Dissociable Processes in Classification: Implications From Sleep Deprivation

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Military personnel often continue at high levels of performance despite being deprived of sleep. This article examines sleep deprivation effects on two forms of classification learning. In AN classification, participants are trained on one category and are then required to classify new items into the A or a previously unseen non-A category. In AB classification, participants are trained on A and B category members and are then required to classify new items into the A or B category. Preliminary results suggest that sleep deprivation impairs AN classification learning but leaves intact AB classification learning. Implications for military training are discussed.

An ability to perform maximally when sleep deprived is critical for military personnel (Belenky et al., 1994). A common belief is that sleep deprivation leads to a global cognitive slowing, but recent reviews suggest that while some tasks are adversely affected, others are relatively unaffected (Harrison & Horne, 2000). Williamson and colleagues (Williamson, Feyer, Mattick, Friswell, & Finlay-Brown, 2000) found that sleep deprivation impaired performance across a range of perceptual, attentional, and memory tasks but found relatively intact visual search and logical reasoning. Others have found intact rule-based performance and impaired complex reasoning abilities (Harrison & Horne, 2000). These data are suggestive of a more complex relationship between sleep deprivation and cognitive performance, but it is difficult to draw direct comparisons. For example, the tasks differ in the nature of the cognitive processes that are recruited and are the focus of the empirical investigation but also differ along a number of other dimensions, such as the nature of the perceptual, motor, and motivational aspects of the tasks. In addi-

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tion, the duration of sleep deprivation affects performance, and so it is important to control the duration of sleep deprivation across tasks.

The focus of this article is to explore the implications of 24 hours of sleep deprivation on two types of classification learning that are thought to be mediated by distinct memory systems and cognitive processes (Ashby & Maddox, 2005). Critically, the tasks differ only in the underlying cognitive processes that are required to solve the task, while holding constant the perceptual, motor, and motivational aspects of the task. Classification learning has important implications for the military because it is one of the most important and ubiquitous tasks faced by personnel at every level. Command personnel must classify information rapidly in order to make assessments of whether a mission is successful or not. They must also classify units as ready for combat or mop up. Individual foot soldiers in the field must constantly classify individuals in their environment as either friend, foe, or civilian.

In the next section we briefly describe the two classification learning tasks and provide evidence for their dissociable neural and cognitive processing. Then we speculate on the potential effects of sleep deprivation on performance in these tasks, and we review briefly the results from an ongoing study that suggests that sleep deprivation adversely affects performance in one, but not the other classification learning task. We conclude with some general remarks.

**TWO CLASSIFICATION LEARNING TASKS**

In a typical classification learning task, the participant is presented with a series of objects or items that are each drawn from one or more structured categories. During this training period, the participant is asked to classify each object into one of several categories and receives corrective feedback regarding their responses. Through trial-by-trial feedback, the participant learns to discriminate among the categories. Following training, the participant is generally presented with a series of test items that are used to evaluate the participant's category knowledge. The participant is required to generate a classification response but receives no feedback. These items are also members of the trained categories but are often novel members not presented during training. Both tasks outlined below use this training-test format.

In the A not A (AN) classification learning task, participants are shown members of category A during training and during the test are asked to decide whether novel items are in category A or are not in category A. In the AB classification learning task, participants are shown members of category A and B during training and during the test are asked to decide whether novel items are in category A or category B. Critically, in the design adopted in our study, the same stimuli are used in the test phase for both the AN and AB tasks. Thus, any differences observed here in
AN and AB performance cannot be attributed to differences between the structures of non-A versus B category or to any stimulus-specific differences.

As shown in Figure 1, we utilize as stimuli cartoon animals (adapted from a study by Bozoki, Grossman, & Smith, 2006) that vary along 10 binary dimensions, such as body shape (round or square), head position (facing forward or upward), tail shape (feathery or pointy), etc. With 10 binary valued dimensions there are $2^{10} = 1,024$ unique stimuli to choose from. In the AN and AB classification learning task, one stimulus serves as the category A prototype with all 10 of its feature values being referred to as prototypical features. All other stimuli can be defined relative to the prototype and can differ on 1 to 10 of the prototypical feature values. The stimulus with all 10 non-prototypical features is the non-A prototype in the AN task and is the B prototype in the AB task.

EVIDENCE FOR DISSOCIABLE NEURAL AND COGNITIVE PROCESSES

Despite the fact that more work is needed to thoroughly understand the neural and cognitive underpinnings of AN and AB classification learning, a clear picture is beginning to emerge. AN classification learning is intact in patients with Parkin-

![Figure 1](image)

**Figure 1** Example stimuli from one stimulus set. The left-most stimulus represents the prototype of category A; stimuli to the right from the prototype represent examples of stimuli with increasing distances from the A prototype. The right-most stimulus becomes a category B prototype. Stimuli having a distance 0 to 4 from the prototype A were considered category A members, and stimuli at the distance 6 to 10 were considered category B (non-A) members.
son's disease (Reber & Squire, 1999), schizophrenia (Kéri, Kelemen, Benedek, & Janka, 2001), Alzheimer's disease (Kéri, Kálmán, Kelemen, Benedek, & Janka, 2001), and amnesia (Knowlton & Squire, 1993; Zaki, Nosofsky, Jessup, & Unverzagt, 2003). Neuroimaging studies with the AN task report learning-related reductions in occipital cortex activation to category A exemplars (Alzenstein et al., 2000; Reber, Stark, & Squire, 1998a, 1998b). These data suggest that the perceptual representation memory system might mediate AN classification learning.

Unlike the results for AN classification learning, AB classification learning is impaired in Alzheimer's disease (Sinha, 1999) and amnesia (Sinha, 1999; Zaki et al., 2003). Neuroimaging studies with the AB task report learning-related changes in occipital lobe (as seen with the AN task) but also report learning-related changes in prefrontal and parietal cortices (DeGutis & D'Esposito, 2007; Seger et al., 2000). Taken together these finding suggest that explicit reasoning and episodic memory processes might mediate AB classification learning. Consistent with this dual system framework, a recent fMRI study that used the exact procedures described above (Zeithamova, Schnyer, & Maddox, 2007) found that the perceptual representation memory system that is mediated primarily by activation in the occipital lobe was involved in AN classification learning, whereas the explicit and episodic memory systems that are mediated primarily by activation in the frontal and medial temporal lobes were involved in AB classification learning.

SLEEP DEPRIVATION AND AN VERSUS AB CLASSIFICATION LEARNING

The previous review suggests that AN classification learning is mediated by posterior brain regions that are involved in early perceptual learning, whereas AB classification learning is mediated by frontal and medial temporal lobe regions. Although to date no study has examined category learning under conditions of sleep deprivation, the most reasonable initial prediction based on the extant sleep deprivation literature is that AB learning should be impaired. This follows because a number of studies suggest that complex decision-making tasks that involve frontal structures are affected by sleep deprivation (Drummond et al., 2000, 1999). Concrete predictions regarding the AN task are less forthcoming. On the one hand, it seems like early perceptual learning processes could be hard hit by sleep deprivation as suggested by some research (Williamson et al., 2000). On the other hand, if sleep deprivation affects primarily frontal brain functioning, and AN learning is better when that system is not attempting to learn, it may be the case that AN learning will be unaffected. The current study compared these two types of category learning under tight experimental control utilizing the same stimuli under equivalent test conditions.
SLEEP DEPRIVATION IN WEST POINT CADETS: PRELIMINARY RESULTS

In an ongoing investigation of sleep deprivation (Maddox, Zeithamova, & Schnyer, 2008), West Point cadets completed AN and AB classification learning tasks after waking from a good night’s sleep and then 24 hours later after being kept awake continuously for 24 hours. A control group comprised of college students from the University of Texas at Austin also completed AN and AB classification tasks after a good night’s sleep and then 24 hours later completed additional AN and AB classification learning tasks, but this group was allowed to engage in their regular evening sleep during that 24-hour period. Preliminary results suggest that sleep deprivation led to impaired AN classification learning relative to the control group but did not lead to impaired AB classification learning relative to the control group (see Figure 2). Thus, based on a comparison of the sleepless and control groups, it is clear that the withdrawal of sleep led directly to an AN classification learning deficit but not an AB classification learning deficit.

To determine the locus of the AN classification learning deficit, we compared performance across sleep-deprived and control participants for test stimuli that were more or less representative of the category prototype—that is, stimuli that shared more or fewer features with the prototype. Somewhat to our surprise, we found that the locus of the AN sleep deprivation deficit was in participants’ failure to accurately classify the stimuli that were most similar to the category prototype; in a sense, the less difficult stimuli.

![Figure 2](image-url) Performance decrement from session 1 to session 2 for sleepless minus control groups.
CONCLUSIONS

This article explores the implications of sleep deprivation on the learning of neu- rally and cognitively dissociable classification tasks. Preliminary data from an on- going study suggests that sleep deprivation adversely affects learning in AN classifi- cation tasks that are thought to be mediated by a perceptual representation memory system in the occipital cortex but did not adversely affect learning in AB classification tasks that are thought to be mediated by a explicit and episodic mem- ory system mediated by frontal and medial temporal lobes. In addition, we found that the locus of the AN classification learning deficit was isolated to the stimuli that should be "easier" to classify.

These findings have implications for military training and performance. They suggest that the nature of classification training could be biased toward training on multiple categories, such as AB training, and less on single category training, such as AN training. For example, when training to distinguish friend from foe, it might be important to train on members from both categories (as in AB training) and not just train to identify one group (as in AN training). The results also suggest that when AN training is required, it would be wise to overtrain on the easier classification stimuli because performance on these items suffers most under sleep de- privation. Thus, if one can only train on one group, say friend or foe, it is important to overtrain on the most distinct or obvious members. Sleep deprivation is a serious problem that military personnel must deal with. An understanding of the cognitive processes that are and are not affected by sleep deprivation is critical to the mission of the military. Studies, like this one, that examine specific experimental effects while holding as many other aspects of the task constant will yield important re- sults and help us to better achieve this mission.

ACKNOWLEDGEMENT

This research was supported by Army Grant W911NF-07-2-0023, through the Center for Strategic and Innovative Technologies at the University of Texas at Austin.

REFERENCES


