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# TIME OF DAY, SPEED OF RESPONSE, ALERTNESS AND FATIGUE

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## ABSTRACT

**Background:** Human performance changes over the course of the day. The profile of the time-of-day effect depends on the type of task carried out. Responses in reaction time tasks are faster later in the day, and this may reflect a speed-error trade-off or changes in the speed of encoding new information. Alertness peaks in the late morning and is reduced after task performance. The present study examined whether changes in reaction time reflected differences in fatigue caused by performing the task in the morning and afternoon. **Method:** Two hundred and seventy two staff or students (159 females, 113 males; mean age 35.4 years, age range 17-65 years) from Cardiff University participated in the study. They completed the tasks in either the late morning (11.00-13.00) or afternoon (16.00-18.00). Participants carried out a focused attention two-choice reaction time task and a categoric search task. They also rated their alertness before and after the tasks. The main outcomes of interest were mean reaction times and alertness. Secondary outcomes were selective attention measures, errors, lapses of attention and the speed of encoding new information. **Results:** Reaction times in both tasks and for specific conditions in the tasks were faster later in the day. Alertness was higher in the morning. Performing the tasks induced fatigue, but this did not vary over the day. **Conclusion:** The present study confirmed that alertness is higher in the late morning than in the late afternoon. In addition, alertness is reduced by task performance. Reaction times were quicker later in the day, but these did not reflect diurnal variation in the fatigue induced by performing the tasks.

**KEYWORDS**: Time of day; Focused attention; Categoric search; Choice reaction time; Alertness; Fatigue.

## INTRODUCTION

There has been considerable research on the effects of time of day on performance.[1-3] Psychomotor tasks are usually performed faster in the afternoon than in the morning,[1-3] with the slower speed in the morning being due to sleep inertia or low circadian alertness. Faster speeds in the afternoon are associated with an increased error rate in some tasks.[4-5] This speed-error trade-off could be due to fatigue over the day. Alertness ratings often show a peak in the late morning and then decline in the afternoon.[6] The present study compared the performance of choice reaction time tasks in the late morning and late afternoon. Alertness ratings were also taken to confirm that there were the expected changes over the day. Alertness was rated before and after the choice reaction time tasks. Performing the tasks leads to fatigue, and the present study examined whether this effect changed over the course of the day. Acute fatigue, produced by carrying out performance tasks, is usually greater when levels of alertness are reduced.[7] This was examined in the present study.

The present research investigated time-of-day effects on two-choice reaction time tasks developed by Broadbent et al.[8,9] The first task involved focused attention, with the target letter always being presented in a central location. In the second task, a categoric search task, the target could be in one of two possible locations near or far from the centre of the screen. These tasks have been used to investigate the effects of factors such as caffeine, exposure to noise, nutrition and minor illnesses.[10-19] Many of these studies have focused on global outcomes such as mean reaction time, errors, and lapses of attention (occasional very long reaction times). Others have examined the encoding of new information (the difference between responses to new stimuli and those which are a repetition of the previous trial). A recent study showed that the encoding of new information in a focused attention task was quicker later in the day.[20] The encoding of new information has been shown to be changed by drugs which influence cholinergic functioning.[21] Broadbent et al.[9] examined selective attention measures derived from these tasks and found significant effects on the time of day. The Eriksen effect, which is a measure of focused attention, was larger in the morning, suggesting that later in the day, attention is set at a wide angle. Smith[16] conducted a study which replicated this effect. In the categoric search task, stimuli presented in the same location as the previous trial are responded to more quickly than those in a different location. This is known as the place repetition effect, and it is greater in the afternoon.[9]

The main focus of the present study was on the speed of response at different times of the day. Alertness ratings were also recorded, and it was predicted that these would be lower after performing the task. The present study examined whether this fatigue effect might underlie the differences in speed observed across the day. Secondary outcomes included lapses of attention (errors and long reaction times) and the selective attention measures derived from the two tasks (the Eriksen effect from the focused attention task and the place repetition effect from the categoric search task).

## METHOD

The study was carried out with the informed consent of the participants, following approval from the ethics committee, School of Psychology, Cardiff University.

### *Design*

A between-subjects design was used, with volunteers being randomly allocated to times in the late morning (11.00-13.00) or afternoon (16.00-18.00). Prior to the test session, the volunteers were familiarised with the tasks.

### *Participants*

Volunteers were recruited from the university staff and students. Two hundred and seventy-two volunteers (159 females, 113 males; mean age 35.4 years, age range 17-65 years) completed the study.

### *Details of the tasks*

#### Mood rating

Mood was assessed both before and after each set of performance tests using 18 computerised visual analogue rating scales (e.g. Drowsy/Alert; Happy/Sad; Tense/Calm.). These yield three mood dimensions: Alertness, Hedonic tone and Anxiety. The alertness ratings were used in the present analyses.

#### Focussed Attention Task

This task was developed by Broadbent et al.[8,9] Target letters were upper case A's and B's. On each trial, three warning crosses were presented on the screen, with the outside crosses being separated from the middle one by either 1.02 or 2.60 degrees. Volunteers were told to respond to the letter presented in the centre of the screen and ignore any distracters presented in the periphery. The crosses were on the screen for 500 msec and were then replaced by the target letter. The central letter was either accompanied by 1) nothing, 2) asterisks, 3) letters which were the same as the target or 4) letters which differ - the two distracters were identical, and the targets and accompanying letters were always A or B. The correct response to A was to press a key with the forefinger of the left hand, while the correct response to B was to press a different key with the forefinger of the right hand. Volunteers were given ten practice trials followed by five blocks of 64 trials. In each block, there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distracter conditions. The nature of the previous trial was controlled.

#### The task gives three main types of outcome measures

1. Global indicators of speed, accuracy and lapses of attention.
2. Speed of encoding of stimuli
3. Resistance to distraction and focusing of attention.

#### Categoric search task

This task was also developed by Broadbent et al.[8,9] Each trial started with the appearance of two crosses in the positions occupied by the non-targets in the focused attention task (i.e. 2.04 or 5.20 degrees apart). Volunteers did not know, in this task, which of the crosses would be followed by the target. The letter A or B was presented alone on half the trials and was accompanied by a digit (1-7) on the other half. Again, the number of near/far stimuli, A versus B responses and digit/blank conditions were controlled. Half of the trials led to compatible responses (i.e. the letter A on the left side of the screen or the letter B on the right), whereas the others were incompatible. The nature of the preceding trial was also controlled. In other respects (practice, number of trials, etc.), the task was identical to the focused attention task.

#### The task gives four types of measures

1. Global indicators of speed, accuracy and lapses of attention.
2. Speed of encoding of stimuli
3. Speed of response organisation
4. Measures of spatial attention.

These tasks have been shown to be sensitive measuring instruments that can detect subtle changes in state.

## RESULTS

The data from the performance tasks were analysed with a MANOVA. The between-subject factor was the time of day, and the dependent variables were the outcomes of the performance tasks. Separate analyses examined changes in alertness.

### *Time of day effects*

#### Focused attention choice reaction time task

The speed of reaction time for three types of trial were analysed:

- No distractors
- * as a distractor
- Agreeing or disagreeing letters as distractors.

All of the above conditions showed that reaction times were significantly faster later in the day (see Table 1). There were also more lapses of attention (RTs > 750 msec) in the morning. There were more errors in the afternoon, but this effect was not statistically significant. Similarly, neither the Eriksen effect nor the speed of encoding showed significant effects of the time of day.

**Table 1: Time of day effects in the speed of responding (msec) in the focused attention task (scores are the means, SDs in parentheses).**

| Condition | Morning | Afternoon | Significance |
|---|---|---|---|
| No distractor | 450 (82) | 429 (72) | F (1,270) =5.22 p <0.05 |
| *distractor | 447 (80) | 425 (70) | F (1,270) =5.82 p <0.05 |
| Agree/Disagree letters as distractors | 459 (83) | 439 (76) | F (1,270) =4.42 p <0.05 |
| Lapses of attention | 5.6 (13.7) | 3.0 (8.0) | F (1,270) = 3.76 p <0.05 |

**Categoric search choice reaction time task**

As in the focused attention task, reaction times were significantly quicker in the afternoon, and there were more lapses of attention (RTs > 1000 msec) in the morning (see Table 2).

**Table 2: Time of day effects in the speed of responding (msec) in the categoric search task (scores are the means, SDs in parentheses).**

| Condition | Morning | Afternoon | Significance |
|---|---|---|---|
| Overall RT | 570 (78) | 550 (70) | F (1,270) =5.45 p <0.05 |
| Lapses of attention | 15.2 (21.8) | 9.4 (13.5) | F (1,270) = 7.10 p <0.01 |

There were more errors in the afternoon, although this effect was not significant. The place repetition effect was greater in the afternoon but this effect was not significant.

**Alertness**

Alertness was significantly lower in the afternoon than in the morning, and it decreased from pre- to post-task (see Table 3). There was no significant interaction between the time of day and pre/post-task ratings, suggesting that the task-induced fatigue did not vary over the day.

**Table 3: Time of day effects on alertness before and after performing the tasks (high scores = greater alertness; scores are the means, SDs in parentheses).**

| Condition | Morning | Afternoon | Significance |
|---|---|---|---|
| Pre-task alertness | 279 (68) | 237 (83) | F (1,270) = 12.2 p < 0.001 |
| Post-task alertness | 242 (72) | 209 (68) | F (1,270) = 14.8 p < 0.001 |

## DISCUSSION

The aim of the present research was to examine the speed of performing different types of choice reaction time tasks in the late morning and afternoon. It was predicted that reaction times would be faster later in the day. Subjective alertness was also recorded, and it was predicted that this would be higher in the late morning compared to the early afternoon. Alertness was recorded before and after performing the tasks, and it was predicted that performing the tasks would induce fatigue. Secondary measures included lapses of attention, errors and measures of selective attention. It was predicted that errors would be greater in the afternoon, lapses of attention higher in the morning, focusing of attention would be greater in the morning, and responses to stimuli in the same location as the previous trial would be quicker in the afternoon.

The results confirmed the faster reaction times later in the day. There were also more errors later in the day, although this effect was not statistically significant. Lapses of attention, occasional long reaction times, were more frequent in the morning. The place repetition effect was larger in the afternoon, although the effect was not statistically significant. Alertness ratings were significantly higher in the morning, and this was observed for both pre-and post-task ratings. Alertness was lower after performing the task, and the magnitude of this effect was not influenced by the time of day. Some effects, namely the Eriksen effect and encoding of new information, did not show the predicted trends over the day. This may be because these time-of-day effects vary depending on the characteristics of the person[9] or may also be changed by factors such as consumption of caffeine[12] or smoking.[21]

Overall, the present study replicated two well-established effects in time-of-day research, namely the changes in alertness over the day and the faster reaction times later in the day. The underlying mechanism investigated was the fatigue induced by performing the tasks. As expected, the post-task ratings of alertness were lower than the pre-task ratings. However, the size of this effect was constant over the day, which suggests that it could not account for the changes in the speed of response. Time of day effects are important in work and education, and also many activities in other contexts (e.g. driving). Effects observed in the laboratory may translate into reduced efficiency and safety in real life.

## CONCLUSION

It is well established that human performance varies with the time of the day and time- of-day effects depend on the type of task. Psychomotor tasks are performed faster in the afternoon compared to late morning, and this may be due to a speed-error trade-off or increased speed of encoding new information. Alertness ratings peak in the late morning and are reduced after performing tasks. The present study examined whether diurnal variation in reaction time reflected the fatigue caused by performing the task. Two hundred and seventy two students or staff (159 females, 113 males; mean age 35.4 years, age range 17-65 years) from Cardiff University took part in the study. They completed the tasks between 11.00-13.00 or 16.00-18.00. They carried out a focused attention choice reaction time task and a categoric search task. They rated their alertness before and after performing the tasks. The main outcomes of interest were mean reaction times in the two tasks and alertness. Secondary outcomes were errors, lapses of attention, selective attention measures, and the speed of encoding new information. Reaction times in both tasks were faster later in the day. The alertness was higher in the morning, and performing the tasks induced fatigue, which did not vary over the day. The present study confirmed that alertness is higher in the late morning than in the late afternoon and that alertness is reduced by task performance. Reaction times were quicker later in the day, but these did not reflect differences in the fatigue induced by performing the tasks at different times of the day. Future research must identify the mechanisms underlying these time-of-day effects and also consider their implications for work, education and other real-life activities.

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