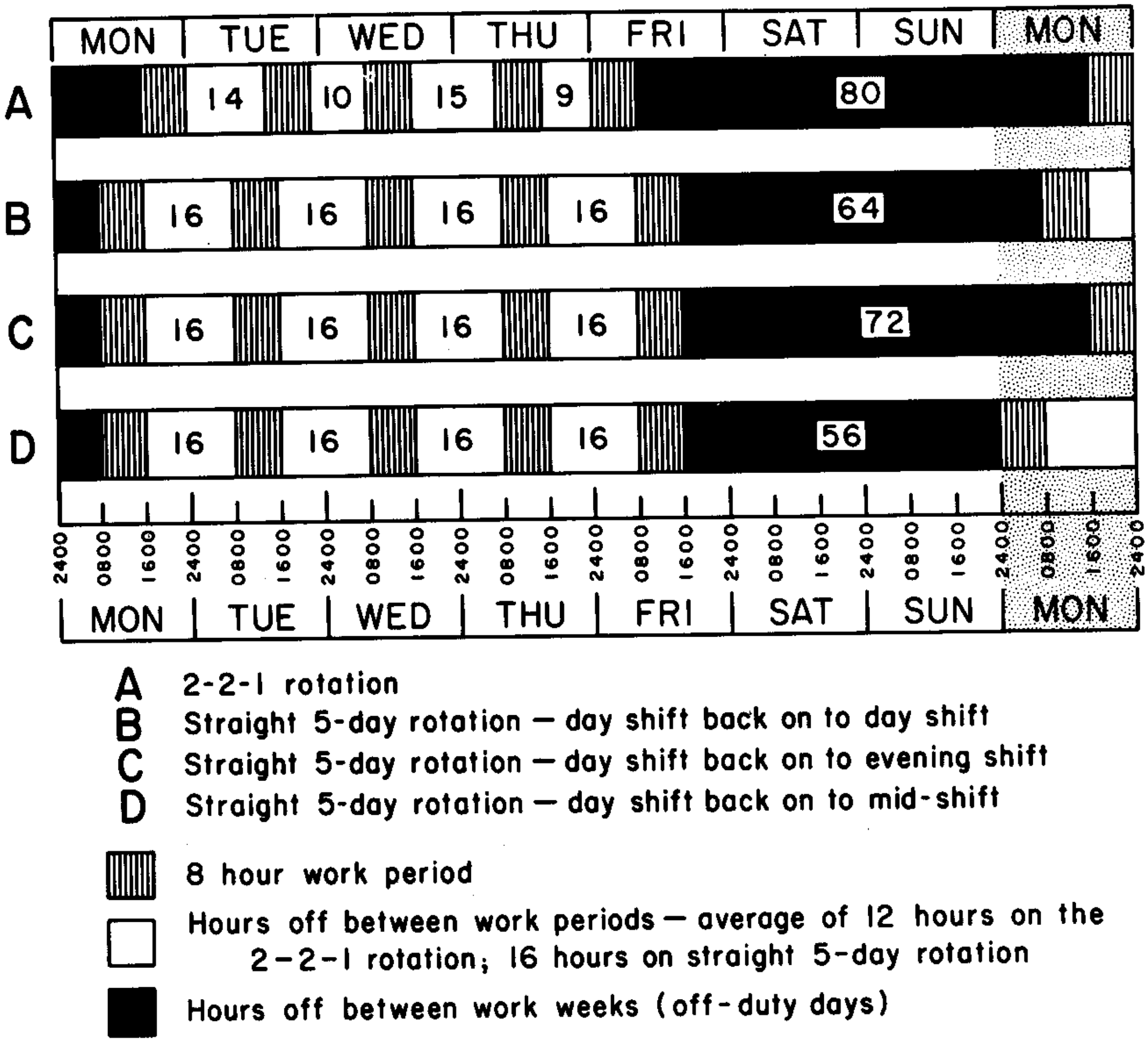

FIGURE 1. Graphic representation of a week on the 2-2-1 and 5-day rotations. The weeks shown begin on Monday; however, a controller's work week may start on any day and his weekend will necessarily be days other than Saturday and Sunday.

men No. 1), during the first 4 hours (specimen No. 2) and the last 4 hours (specimen No. 3) of each shift. Blood specimens were taken from each subject when he began his work week and again at the end of his work week. Urine was analyzed for epinephrine, norepinephrine, 17-ketogenic steroids, sodium, potassium, and creatinine. Blood plasma was analyzed for total phospholipid and phosphatidyl glycerol.[5]

Each subject completed a series of questionnaires and psychological tests before and after each shift under consideration. The following techniques were used to assess mood, anxiety, and attitude:

1. The State-Trait Anxiety Inventory (STAI): This questionnaire, developed by Spielberger, Gorsuch, and Lushene,[10] consists of two scales which ask the respondent to respond to items concerning his general (A-trait) and current (A-state) anxiety levels. Each scale is comprised of 20 items which the respondent rates on a four-point scale. A typical item would be "I feel tense," which would be rated from "almost always" to "almost never" for A-trait, and from

"much so" to "not at all" for A-state. The A-State Scale was administered to each subject before and after each shift under consideration; the A-Trait Scale was only administered before the first shift of the work week.

2. Composite Mood Adjective Checklist (CMACL): The CMACL, as developed by Malmstrom,[2] was used to assess affective states before and after selected shifts. This list consists of 80 adjectives (e.g., angry, sleepy, happy) rated by the subject on a nine-point scale from "not at all" to "definitely," descriptive of his current feelings. The CMACL was completed before and after each shift on the 2–2–1 schedule, and before and after the day and mid shift sequences on the 5-day schedule.

3. Attitude and Shift Experience Questionnaire: Before each shift the subjects completed a questionnaire to indicate their attitudes toward working the upcoming shift (e.g., How much are you looking forward to working today? How do you feel today?) on five-point rating scales. For the specific questions refer to Appendix 1. After the shift a corresponding questionnaire was completed and, in addition to indicating their attitudes and feelings, the subjects were asked to rate the shift in terms of difficulty and satisfaction.

TABLE I

Comparison of Heart Rates at Different Work Positions 5-day vs 2-2-1 Rotations

Work Position	Average Heart Rate 5-day Rotation	2-2-1 Rotation	p***
Midshift			
Radar	73	81	≤ 0.01
Cab	76	83	≤ 0.02
Supervisor	76	80	**
Prework	78	83	N.S.
All positions	70	81	≤ 0.01
Day work			
Radar	81	81	N.S.
Cab	81	83	N.S.
Supervisor	85	81	**
Prework	81	83	N.S.
All positions	81	81	N.S.

** Data insufficient for statistical test

*** Wilcoxon matched signed rank test

In addition to the various physiological, biochemical and psychological measures, each participant was asked to report the number of hours of sleep obtained prior to reporting for work.

TABLE II

Comparisons of Heart Rates During Day Work on 5-day and 2-2-1 Rotations

Work Position	Average Heart Rate 5-day Rotation	2-2-1 Rotation	p***
Approach control radar	81	81	N.S.
Departure control radar	80	86	N.S.
Ground control	82	86	**
Local control	86	86	**
Clearance delivery & data	80	81	**
Coordinator	83	83	N.S.
Supervisor radar	85	80	**

** Data not sufficient to make a statistical test

*** Wilcoxon matched pairs signed rank test

III. Results.

Physiological-Biochemical Measures

A. *Heart rate.* Table I shows a comparison between various work positions during day/evening work and mid shift work on the two shift rotation patterns. Statistically significant differences occur on the mid shift with the average heart rate being higher on the 2–2–1 rotation. Table II shows, where data are sufficient for statistical test, that there are no significant differences during day work between heart rates on the two shift rotation patterns for the various work positions. Table III shows only one point of statistically significant difference between mid shift positions on the two rotations: approach control radar. Most of the mid shift data in Table III are insufficient for statistical comparison because of the fact that only one controller was in the cab and one in the radar room. When the different positions are considered separately, data for each of them become scanty. Table I shows data combined for the various positions.

Within the group on the 2–2–1 rotation there are no points of statistically significant difference between work positions.

B. *Urine Chemistry (Table IV).*

1. Epinephrine (E). There was no significant difference in E excretion by the two groups during day work. A significantly elevated excretion

TABLE III

Comparison of Heart Rates During Mid Shift

Work on 5-day and 2-2-1 Rotations

Work Position	Average Heart Rate 5-day Rotation	2-2-1 Rotations	p***
Approach control radar	73	81	≤ 0.02
Departure control radar	75	81	**
Coordinator radar	82	86	**
Supervisor radar	77	78	**
Local control cab	75	75	**
Ground control cab	79	84	**
Clearance delivery & data	79	84	N.S.

** Data not sufficient for statistical test

*** Wilcoxon matched pairs signed rank test

of E occurred during nocturnal sleep by the group on the 2–2–1 rotation; however, E excretion over an entire week of day work was slightly, but insignificantly, higher than E excretion over a week on the 2–2–1 rotation.

When the mid shifts were similarly compared, the excretion of E was significantly elevated in the 2–2–1 group, except during day sleep when the two groups' E excretion was equal.

2. Norepinephrine (NE). NE excretion was significantly greater during day work on the 5-day rotation than on the 2–2–1 rotation. There was no significant difference in NE excretion during nocturnal sleep on the two rotation patterns. The entire week of day work caused a significantly higher excretion of NE than did the 2–2–1 rotation.

There were no significant differences in NE excretion by controllers on the mid shifts of the two rotation patterns. Likewise, NE excretion did not differ significantly during day sleep on the two rotation patterns.

3. 17-Ketogenic steroids (KGS). KGS excretion was significantly higher during the first half of the mid shift on the 2–2–1 rotation than it was during the comparable period on the 5-day rotation. That trend was reversed, however, during day sleep when KGS excretion was significantly elevated in the 5-day group. When the KGS data were normalized as percent of the baseline (night sleep specimen D–3), adrenocortical responsiveness was seen to be significantly higher in the 2–2–1 group during the first half of the mid shift and for the whole week than it was on the mid shift in the 5-day group. Day work was characterized by significantly elevated KGS excretion by the 5-day group. The difference between the groups was not seen, however, during nocturnal sleep. When a week of day work on the 5-day rotation was compared to day/evening work on the 2–2–1 (D–4 specimen), it was apparent that the 5-day rotation was significantly more stressful than was the 2–2–1 rotation. Adrenocortical responsiveness (% baseline) was not significantly different in the two groups.

4. Sodium (Na) and Potassium (K). Na excretion and K retention were characteristic of the 2–2–1 rotation on both the day and mid shifts, with the exception of Na excretion on the first half of the day shift. The two rotation patterns could not be distinguished on the basis of the Na/K ratio, however, for either day shift or mid shift.

5. Phospholipids. Table V shows that there are no points of statistically significant difference between the two work schedules as far as total plasma phospholipids are concerned. However, the two shift rotation patterns can be differentiated significantly on the basis of phosphatidyl glycerol levels in the controllers' plasma specimens, with the higher value occurring in connection with both the day shift and mid shift of the 5-day rotation. When the change in phospholipid levels over the work weeks (postwork minus prework levels) on the two rotation patterns are compared, there are no points of significant difference in either total phospholipid or phosphatidyl glycerol levels.

Psychological Measures

A. *STAI.* The findings for the two scales of the STAI are summarized in Table VI. There were no significant differences between the anxiety levels of the two controller groups as a function of shift rotation schedule.

Controllers under both shift rotation schedules had significantly higher mean A-state than A-trait scores ($p<.05$) for both comparisons). In addition, the A-state level was significantly higher after work than it had been before shifts ($p<.05$ or less for each comparison). There also appeared to be a slight tendency for A-state levels to be higher in association with mid shifts than other shifts; however, the differences were not statistically significant.

TABLE IV

Urine Chemistry
5-day vs 2-2-1 Rotation

	Rotation Pattern	Epinephrine	Norepinephrine	17-KGS	17 KGS % baseline	Na	K	Na/K
D1	5*	1.71 ± 0.95	3.65 ± 0.89	1602.79 ± 537.70	191.56 ± 66.56	10.43 ± 2.91	2.78 ± 0.62	4.15 ± 1.69
	2**	1.41 ± 0.54	3.10 ± 0.81	1144.92 ± 293.77	168.69 ± 47.19	12.52 ± 2.94	3.04 ± 0.78	5.08 ± 1.54
	p	N.S.	≤ 0.01	≤ 0.01	N.S.	N.S.	N.S.	N.S.
D2	5	1.47 ± 0.67	3.98 ± 1.06	1463.00 ± 476.35	179.38 ± 80.68	9.93 ± 1.94	2.20 ± 0.69	5.01 ± 1.84
	2	1.33 ± 0.51	2.95 ± 0.63	1007.93 ± 317.22	145.11 ± 34.70	13.12 ± 3.38	2.78 ± 0.77	5.57 ± 2.04
	p	N.S.	≤ 0.05	≤ 0.01	N.S.	≤ 0.01	≤ 0 01	N.S.
D3	5	0.27 ± 0.10	2.44 ± 1.11	863.48 ± 296.92	100.00	6.78 ± 1.87	1.16 ± 0.48	7.31 ± [illegible] 72
	2	0.55 ± 0.21	2.18 ± 0.44	755.91 ± 222.96	100.00	8.73 ± 2.11	1.61 ± 0.50	6.38 ± 2.32
	p	≤ 0.01	N.S.	N.S.		≤ 0.05	N.S.	N.S.
D4	5	1.59 ± 0.80	3.81 ± 0.83	1532.82 ± 494.93	185.40 ± 71.98	10.18 ± 2.13	2.55 ± 0.47	4.58 ± 1.71
	2	1.37 ± 0.49	3.02 ± 0.65	1087.83 ± 270.31	158.17 ± 36.26	12.82 ± 2.89	2.91 ± 0.68	5.42 ± 1.59
	p	N.S.	≤ 0.01	≤ 0.01	N.S.	≤ 0.05	N.S.	N.S.
M1	5	0.70 ± 0.42	2.76 ± 0.34	759.84 ± 230.46	94.25 ± 43.74	7.67 ± 2.45	1.83 ± 0.67	4.62 ± 1.10
	2	1.41 ± 0.54	3.10 ± 0.81	1144.92 ± 293.77	168.69 ± 47.19	12.52 ± 2.94	3.04 ± 0.78	5.26 ± 1.60
	p	≤ 0.01	N.S.	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	N.S.
M2	5	0.90 ± 0.54	2.92 ± 0.60	1056.90 ± 303.07	132.13 ± 57.70	8.35 ± 2.16	2.13 ± 0.76	4.61 ± 1.55
	2	1.33 ± 0.51	2.95 ± 0.63	1007.93 ± 317.22	145.11 ± 34.70	13.12 ± 3.38	2.78 ± 0.77	5.57 ± 2.04
	p	≤ 0.01	N.S.	N.S.	N.S.	≤ 0.01	≤ 0.01	N.S.
M3	5	0.84 ± 0.64	2.49 ± 0.64	1346.03 ± 398.32	169.91 ± 66.35	9.84 ± 1.96	2.35 ± 0.41	4.18 ± 0.99
	2	0.84 ± 0.71	2.36 ± 0.52	755.91 ± 227.96	150.34 ± 65.47	12.91 ± 3.93	2.85 ± 1.17	3.57 ± 1.28
	p	N.S.	N.S.	≤ 0.01	N.S.	N.S.	≤ 0.01	N.S.
M4	5	0.82 ± 0.35	2.85 ± 0.45	1188.88 ± 249.34	116.26 ± 52.03	8.20 ± 2.03	2.07 ± 0.62	4.55 ± 1.16
	2	0.93 ± 0.49	2.61 ± 0.77	1087.83 ± 270.31	158.17 ± 36.26	11.42 ± 4.60	2.35 ± 1.07	5.61 ± 1.89
	p	N.S.	N.S.	N.S.	≤ 0.05	≤ 0.05	N.S.	N.S.

D-1 = Day shift specimen #2
D-2 = Day shift specimen #3
D-3 = Day shift specimen #1 (night sleep)
D-4 = All #2 & #3 specimens for whole work week

M-1 = mid shift specimen #2
M-2 = mid shift specimen #3
M-3 = mid shift specimen #1 (day sleep)
M-4 = All #2 & #3 specimens for whole work week

*5-day rotation
**2-2-1 rotation

TABLE V

Plasma Phospholipids
5-day vs 2-2-1 Rotation

		Total Lipid Phosphorus	Phosphatidyl Glycerol
Prework	5-day	2406 ± 250.19 (s.d.)	34.23 ± 4.16 (s.d.)
	2-2-1	2211 ± 186.43	27.48 ± 3.62
	p*	N.S.	$p \leq 0.01$
Postwork	5-day (day shift)	2242 ± 226.70 (s.d.)	35.16 ± 5.44 (s.d.)
	2-2-1	2222 ± 181.60	28.42 ± 3.49
	p	N.S.	$p \leq 0.01$
Postwork	5-day (mid shift)	2392 ± 216.44 (s.d.)	33.19 ± 5.35 (s.d.)
	2-2-1	2227 ± 165.88	29.07 ± 3.70 (s.d.)
	p	N.S.	$p \leq 0.01$
Prework Postwork differences	5-day (day shift)	14.40 ± 51.82	1.47 ± 3.50
	2-2-1	26.80 ± 41.60	0.80 ± 5.37
	p	N.S.	N.S.
Prework Postwork differences	5-day	-13.92** ± 66.46	-1.03 ± 4.34
	2-2-1	16.00 ± 46.63	1.59 ± 5.30
	p	N.S.	N.S.

* Paired t test
** Prework values higher than postwork values.

B. *CMACL.* The CMACL data were scored for the 15 mood factors developed by Malmstrom[2] and for an overall index proposed by Smith.[6,9] The findings for the controllers under the 5-day shift rotation schedule are discussed at length in a previous publication.[9] The results presented within this section will be concerned primarily with the comparisons between the 5-day and 2-2-1 shift schedules.

The mean overall affect index of 6.94 (range of possible values was one to nine) for controllers under the 5-day schedule did not differ significantly from the mean of 6.88 for controllers on the 2-2-1 schedule (the higher the index, the more positive the affect). In both groups there was a significant decline (Table VII) in the overall index from preshift to postshift assessments ($p<.01$ for both comparisons). Also in

TABLE VI

Mean A-State and A-Trait Raw Scores for Air Traffic Controllers

Under Two Shift Rotation Schedules

Watch	Time	Rotation Schedule 5-day	 2-2-1
		A-Trait	
----	----	30.0	29.3
		A-State	
Day	Pre	29.4	30.6
	Post	35.2	34.9
Evening	Pre	----	31.5
	Post	----	33.9
Mid	Pre	31.3	32.1
	Post	35.8	36.2

both groups, the mean index for day shifts was higher than mid shifts ($p<.01$ for both comparisons); however, the mean index for the day shift was higher under the 5-day than the 2–2–1 schedule ($p<.01$). There was no difference between the schedules on the index for mid shifts. Within the 2–2–1 schedule, there was a significant interaction ($p<.01$) between types of shifts and preshift and postshift mood assessment. It was found that, before work, the mean overall index was higher for evening shifts than for day shifts or mid shifts ($p\leq.01$) for each comparison). After work, the mean overall indices for evening and day shifts were equal and lower than the indices before work. The index for the mid shifts was significantly lower than for both the day and evening shifts ($p\leq.01$ for both comparisons).

There were no significant effects for seven specific mood factors, *Aggression*, *Anxiety*, *Anxious*, *Depression*, *Distrust*, *Dizzy*, and *Nonchalance.*

There were five factors on which differences between the two shift schedules were noted. Mean *Concentration* and *Social Affection* scores were higher under the 5-day schedule than the 2–2–1 schedule ($p\leq.05$ for both comparisons). It was also found that prior to day shifts, the mean *Vigor* and *Surgency* scores were higher, and mean *Fatigue* scores lower, for the 5-day than for 2–2–1 rotation schedules ($p\leq.05$ or better for each comparison). This trend continued to postday shift assessments only for the *Vigor* factor. Furthermore, it was found that the preshift *Vigor* scores on both schedules were higher for day than mid shifts, but after shifts this was true only for the 5-day schedule ($p\leq.05$ or better for each comparison). In addition, scores on the *Surgency* factor obtained following mid shifts tended to be higher on the 2–2–1 than the 5-day schedule.

As noted in the analysis of controller mood data for the 5-day schedule (see Smith, Melton, and McKenzie[9]), controllers on the 2-2-1 rotation also had higher *Friendly*, *Concentration*,

TABLE VII

Mean Scores for the Overall Affect Index and the 15 CMACL Mood Factors for Air Traffic Controllers Under Two Shift Rotation Schedules.

Factor	Time	Schedule: 5-Day (N=16) Day	Mid	2-2-1 (N=20) Day	Evening	Mid
Overall Index (1-9)	Pre	7.43	6.86	7.00	7.43	6.81
	Post	7.05	6.42	6.87	6.74	6.43
Aggression (6-54)	Pre	8.4	9.9	8.2	9.5	8.2
	Post	7.2	8.3	8.8	9.5	8.7
Anxiety (7-63)	Pre	10.2	11.6	10.1	10.8	10.2
	Post	11.9	12.2	11.9	10.8	11.7
Anxious (1-19)	Pre	2.3	1.7	2.3	3.0	1.9
	Post	2.4	1.6	2.3	2.3	2.0
Concentration (9-81)	Pre	53.8	49.3	43.8	53.1	38.8
	Post	44.1	41.4	41.1	42.1	36.4
Depression (12-108)	Pre	20.6	24.1	21.7	21.9	23.1
	Post	20.1	24.2	21.5	22.4	21.4
Distrust (3-27)	Pre	4.6	5.4	5.9	7.0	5.6
	Post	4.8	4.5	5.4	5.6	5.4
Dizzy (4-36)	Pre	5.0	5.6	4.3	5.1	4.6
	Post	5.4	6.4	5.1	4.8	7.4
Fatigue (8-72)	Pre	19.4	32.4	24.8	16.6	30.6
	Post	25.1	45.4	26.9	30.7	42.5
Friendly (3-27)	Pre	18.7	16.4	16.4	19.5	15.7
	Post	15.7	14.2	15.9	15.6	14.3
Nonchalance (2-18)	Pre	9.3	9.4	7.9	8.9	8.5
	Post	7.6	9.4	7.9	8.6	8.2

TABLE VII

(Continued)

Mean Scores for the Overall Affect Index and the 15 CMACL Mood Factors for Air Traffic Controllers Under Two Shift Rotation Schedules.

		Schedule				
		5-Day (N=16)		2-2-1 (N=20)		
Factor	Time	Day	Mid	Day	Evening	Mid
Sleepy (4-36)	Pre	9.9	17.9	12.3	7.3	16.8
	Post	14.2	26.8	13.9	16.6	24.4
Social Affection (4-36)	Pre	22.0	20.0	19.5	23.4	18.4
	Post	19.6	18.4	18.9	18.9	16.7
Surgency (5-45)	Pre	25.9	20.9	22.8	29.1	21.3
	Post	23.7	17.6	22.5	20.7	19.2
Vigor (3-27)	Pre	17.9	12.9	14.9	20.1	13.0
	Post	15.2	8.0	13.5	13.3	9.5
Zuckerman Affect Adjective Checklist (21-189)	Pre	49.7	58.1	56.5	48.4	59.6
	Post	46.6	65.4	61.1	58.9	64.9

The values in parentheses represent the range of possible scores on each factor.

Social Affection, *Vigor* and *Surgency* scores before than after all types of shifts ($p \leq .05$ or better for each comparison). Consistent with these findings, scores for the *Fatigue* factor were higher after shifts on both schedules.

The scores for the *Sleepy* factor tended to be higher for mid than for day shifts for both schedules ($p \leq .01$ for both comparisons).

It was noted from the 2-2-1 schedule data that feelings tended to be more positive prior to evening shifts than prior to the other two types of shifts. This was true for the *Concentration*, *Social Affection*, *Vigor*, *Fatigue* and *Sleepy* factors ($p \leq .05$ or better for each comparison). However, postevening shift scores were essentially equal to those from mid shifts in the *Sleepy* and *Fatigue* factors, and were equal to scores from both mid and day shifts on the remaining factors.

C. *Attitude and Shift Experience Questionnaire.* The mean ratings for both controller groups on the four preshift and five postshift questions are presented in Table VIII. Under both rotation schedules, the controllers indicated that they looked forward more to (question 1) and had more enthusiasm for (question 2) day shifts than mid shifts ($p \leq .05$ or better for each comparison). Subjects on the 5-day schedule

TABLE VIII

Mean Rating for Preshift and Postshift Questionnaire Items

	Rotation Schedule				
	5-day ATCSs (N=16)		2-2-1 ATCSs (N=19)		
	Day	Mid	Day	Evening	Mid
Pre-shift					
1. Looking Forward to Work	3.48	2.81	3.11	3.61	2.61
2. Enthusiasm	3.54	2.97	3.24	3.87	2.72
3. General Feelings	3.78	3.20	3.53	4.11	3.39
Post-shift					
1. General Feelings	3.49	2.81	3.37	3.47	2.83
2. Tension	3.21	3.56	3.34	3.47	3.44
3. Feel Good or Bad About Shifts	3.80	3.32	3.42	3.53	3.28
4. Statisfaction	4.00	3.51	3.53	3.63	3.33
5. Difficulty	2.77	3.75	3.19	3.46	4.24

also indicated that their general feelings were better before day than mid shifts (question 3); however, there was no difference between these shifts on this question for the 2-2-1 schedule. On the 2-2-1 rotation it was also found that on each of these three questions the evening shift was rated significantly more positive than the day shift.

After shifts the findings for general feelings (question 1) and shift difficulty (question 5) were the same for both rotation schedules; feelings were more positive, and shifts judged more difficult for day than mid shifts. Under the 5-day schedule it was also found that satisfaction with the shift (question 4) and positive feelings about the shift (question 3) were greater for day than mid shifts. There were no differences between types of shifts on these questions for the 2-2-1 rotation. It was also found that ratings for the evening shifts were equal to the day shift rating for each postshift item on this rotation schedule.

There were no significant correlations between responses to the questionnaires and STAI or CMACL response trends.

TABLE IX

Comparison of Hours of Sleep Prior to Work

Shift Rotation Pattern		Work Day 1	2	3	4	5	Weekly Average (Derived from all participating subjects)
5-day (days)		7:04	6:58	6:56	7:11	7:10	6:58
	Δ	1:03	0:09	0:57	1:11	4:40	0:53
	p*	≤ 0.05	N.S.	≤ 0.05	≤ 0.05	≤ 0.01	≤ 0.01
2-2-1		8:07	6:49	5:59	6:00	2:30	6:05
	Δ	2:08	1:15	0:35	0:11	3:50	0:06
	p**	N.S.	N.S.	N.S.	N.S.	≤ 0.01	N.S.
5-day (mid)		5:59	5:34	5:24	5:49	6:20	5:59

*Significance level of difference between values on day shifts and 2-2-1 rotation
**Significance level of difference between values on mid shifts and 2-2-1 rotation

Sleep Patterns

Table IX shows, day by day, for the 12 individuals who participated in both studies, the hours of sleep prior to work. The controllers on the 5-day rotation slept significantly longer at night prior to day shifts than they did in the day prior to mid shifts. These same controllers on the 2-2-1 rotation slept significantly less prior to work than they did prior to day work on the 5-day rotation; however, the one mid shift included in the 2-2-1 schedule substantially lowered the average amount of sleep because most controllers only took a short nap prior to that single mid shift.

Every day on the 2-2-1 schedule is a quick turnaround day. The amount of sleep taken prior to day 2 is not significantly different for the two rotation patterns; on day 3 the controllers on the 5-day pattern slept an average of 57 minutes more than those on the 2-2-1, prior to day 4 the group on the 5-day rotation slept 1 hour and 11 minutes longer, and prior to day 5 the controllers on the 5-day rotation slept 4 hours and 40 minutes longer. On a whole week basis, when the controllers were doing day work on the 5-day rotation, they slept an average of 1 hour and 36 minutes longer per night than they did a year later on the 2-2-1 rotation. However, when the single mid shift is not included in the comparison, on the 2-2-1 rotation they slept an average of 18 minutes more than they did prior to the first 4 days of the 5-day rotation. When a week of work on the 2-2-1 rotation is compared with a week of mid shifts, it develops that, on the 2-2-1, the group slept an average of 1 hour and 2 minutes more per night than they did prior to 5 straight mid shifts.

IV. Discussion.

Physiological-Biochemical Measures

A. *Mid shift.* With regard to mid shift work, the two rotation patterns can be differentiated on the basis of heart rate. The mean heart rate for all work positions for the entire week on the 5-day rotation was significantly lower than it was for the one mid shift on the 2–2–1 rotation. Heart rates during day work, however, were equal on the two rotations. Since the mid shift mean heart rate for all positions on the 2–2–1 rotation was equal to the day shift heart rates, the difference is obviously due to depression of the heart rate below the day rate (indeed, below the prework rate) on the 5-day rotation rather than to an elevation of heart rate above the day rate on the 2–2–1 rotation. The reason for the difference is not readily apparent; however, it should be borne in mind that conditions on the two rotation patterns are not strictly comparable. When the daily means of heart rate on the 5-day rotation are graphed, there is a linear increase over the five mid shifts. The fifth mid shift gives rise to a mean heart rate (76 bpm) that is not significantly different from the mean heart rate on the single mid shift on the 2–2–1 rotation (81 bpm). Thus, the difference can probably be accounted for by averaging of the heart rates over the five mid shifts.

The urinary variables show that there are only two points of significant difference between the two groups, a significantly elevated adrenocortical response and a natriuresis on the 2–2–1 rotation. The values for day sleep (M-3 specimens) indicate that a week of mid shifts is about twice as stressful as a week of work on the 2–2–1 rotation.

B. *Day shift.* The mean heart rates for all subjects for all tower positions are equal for the two rotation schedules.

Urine chemistry shows several points of significant difference in response to work on the two rotation schedules. Sympathetic arousal, as indicated by norepinephrine excretion, is greater on the 5-day rotation than on the 2–2–1. Adrenocortical level of activity is significantly elevated on the 5-day rotation. Though dietary factors are difficult to assess, the excretion of sodium is enhanced on the 2–2–1 rotation, suggesting a reduced secretion of mineralocorticoids.

Plasma phospholipids are indicative only of the entire week's work, since blood specimens were drawn on the first and last days of the shift. The phosphatidyl glycerol data show that the 5-day rotation was significantly more stressful than was the 2–2–1. It is important to note the difference in phosphatidyl glycerol levels in the prework specimens. The level of this stress indicator is significantly lower in the controllers' blood on the 2–2–1 rotation. This finding can possibly be attributed to the extended weekend. The amplitudes of the changes in phosphatidyl glycerol levels are not significantly different over the week's work for the two rotation patterns.

Psychological Measures

The results indicate that controllers at this facility find their work fatiguing, moderately anxiety arousing, and satisfying. These trends were present under both shift schedules, there being relatively little difference between these schedules on any of the measures obtained under these schedules. There was some evidence that affect states associated with day shifts were somewhat less positive for the 2–2–1 than the 5-day schedules. However, this may have been in part a function of the added assessment of evening shifts for the 2–2–1 schedule. In other words, the referent for this group may have been somewhat different than for the 5-day group, since no rating of evening shifts was obtained for the 5-day schedule.

There was clear agreement that mid shifts are associated with stronger negative feelings than day or evening shifts. These data are thus consistent with other findings[7,8] concerning the attitudes of controllers toward their work; it has been determined in the surveying of controllers at a variety of facilities that the aspect of ATC work which they disliked the most, and significantly more than any other aspect of their work, was working the mid shift.

The findings with respect to anxiety suggest that controllers tend to experience somewhat more anxiety (A-state) while doing ATC work than they do on the average in other settings (A-trait). However, the degree of anxiety experienced during work is probably well within normal limits as the mean A-State Scale score for the controllers corresponds to approximately the 42nd percentile for normal college undergraduate students. It also appears, at least by

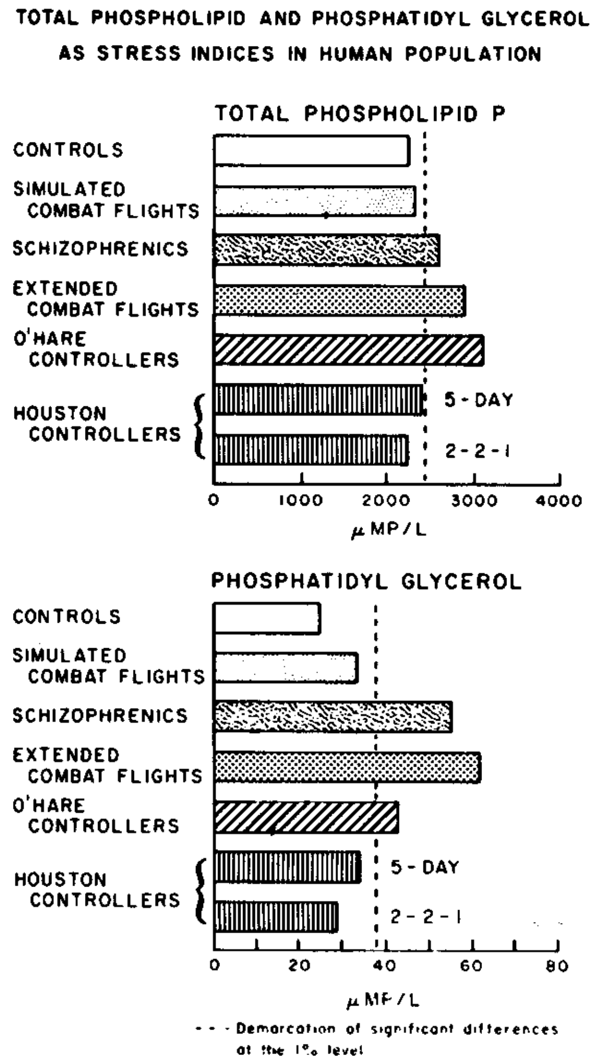

FIGURE 2. Comparison of plasma phospholipids in various stressed and non-stressed groups.

student standards, that general anxiety or A-trait levels are quite low as the mean A-trait score for controllers is equivalent to the 24th percentile according to such normative data. It thus appears that while ATC work may cause some moderate anxiety arousal in controllers, the resulting anxiety level is well within "normal" limits.

The major outcome of work appeared to be increased feelings associated with fatigue; however, as noted, shift schedule had relatively little effect on such feelings. The CMACL factors which showed the greatest effects were those associated with "physical" conditions such as *Sleepy*, *Fatigue*, or *Vigor*. In addition, there was evidence of decreased sociability at the end of the shift. These effects were greater for the mid shift, even though work load is lowest for the mid shift, which suggests that boredom and inactivity in a situation which demands vigilance may be a most important factor in judged "fatigue" level.

Sleep Patterns

While there are significant differences between the two shift patterns reflected in the controllers' body chemistry, generally favoring the 2–2–1 rotation, it should be carefully pointed out that neither group significantly differed from the general population. Under low-stress conditions it would not be expected that any sort of operational deficiency would result from the shift rotation pattern alone. However, in a high-stress situation any additionally stressful factor would be expected to increase the potential for error, and it is commonly believed that the quick turnaround feature of the 2–2–1 rotation constitutes such an additional stress. It has been generally assumed that controllers on the 5-day rotation will utilize a full 8 hours of their 16-hour off period for sleep, thus returning to work fully rested and capable of meeting the most rigorous demands of their job. The data for sleep patterns indicate that such an assumption is not entirely valid. It is of interest that most controllers deliberately take only a short nap prior to working the one mid shift on the 2–2–1 schedule. They explained that by so doing they would be tired enough at the end of the shift to sleep well during the day, then they would be rested for the weekend and their normal day-night schedule would not be seriously disrupted. Contrarily, on the 5-day rotation controllers commonly complained that after 5 consecutive mid shifts their whole weekend was devoted to trying to become readjusted to day wakefulness and night sleep.

At Houston, when the 5-day rotation was in effect, controllers worked a week of evenings, then a week of days, then another week of evenings, then another week of days, then a week of mid shifts. Five weeks were required to complete the entire pattern of duty periods. Data were not collected on evening shifts in that study; however, it is probably a valid assumption that the controllers slept about the same amount as they did prior to the day shift. Assuming that a controller worked mid shifts every 5th week, an extrapolation of the sleep data shows that he would sleep an average of 6 hours and 46 minutes out of every 24 hours. On the 2–2–1 rotation he would sleep an average of 6 hours and 35 minutes, a difference of 11 minutes per night over a 5-week period.

Strong managerial reasons may lead to the selection of one or the other of the shift rotation patterns, but physiologically and psychologically, such a strong case could not be made at Houston. There is no evidence that controllers suffer unusual changes in anxiety, affect or attitude as a function of working under either schedule. If a choice were to be made based on the controllers' physiological responses, it would have to be the 2–2–1 rotation. Studies similar to the one described here are being planned at one or more high-density facilities, employing different shift rotation patterns. In those studies, data will be collected on day, evening, and mid shifts on the 5-day rotation in order to provide a better comparison with the 2–2–1 rotation.

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Appendix I

Form I

1. How much are you looking forward to working today?

   ___ very much ___ quite a bit ___ some ___ not much ___ not at all

2. How enthusiastic do you feel about doing ATC work today?

   ___ very high ___ high ___ some ___ little ___ not at all

3. In general, how do you feel today?

   ___ excellent ___ good ___ o.k. ___ poor ___ bad

4. How tense do you now feel?

   ___ very tense ___ moderately tense ___ slightly tense ___ no tension ___ completely relaxed

Form II

1. How do you generally feel now, after the end of a day's ATC work?

   ___ excellent ___ good ___ o.k. ___ poor ___ bad

2. How tense do you feel now?

   ___ very tense ___ moderately tense ___ slightly tense ___ no tension ___ completely relaxed

3. How do you feel about today's shift?

   ___ very good ___ good ___ o.k. ___ bad ___ very bad

4. How satisfied were you with today's shift?

   ___ very satisfied ___ satisfied ___ neither satisfied nor dissatisfied ___ dissatisfied ___ very dissatisfied

5. How difficult was today's shift?

   ___ very difficult ___ difficult ___ neither difficult nor easy ___ easy ___ very easy