INTRODUCTION

Caffeine is said to have, non-specific arousal enhancing effects and specific cognitive effects (Van der Stelt & Snel, 1993, 1998). If true, especially in states of fatigue the energising effects of caffeine should be found more prominently. The antihypnoid or fatigue compensating effects of moderate amounts of caffeine, appear to be caused predominantly by the blocking of inhibitory adenosine receptors which are found diffusely distributed in the brain. It implies that effects of caffeine will be seen as increases of cortical arousal. Indeed, caffeine has been found to induce increased cortical arousal, manifested as increase in frequency in the EEG. Also, after ingesting caffeine doses up to 250 mg caffeine, subjects report a decrease of fatigue, sleepiness or drowsiness, increased alertness or more vigour (e.g. Koopmans & Van Boxtel, 1988; Reyner & Horne, 1997). Bonnet and Arand (1992) used caffeine to develop a physiological arousal model of chronic insomnia in a group of healthy adults. The subjects received three times daily 400 mg caffeine for 7 nights and days. In addition to a reduced sleep efficiency, sleepiness during day time, as measured with the MSLT, was significantly increased (cf. Koopmans & Van Boxtel, 1988). Obviously, arousing effects of caffeine at night may cause increased sleepiness during daytime.

One obvious way to induce fatigue is staying awake during the night: the more hours awake, the more fatigued. Our aim was to study whether caffeine affects specific and/or non-specific cognitive functions, and whether these effects are dependent on fatigue and whether changes in the EEG are localised at specific sites on the scalp.

METHOD

The subjects were 30 young (21.2 ± 1.7 yrs) healthy, non-smoking regular coffee-consumers (2–7 cups/day). The subjects received in a cross-over design, deceptively and double blind, 200 mg + a 50 mg caffeine maintenance dose or placebo put into a cup of decaffeinated coffee. After familiarisation with different tasks and after 12 hour abstinence of caffeine, the subject were tested. Subjects were tested either in a fatigued or a well-rested condition. To induce fatigue the subjects were kept awake and were tested between 4.00 and 6.30 a.m., whereas in the well rested condition they were tested between 09:00 and 11:30 am. In the tasks subjects were asked to react as fast and as accurately as possible to a specified target stimulus. The tasks used were based on Sanders’ cognitive-energetic model (Sanders, 1983); independent
variables stimulus degradation, stimulus-response compatibility and time-uncertainty (for details see: Lorist, 1984a). In the second part of the study a visual focused selective search task was used with memory loads (ML) of 2 and 4 letters (for details see: Lorist, 1984b; 1998) The task was to detect whether one of two displayed letters belonging to the memory set appeared on the correct diagonal of the screen. Dependent variables were task performance (reaction time, hits and errors) and changes in event related potentials, derived from the EEG recorded during task performance at Fz (frontal), Cz (central), Pz (parietal) and Oz (occipital).

RESULTS*

In the 'Sanders' tasks, caffeine shortened reaction-time (56 ms or 8.2%) for the intact stimuli; 78 ms or 10.1% for the degraded stimuli) and decreased the number of errors. The effects of caffeine were additive with stimulus-degradation and variable-stimulus intervals.

![Selective attention task diagram](image)

Figure 1: Reaction times on the selective search task in well rested and fatigued subjects

* Only significant results are mentioned of p<0.05
In the ERPs the stimulating effects of caffeine appeared as amplitude-increases of the N1 component and the P3, which are said to represent stimulus encoding and stimulus evaluation respectively. Apparently, caffeine affects the perceptual and response stages of information processing, but not the central processing stage. Interestingly, after the subjects were kept awake till 3 o’clock in the morning it was found that beneficial effects of caffeine were found both in the well rested and the fatigued subjects, suggesting that caffeine can do more than compensate performance impairment due to fatigue.

As for the selective search task, with caffeine the subjects reacted faster (27 ms or 4.5% with ML 2; 58.5 ms or 8.7% with ML 4), and more accurately, whereas the ERPs showed larger N1 and N2b components, suggesting improved selection of relevant information.

Caffeine counteracted fatigue as shown from larger P3 in comparison with the placebo at Cz and Pz. Caffeine similarly influenced the ERPs of the non-attended stimuli, independently of memory load, stimulus category or state. This effect prevailed over the centro-posterior area, suggesting an improved signal-to-noise ratio.

DISCUSSION

The stronger stimulating effects of caffeine on task performance and EEG-activity in fatigued, sleep deprived subjects compared to well-rested subjects do not necessarily mean that such effects are caused by caffeine only. The effects may be the outcome of the interaction of caffeine, the effort to mobilise energetic resources to stay awake and the relief of caffeine withdrawal (Linde, 1995). A second comment refers to the generalisation of these findings to other situations, in which one has to stay awake, for example when working at night (shift work). In SD laboratory studies, the subjects are kept relatively idle, while during shift work one is active. Notwithstanding this difference, similar positive effects of caffeine on task performance and fatigue during overnight working have been observed and this has been replicated in many studies (for review, Snel, 1993). Caffeine in doses up to 300 mg (about 3 to 4 cups) in overnight work apparently causes dose-related beneficial effects on task performance and on compensating fatigue. Hence, it is not the work that makes people tired but the inappropriate stage of the circadian sleep-wake cycle at which people have to stay awake; in such a situation caffeine may help. A further comment follows from Sanders’ cognitive-energetic model. It means that caffeine is able to mobilise the energetic sources, and since these are finite, it should mean that improvement of functioning and the compensation of fatigue in fact delays the negative effects of being awake at night and should result in impaired performance and more sleepiness during daytime. In view of the emphasis on the beneficial economical advantages of flexible working times and its wide acceptance, it is worth to study this assumption.
REFERENCES

DIURNAL TYPE AND CAFFEINE
ATTENTION, MEMORY SEARCH AND VISUAL ERPs

J. Snel¹, M.M. Lorist², J. Ruijter¹ and M.B. de Ruiter¹

¹Department of Psychonomics, Faculty of Psychology, University of Amsterdam
²Faculty of Psychology, Rijks Universiteit Groningen

INTRODUCTION

Although caffeine is said to have arousing effects on perceptual and cognitive functions, these effects are not always consistent (see review, Van der Stelt & Snel, 1998). Causes of these inconsistencies are person bound factors such as boredom, fatigue, motivation, morningness-eveningness (M-E) and environmental factors, like noise and time pressure. In general, effects of caffeine appear most clearly in suboptimal states, for example when one is tired (Lorist et al., 1994a/b, 1998). In drug research these factors are not always taken into account or are not reported, which makes it difficult to disentangle the effect of such factors from the effect of the experimental factor being studied. In this study we assess the influence of M-E type on the effects of caffeine.

Morning types are reported to have a relatively advanced circadian phase position and evening types a relatively delayed one (Kerkhof, 1981). Consequently, in the morning, morning types are usually more active and perform better than evening types and vice versa. The assumption we like to test is that when measured in the evening, morning types who are expected to perform worse than evening types will benefit more from caffeine than evening types.

METHOD

Based on Kerkhof’s diurnal type questionnaire (score range 7-31) (Kerkhof, 1984), 15 moderate to extreme morning types (mean score = 24.9±2.1) and 15 evening types (mean = 12.2±1.6), participated. They were healthy, non-smoking students (mean = 21.4±3.1 yr.), daily coffee drinkers (range 2-6 cups/day, mean = 3.8±1.5). At 19.30 p.m., the subjects received in a cross-over design one cup of decaffeinated coffee with either 200 mg lactose or 200 mg caffeine in a deceptive, double blind and randomised procedure. Testing started 30 min after coffee intake. The tasks were a visual focused attention and a memory search task (for details see Lorist, 1995). The instruction was to attend to the diagonal which was designated relevant by the cue frame, and to press a button as quickly and accurately as possible as soon as a target letter appeared. A 200 ms pre-stimulus period was used as baseline for the Event Related Potentials (ERPs). The epoch used for analysis lasted until 1080 ms post-stimulus. Attention processes were evaluated by comparing ERPs of relevant and irre-