Time of day effects on performance in a range of tasks[1]

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Performance on eight tasks ranging from novel laboratory tests to highly practised familiar skills was measured at five times of day between 8 AM and 9 PM. Five tasks showed a consistent tendency for improvement in efficiency from 8 AM through 9 PM; in one task there was deterioration; and in the remaining two the effects were not significant. The results suggest that the observed trends are related to the underlying state of arousal as indicated by body temperature.

Fluctuations in performance efficiency during the waking day have been observed by a number of investigators (e.g., Kleitman, 1963). Although the evidence presented by Kleitman for the existence of systematic trends is impressive, the majority of studies have been carried out with very small samples of Ss. This may explain the considerable disagreement as to the detailed form of the diurnal curves of efficiency.

The present investigation attempted to overcome this problem by studying relatively large and homogeneous samples of Ss. A wide range of tests was used in order to assess the extent to which time of day effects, if present, were task-specific.

Method

Latin square designs were used for each task to control for practice effects. After preliminary training, each S was tested once in isolation without KR, at each of the following times: 8:00 AM, 10:30 AM, 1:00 PM, 3:30 PM, and 9:00 PM. Normally only one test was carried out on any one day, the series being completed over 5 successive days; occasionally tests at 8:00 AM and 9:00 PM were made on the same day. Ss (Naval ratings with an age range of 17-33 years) followed a normal "shore base" routine for sleep and meals and did not engage in any activity likely to affect their performance during the testing periods.

Tasks

(1) Five-Choice Serial Reaction: 30 Ss tapped one of 5 metal disks to extinguish one of 5 lights and automatically light another. Order of light presentations was random and high S-R compatibility was provided by a pentagonal array of lights and disks. Task duration was 30 min. Ss were scored on correct and incorrect responses and "gaps," i.e., periods of 1.5 sec between successive taps.

(2) Vigilance: 25 Ss listened to a 500 cps tone of (normally) 600 msec duration, repeated every 3 sec. The "signals" were 24, 670 msec tones dispersed at random during the 53 min session. Scores were correct detections and false reports.

(3) Card Sorting: 30 Ss sorted 8, 64 card packs comprising playing card packs with 9s, 10s, and court cards removed. Cards were sorted into 2 (red and black) and 8 categories (i.e., by number). Duration was 12-15 min; scores were sorting times.

(4) Letter Cancellation: 25 Ss checked through sheets of English prose, cancelling each letter "e." Duration was 30 min; scores were number of letters processed (whether cancelled or not) and percent omission errors.

(5) Time Estimation: 30 Ss made 2 estimates of intervals of 10, 20, 30, 60, and 120 sec by the production method. Duration was 20 min; scores were time intervals produced.

(6) Digit Span: 30 Ss were tested using standard procedure (Terman & Merrill, 1937). Duration was 5 min; S's score was length of sequence repeated without error.

(7) Simple Reaction Time: 25 Ss gave 75 RTs to extinction of a lamp. Time uncertainty varied randomly between 3 and 5 sec. Duration was 20 min; score was mean RT.

(8) Calculations: 25 Ss summed columns of 5, 2 digit numbers, at their own pace. Duration was 60 min. Scores were number attempted and % error. (Note: This test differs from the other seven in that it is a "naturally" familiar task that all Ss had previously performed for several hours per day for 15 days.)

Results and Discussion

Mean performance scores are shown in Table 1, together with the significance level of the overall "time of day" effect resulting from the appropriate F test in analyses of variance of the data.

The results suggest that the tasks fall into three groups. In the largest of these (Tasks 1, 2, 3, 4, and 8) an improvement in at least one aspect of performance occurred as the day progressed. All these tasks were repetitive, and with the exception of Card Sorting, were of at least 30 min duration. As such, they might reasonably be classified as "unstimulating," and therefore be expected to be sensitive to S's level of motivation or degree of arousal (Wilkinson, 1965), or in common sense terms, to how hard S is "trying" (note that in the self paced tasks, it is speed, rather than error, which is the sensitive score).

Three tasks did not show significant improvement through the day. One of these (RT) exhibited a nonsignificant trend in the direction of improvement, suggesting it may be similar to the main groups of tasks. More surprising was the lack of an effect of time of day on Time Estimation, since such an effect has been reported by Thor (1962), and would be expected in view of the rise in body temperature associated with

Table 1.
Mean performance scores at five times of day.

Test/Score	TIMES OF DAY 8 AM	10:30 AM	1 PM	3:30 PM	9 PM	Significance Level (p .05 and below)
1. 5-Choice						
(a) Correct (No.)	2692	2669	2649	2747	2751	<.05
(b) Errors (No.)	30.8	28.3	35.4	28.5	28.1	NS
(c) Gaps (No.)	15.9	13.3	20.0	12.1	10.0	<.05
2. Vigilance						
(a) Correct detections (%)	56.0	62.5	58.3	62.5	68.2	<.025
(b) False reports (No.)	8.6	8.0	9.2	10.6	11.3	NS
3. Card Sorting						
(a) Time for 2 categories (sec)	63.9	61.9	62.2	62.9	60.9	<.001
(b) Time for 8 categories (sec)	87.2	85.2	86.1	86.0	83.8	<.001
4. Letter Cancellation						
(a) Output (No.)	1515	1675	1598	1673	1706	<.001
(b) Error (%)	1.49	1.40	1.67	1.58	1.43	NS
5. Time Estimation*						
(a) 10 sec	10.25	10.01	10.82	9.53	10.89	NS
(b) 120 sec	136.50	121.00	124.14	111.52	117.21	NS
6. Digit Span (actual)	7.58	7.98	7.79	7.74	7.31	<.025
7. Reaction Time (m/sec, actual)	326	320	330	315	314	NS
8. Calculations						
(a) No. done	331	350	338	340	377	<.001
(b) % Error	2.46	2.87	2.79	2.31	2.57	NS

Results for time intermediate between 10 and 120 sec are not shown, but the results were substantially similar.

time of day (Blake, 1967), and the observed association between body temperature and time estimation (Kleber, Lhamon, & Goldstone, 1963; Baddeley, 1966).

The one task at which performance, after initial improvement, tended to *deteriorate* throughout the day was Digit Span. This could be interpreted either in terms of the negative correlation between level of arousal and short-term memory (Kleinsmith & Kaplan, 1963) or as a direct effect of body temperature on rate of forgetting. French (1942) studied the retention of a maze habit by goldfish and noted that retention improved as temperature was lowered, although there do not appear to be any comparable data for men.

In general, however, these results show a definite diurnal variation in performance with efficiency improving throughout the day. With the exception of a temporary drop following lunch, this trend is consistent, and is closely associated with the diurnal rise in body temperature. The fact that the results are based on relatively large samples of Ss, and that the effect is observable in a number of tasks ranging from novel laboratory tests to a familiar, highly practiced operation suggests that the time of day effect has wide generality.

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Notes

1. This research was supported by the Royal Naval Personnel Research Committee of the British Medical Research Council.

2. This note was prepared by his colleagues from data collected by Mr. Blake before his accidental death in October, 1965.