Sleepiness Enhances Distraction During a Monotonous Task

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Study Objectives: Although sleepiness appears to heighten distraction from the task at hand, especially if the latter is dull and monotonous, this aspect of sleep loss has not been assessed in any systematic way. Distractions are a potential cause of performance lapses (as are microsleeps). Here, we investigate the effects of sleepiness on a monotonous task, with and without distraction.
Design: Repeated Measures 2 × 2 counterbalanced design, comprising Sleepiness (night sleep restricted to 5 hours × normal sleep) and Distraction (distraction × no distraction).
Setting: Participants underwent 30-minute sessions on the Psychomotor Vigilance Test (2:00 PM - 3:10 PM), with or without an attractive distraction to be ignored, under normal and sleep-restricted conditions.
Participants: Sixteen healthy young adults (mean age 21.10 years; 21-25 years [8 men; 8 women]) without any sleep or medical problems and without any indication of daytime sleepiness.
Interventions: Normal sleep versus sleep restricted to 5 hours and distraction versus no distraction. Distraction comprised a television in the visual periphery, showing an attractive video that had to be ignored.
Measurements & Results: Psychomotor Vigilance Test performance was monitored, as were the participants' head turns toward the television via videocameras. There was a significant increase in both head turns and lapses during sleep restriction plus distraction. Moreover, sleepiness also increased head turns even during no distraction. Distracting effects of sleepiness were clearly evident during the initial 10 minutes of testing.
Conclusions: Distractibility is an important aspect of sleepiness, which has relevance to safety in the real world, eg, sleepy driving.
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INTRODUCTION

IN CONTEMPORARY 24/7 SOCIETY, MANY PEOPLE WORK UNDER CONDITIONS OF ACUTE SLEEP LOSS, WHETHER THIS SLEEP LOSS BE THROUGH SHIFTWORK, by long working hours, or simply from late-night socializing. However, despite the large number of studies looking at sleep loss, certain aspects of sleepiness more relevant to a work setting are not so well understood as might otherwise seem.

Our reasoning begins with laboratory findings with arguably the most common type of psychological performance test to assess sleepiness: simple, unprepared reaction time with instant visual feedback ("knowledge of results"[1,2]), exemplified by the Psychomotor Vigilance Test (PVT[3]). This tedious task is sensitive to sleepiness even with only 10 minutes of testing, wherein the key sign of impairment is a "lapse," often a "microsleep,"[3-5] typified by drooping eyelids and theta electroencephalographic activity. Between lapses, response time is near to normal.[6] Good experimental practice requires participants to be well trained in the test beforehand (to minimize practice effects), with the experimental setting being within a sound-attenuated and visually sterile environment, ostensibly to avoid unwanted distractions.[2,3,7,8] Although such a lack of novelty coupled with a low task demand enhances any sleep-inducing effects, this may also increase the participants' desire to seek alternative stimulation.

By removing external distractions, few, if any, studies of sleepiness have assessed the impact of distraction in any systematic way. However, in the real world, such a laboratory setting is unusual, as most tedious work environments incorporate unwanted distractions. We define distraction as a "temporary diversion of attention to an unexpected or otherwise interesting peripheral event, resulting in a loss of focused attention to the task at hand."

We argue that sleepiness increases vulnerability to distraction and that distraction itself may be an important measure of sleepiness. Such a propensity for distraction may well have a neuropsychological basis, as the suppression of distractions largely centers on the prefrontal cortex. This region seems vulnerable to sleep loss, as shown by brain imaging studies[9-11] and by neuropsychological findings.[5,12-16] Outside the field of sleep loss, visual distraction by movement or movement-like activities (e.g., flashing light) in the visual periphery causes healthy alert individuals attending to an event ahead of them to divert their gaze toward such movement. This is a well-known eye-movement reflex (cf.[17]), and the degree to which this eye movement can be voluntarily suppressed (e.g., by an "antisaccade") largely depends on the integrity of the "frontal eye fields," which are part of the prefrontal cortex. While nothing is known about whether this suppression is impaired by sleepiness, clinical findings outside this area indicate that dysfunction of the prefrontal cortex adversely affects the suppression of this reflex.[17] Although no sleep-loss study has investigated 'distractibility" specifically, three incidental reports, not concerned with distraction itself, provide some insight into evoked distractions.[18-20] Norton[18] and Blagrove et al[19] both clearly indicated the disruptive effects of auditory or visual distractions on task performance in sleepy people. Hockey's[20] findings were more interesting in this respect. In assessing the division of attention between a primary (tracking) and a less important secondary task (peripheral monitoring), he reported that sleepiness caused participants to dwell excessively on the latter, less-important task. Despite this being a study of dual tasking, rather than of distrac-

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tion per se, it highlights a tendency to divert attention away from a tedious task.

Here, we investigate the impact of sleepiness on the PVT, when accompanied by distractions caused by a peripheral event that has to be ignored.

METHOD

Participants

Sixteen healthy young adults (mean age 21.10 years; 21-25 years [8 men; 8 women]) were recruited following interviews and a questionnaire-based screening procedure to exclude those who smoked, had an average intake of more than 4 units of alcohol per day (unit = half pint beer, one shot of alcohol, small glass of wine), had sleep or medical problems other than minor illnesses, were on medications liable to cause daytime sleepiness, took daytime naps more than twice per month, or were beyond the normal range (≤ 10) on the Epworth Sleepiness Scale.[21] As a check for stable sleep patterns, they wore Actiwatches (Cambridge Neurotechnology Ltd., Cambridge, UK) for an initial week. Those who consistently slept for 8 hours ± 1 hour per night with regular sleep-wake times were deemed suitable for inclusion in the study. The study was approved by our University's Ethical Advisory Committee, and participants were paid for their involvement. All procedures were fully explained, and participants gave written consent.

Design and Procedure

Participants underwent a repeated-measures 2 x 2 counterbalanced design, comprising Sleepiness (sleep restriction versus normal sleep) and Distraction (distraction versus no distraction). On an initial day, separate from the main study, they underwent a 30-minute practice session on the PVT in order to minimize practice effects. Subsequently, they came to the laboratory on two occasions, a week apart: once following sleep restriction and the other after normal sleep. On both occasions, they experienced distraction and no-distraction conditions (see below). Under the sleep restriction, sleep was reduced to 5 hours by delaying sleep onset at night, with the same rising time. To ensure participant compliance on the nights prior to PVT measurement, they again wore Actiwatches. The sleep data were downloaded and checked blind for adherence to the 5-hour sleep reduction or normal sleep protocols. Participants also completed sleep logs (including lights-out and rising times) as a further check for sleep compliance. Finally, they completed the Karolinska Sleepiness Scale[22] throughout the experimental days.

On nights prior to testing, participants abstained from alcohol and caffeinated drinks from 6:00 PM. They came into the laboratory at 1:00 PM, were given a small lunch, and then relaxed with light reading prior to testing at 2:00 PM. This comprised two, 30-minute PVT sessions separated by a 10-minute break. For one session they were exposed to the distraction (see below) throughout the PVT task, and during the other, "nondistracting" occasion, a standard laboratory practice was followed (see below), free of distractions. The two sessions were counterbalanced.

Psychomotor Vigilance Test

All sessions were conducted in a sound-dampened cubicle with participants seated at a computer screen with their preferred index finger or thumb of the dominant hand resting on a response button, with which they responded immediately to a digital millisecond clock appearing on the screen. Interstimulus intervals averaged 7 seconds within a random range between 2 and 12 seconds.

Distractions

A TV screen located in the visual periphery, 90° from the PVT monitor, was either off (no distraction) or on (distraction) and showing a video with sound. The latter condition consisted of one of two comparably distracting 30-minute episodes of the popular TV programme "The Office." These were selected following a pilot study with other sleep-restricted individuals undergoing similar 30-minute PVT sessions showing various episodes of this program, where "distractibility" was monitored by head turns (i.e., "distractions"—see below). The TV volume was fixed at a mean sound level of 70 dB; similar to that of a normal conversation in a quiet room.

For the main study, the two selected episodes were presented in random order, with participants not shown the same episode twice. For all sessions, participants were asked to ignore the TV screen (whether it was on or off), and to attend fully to the PVT task. They were observed throughout the sessions via two miniature cameras recording (1) the frontal face and (2) a "bird's-eye" view. These recordings were scored blind for "distractions," characterized by a head turn away from the PVT toward the TV screen. We analyzed the PVT data by dividing it into those responses below 500 milliseconds (deemed reaction times) and those above this threshold, with the latter simply identified as lapses. We were not able to synchronize head-turn data with the PVT lapses.

Statistical Analysis

Mean reaction times, lapses, and head turns were assessed by two-way (Sleepiness × Distraction) repeated-measures analyses of variance using the Huynh-Feldt ε adjustment. Data for lapses and head turns were square rooted in order to normalize their distributions. Reaction-time data were already normally distributed.

RESULTS

Psychomotor Vigilance Test

Reaction Times Below 500 Milliseconds

There was a significant effect of Sleepiness ($F_{1,15} = 9.04$, $p < .01$, ε1.00) but no such effect with Distraction ($p = .47$), and neither was there any significant interaction ($p = .97$) (Figure 1).

Lapses—Responses Above 500 Milliseconds

Again, and as expected, there was a significant effect of Sleepiness ($F_{1,15} = 7.41$, $p < .02$, ε1.00). More importantly, Figure 2 also shows a clear interaction between Sleepiness and Distraction ($F_{1,15} = 6.39$, $p < .02$, ε1.00). A main effect of Distraction was just above the acceptable level of significance ($p = .06$). Inspection of Figure 2 reveals the large and significant effects of Distraction when accompanied by Sleepiness (i.e., the interaction effect). Distraction did not significantly worsen lapses under alert conditions.

Head Turns

These showed significant effects of both Sleepiness ($F_{1,15}$ =

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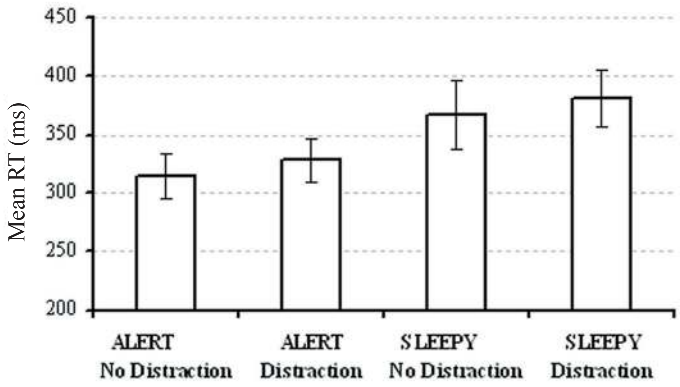

Figure 1—PVT mean reaction times (RTs), for RTs below 500ms for Alert and Sleep Restricted conditions with and without competing distraction. The significant effect of SLEEPINESS is apparent. No significant effect of DISTRACTION, nor any significant interaction, was found.

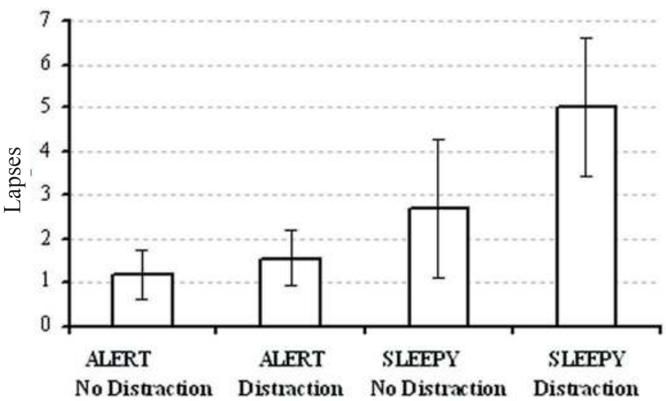

Figure 2—PVT mean lapses (RTs above 500ms) for Alert and Sleep Restricted conditions with and without competing distraction. Although the main effect of distraction was just above the accepted level of significance, the significant interaction between sleepiness and distraction is clearly evident.

18.30, $p < .001$, ε1.00) and Distraction ($F_{1,15} = 21.59$, $p < .0005$, ε1.00) (Figure 3). The Sleepiness × Distraction interaction was also significant ($F_{1,15} = 15.02$, $p < .002$, ε1.00), which can clearly be seen in the additional effect of Distraction during the sleepy condition. Interestingly, and unexpectedly, was the observation of an increase in head-turns during the sleepy versus alert conditions, but under the no-distraction conditions with the TV off. A paired t test, comparing these data was significant ($t_{15} = 4.32$, $p < .001$).

The marked increase in head turns when Distraction was added to Sleepiness was quite evident, even during first 10 minutes of testing. To illustrate this, Table 1 shows the data of Figure 3 broken down into 10-minute epochs.

DISCUSSION

Arguably, this study is the first to show the impact of a competing distraction on sleepiness-related lapses at the PVT. Whereas most studies remove any extraneous distraction to minimize possible confounding variables, we have exploited Distraction to highlight the impact of Sleepiness in what might be considered to be a more realistic working environment. While the addition of a competing distraction did not significantly increase head turns

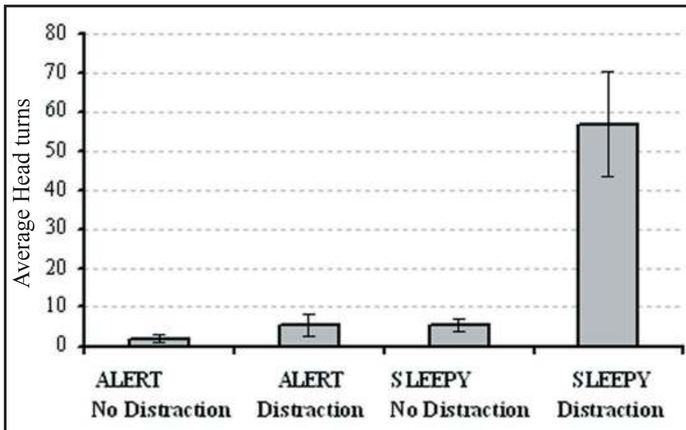

Figure 3—Head turns (indicating distraction) for Alert and Sleep Restricted conditions with and without competing distraction. The main effects of SLEEPINESS and DISTRACTION were significant, as was the interaction between them. Note - there was a significant increase in distractions when sleepy, even without competing distraction ($p < 0.001$) – see Results.

Table 1—Number of Head Turns per Minute as a Function of Time on Task. Data are presented as mean ± SEM. Note the clear effect of distraction on sleepiness throughout the duration of the test, even during the first 10 minutes of testing.

Condition	Time on Task, min		
	0-10	**11-20**	**21-30**
ALERT			
No Distraction	0.11 ± 0.01	0.08 ± 0.01	0.07 ± 0.01
Distraction	0.39 ± 0.03	0.32 ± 0.02	0.14 ± 0.01
SLEEPY			
No Distraction	0.11 ± 0.01	0.25 ± 0.04	0.27 ± 0.04
Distraction	1.85 ± 0.09	2.20 ± 0.09	2.51 ± 0.12

and lapses in the alert condition, the effect of this distraction during Sleepiness was marked, even during the initial period of testing.

Interestingly, even without the distracting TV being on, sleep restriction still produced a small but significant increase in spontaneous head turns compared with the respective alert condition. This suggests that even in nondistractive environments, sleepy people will seek distraction, possibly in an attempt to overcome sleepiness or boredom. Unfortunately, we are unable to determine the extent to which these spontaneous head turns contributed to the increase in lapses.

It is not surprising that reaction times below 500 milliseconds were relatively unaffected by the competing distraction, as head turns would be expected to be associated with longer reaction times, that is, lapses. Nevertheless, given the random nature of the 7-second mean interstimulus interval for the PVT, head turns were usually much briefer, albeit more frequent, than lapses. Thus, not all head turns led to a lapse, which is reflected by the ratio of head turns per lapse. For example, this varied from 1 lapse per 1.6 head turns during alert plus no distraction, to 1 lapse per 11.4 head turns during sleepy plus distraction conditions.

Whereas sleepiness-related distractions may be of little relevance to someone working in an office environment, with others talking in the background, telephones ringing, or movement in the visual periphery, for the individual who has to monitor surveillance screens, it could become more problematic. Of greater concern is the sleepy car or truck driver traveling along a monoto-

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nous road. Is he or she more easily distracted by flashing hazard lights on the hard shoulder or by novel activities adjacent to the road? Moreover, in having the potential to distract, are the dashboard-mounted, navigation/route finders, with dynamic, moving, and colored displays, particularly problematic for the sleepy driver? Our study found marked effects of distraction when coupled with only moderate levels of sleepiness (during the afternoon "dip" following 1 night of 5-hour sleep restriction), during a monotonous task, which, in real-world terms, was of fairly short duration (30 minutes). This situation needs to be contrasted with the not unusual scenario of a lengthy drive during the small hours of the morning, without sleep, and on a monotonous road.

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