

COGNITIVE DEFICITS IN NARCOLEPTICS:
POSSIBLE CAUSES,
SIMILARITIES TO ADHD,
AND CLASSROOM ACCOMMODATIONS

by

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Narcolepsy is a sleep disorder affecting more than 1 in 2,000 Americans. It is characterized by excessive daytime sleepiness, a fast transition into REM sleep, and is often accompanied by cataplexy (a symptom involving involuntary loss of muscle tone in awake patients). In most cases the disorder is autoimmune, the immune system targets and destroys hypocretin (orexin) producing neurons in the hypothalamus. Narcolepsy is permanent and irreversible. Treatments consist primarily of neurostimulant pharmaceuticals designed to keep patients awake during daytime hours; they do not restore the hypocretin pathway. This pathway is implicated in maintaining wakefulness, metabolism, and is also a reward pathway that could factor into complex memory and executive function tasks. Additionally, narcoleptics have altered sleep stage cycles that are key for memory processing and consolidation. It is not yet known if or how narcoleptics process memories differently, however, it is known that narcoleptics exhibit cognitive and attentional deficits. These deficits appear to show similarities to symptoms of attention deficit hyperactivity disorder (ADHD), which is a far more common learning disorder. Little is known about appropriate accommodations

for narcoleptic students in classroom settings. Current recommendations are vague and focus only on preventing sleep attacks, not on the cognitive impairments associated with the disorder. In addition to synthesizing known narcoleptic deficiencies and discussing their possible classroom implications. For this project, I performed a clinical review of relevant literature on cognition in narcoleptics. I found no obvious pattern in task performances between the disorders, but narcoleptic literature was scarce, so pattern detection was difficult. Furthermore, the results vary widely in the narcoleptic studies making observed deficits controversial. In addition, I choose two tasks (Alternating Reactions, and the Dual Task) in which ADHD and narcolepsy seemed to show similar results and quantitatively compared them. I found supported similarity only in narcoleptic and ADHD-I and ADHD-H subtypes reaction times. Error rates were not significantly different on these two tasks either, but when narcoleptics were compared to ADHD controls, no difference was observed, indicating little support for similarity claims. Overall more research is needed into the topic and attention must be paid to replicating previous study finding and reporting hypocretin levels alongside them. It is difficult to say exactly how much accommodation is needed for narcoleptics in academic settings, but I feel that executive function support programs that are used to help ADHD students stay on track should be offered to narcoleptics as well. I hope to encourage further thought into the status of this underrepresented group; this project aims to improve the information available on classroom implications of all aspects of narcolepsy, not just the primary sleep symptoms.

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Table of Contents

Introduction/ Background:	1
What is Narcolepsy?	1
Narcolepsy and Cognition:	6
How is it treated?	8
My experience	9
Project Importance	10
Disabilities in Classroom Settings	11
Methods:	13
Results:	16
Phasic Alertness	16
Visual Scanning (Focused Attention)	17
Dual Task (Divided Attention)	18
Alternating Reactions (Flexibility of Attention)	19
Incompatibility (Focused Attention)	19
Stroop Test (Inhibition)	20
Trail Making Test (Focused Attention)	20
Controlled Oral Word Associated Test (Verbal Fluency)	21
Digit Symbol Substitution Test (Focused Attention)	21
Continuous Performance Test (CPT) (Sustained Attention)	22
Direct Comparison of ADHD and Narcoleptic Task Performance	25
Discussion:	31
Limitations	31
Future Research Directions	34
Conclusion:	35
Bibliography	38

List of Figures

Figure 1. Typical sleep pattern of normal and narcoleptic individuals over a 24 hour period. Image from Dubuc, n.d.	2
Figure 2. Location of hypocretin producing neurons in the brain. The perifornical area (written in red) is the main producer of the neurotransmitter hypocretin. Hypocretin neurons project onto many other areas of the brain (illustrated by the red arrows). Image from Silber & Rye, 2001, pg. 1617.	3
Figure 3. Alternating Reaction task RTs in ADHD and narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM. Only ADHD-C was found to differ significantly ($p < 0.001$) from narcolepsy, see Table 4 for a complete report of p -values.	27
Figure 4. Alternating Reaction task errors in ADHD and narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM	28
Figure 5. Dual Task RTs in ADHD and narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM. ADHD-I and ADHD-C were found to differ significantly ($p < 0.05$), showing faster RTs compared to narcoleptics, see Table 4 for a complete report of p -values.	29
Figure 6. Dual Task errors in ADHD and Narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM. No significant difference was found between narcolepsy and any of the ADHD subtypes, see Table 4 for a complete report of p -values.	29

List of Tables

Table 1: Subject demographics of all studies examined in this review of cognitive deficits in ADHD and narcoleptics. Studies ordered alphabetically by primary author's last name.	15
Table 2. Summary of parallel results from studies of cognitive function in ADHD and narcolepsy.	23
Table 3. Summary of the total number of tasks that observed deficits for various cognitive abilities in both narcoleptics and ADHD individuals. If any difference was found in a task, it was counted in the "Deficit" category.	24
Table 4. P values from unpaired two-tailed t-Tests comparing narcolepsy to each ADHD subtypes and their respective controls in the Alternating Reactions and Dual Task.	30

Introduction/ Background:

What is Narcolepsy?

The first definitive clinical description of narcolepsy is from the late 19th century, though reports of extreme cases date back to 1672 (Schneck, Bassetti, Arnulf, & Mignot, 2007). Narcolepsy is a permanent, debilitating sleep disorder characterized by the intrusion of sleep into daily activities referred to as sleep attacks. Because narcoleptics have little control over their sleep wake cycles, these episodes often occur at inappropriate times. Additionally, narcoleptics enter the rapid eye movement (REM) sleep stage far sooner after sleep onset than healthy individuals, which distinguishes narcolepsy from other disorders that cause excessive daytime sleepiness. Typically, narcoleptics transition into REM within ten minutes of falling asleep, whereas healthy individuals do not enter it until 60-80 minutes of sleep (“Narcolepsy Fact Sheet”, 2015). Throughout a single day, narcoleptics exhibit a sleep pattern that consists of erratic bouts of sleep moving directly into REM whereas healthy individuals only sleep at night and cycle through the stages of sleep successively, with longer and longer blocks of REM as the night progresses. This is illustrated in Figure 1 (Dubuc, n.d.).

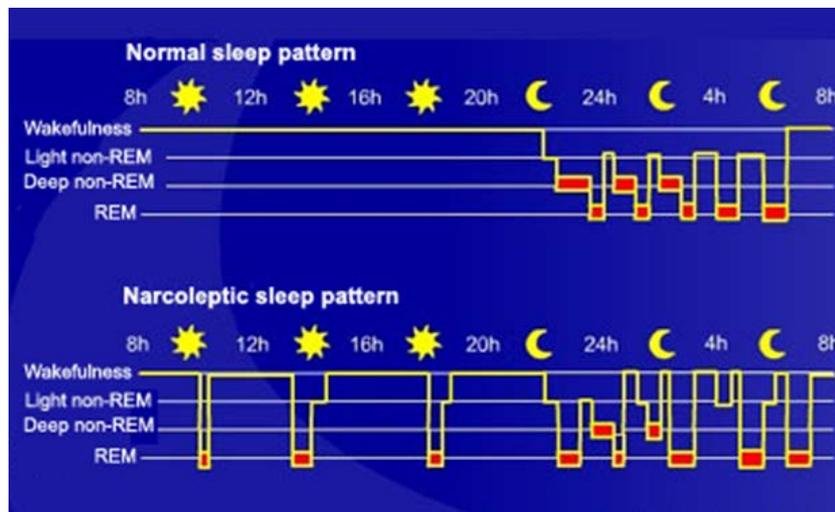


Figure 1. Typical sleep pattern of normal and narcoleptic individuals over a 24 hour period. Image from Dubuc, n.d.

Much is still unknown about narcolepsy. The leading theory to explain the cause of narcolepsy is that it is an autoimmune disorder. Many narcolepsy patients have abnormally low levels of a neurotransmitter called hypocretin or orexin. Hypocretin is produced and released only by a relatively small number of neurons that form a specific pathway originating in the lateral hypothalamus. The main hypocretin pathways are illustrated in Figure 2. Hypocretin is an excitatory neurotransmitter necessary for maintaining wakefulness (Nishino, Ripley, Overeem, Lammers, & Mignot, 2000). As narcolepsy is not usually diagnosed until high school age or older, it is thought that the immune systems of narcoleptic patients are triggered later in life to target and destroy these hypocretin-producing neurons. Unfortunately, this explanation cannot account for all narcoleptics, as studies have found narcoleptic patients who have normal and even drastically high levels of hypocretin despite exhibiting normal narcoleptic symptoms. Additionally, some healthy control subjects have low hypocretin levels yet normal sleep wake cycles (Dauvilliers *et al.*, 2003; Nishino *et al.*, 2000).

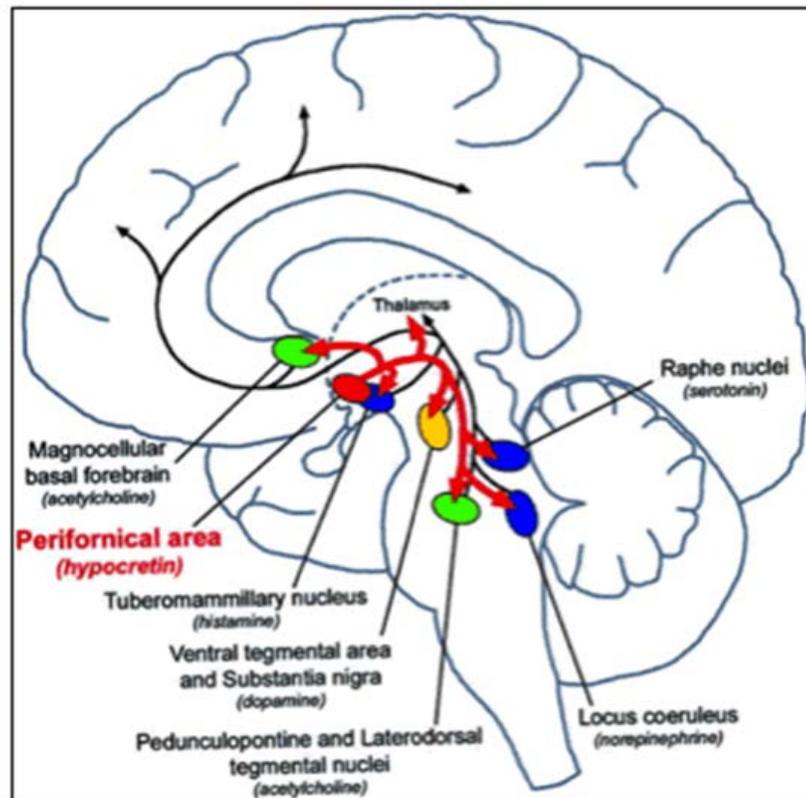


Figure 2. Location of hypocretin producing neurons in the brain. The perifornical area (written in red) is the main producer of the neurotransmitter hypocretin. Hypocretin neurons project onto many other areas of the brain (illustrated by the red arrows). Image from Silber & Rye, 2001, pg. 1617.

Narcoleptics show strong correlations with the existence of a single gene variant: HLA DQB1*0602. This gene encodes a surface protein used by immune cells to identify foreign (i.e. enemy) cells (Rodgers, Meehan, Guilleminault, Grumet, & Mignot, 1997) This gene variant is present in about 25% of the general United States population, but 98% of narcoleptics exhibit this variant. The HLA gene is believed to predispose individuals to narcolepsy, but they may never suffer from the disorder if their immune system is not exposed to a pathogen that resembles hypocretin.

Interestingly, introduction of specific types of flu vaccines, such as one used for H1N1

in 2009, correlate with increased incidence of narcolepsy (Yong, 2013). Additionally, narcoleptics have been found to have a specific type of CD4 T cell (an immunity cell that identifies pathogens) that responded to both fragments of H1N1 and to the neurotransmitter hypocretin (Alberto *et al.*, 2013). Hypocretin-producing neurons are found only in the lateral hypothalamus and perifornical areas, but fibers and receptors are more wide-spread (Huang, Ghosh, & Van den Pol, 2006). It is important to note that hypocretin has a metabolic function and hypocretin receptors have been found in many areas of the body outside of the central nervous system such as the pancreatic islets, adrenal gland, adipose tissue, and bone (Funato, 2015). The regions with the highest density of hypocretin receptors and fibers are the locus coeruleus and the paraventricular thalamus (Huang et al, 2006). The function of these brain regions are discussed further in the section of this paper entitled “Narcolepsy and Cognition”.

Narcolepsy is often accompanied by cataplexy, a symptom that involves loss of voluntary muscle tone when the patient experiences strong emotions. During REM sleep, the brain actively puts the body into a cataplexic state, which prevents injuries that could result from acting out dreams. When a narcoleptic undergoes a cataplexy episode, the brain paralyzes the body as it would during REM sleep despite narcoleptic remaining completely awake. The presence of cataplexy as a symptom classifies individuals as type I narcoleptics, and, when it is absent they are referred to as a type II narcoleptic. Seventy percent of narcoleptics are type I, but not all of them experience full-body cataplexy. Some lose muscle tone only in their eyelids or legs. Interestingly, one study found that type I narcoleptics show an average of 90% loss of hypocretin producing neurons across the anterior, posterior, dorsal, dorsal-medial, and lateral

hypothalamic nuclei, with the most loss sustained in the posterior hypothalamus. The same study found the brain of a type II narcoleptic only showed a 33% reduction, with the loss occurring almost exclusively in the posterior hypothalamus (Thannickal and Siegel, 2015). These results are preliminary findings and, considering the highly variable presentations of narcolepsy, more data is needed to conclude whether the less extreme loss is a consistent finding amongst type II narcoleptics.

Other prominent symptoms of narcolepsy are related to REM sleep overlapping with wake states during transitions between the two. Sleep paralysis is a symptom similar to cataplexy in which sufferers also experience complete paralysis, but sleep paralysis and cataplexy are distinguished by the states during which they occur. While cataplexic attacks happen while the individual is completely awake, sleep paralysis occurs temporarily as the sufferer transitions into wakefulness. Another symptom of narcolepsy, hypnagogic (also called hypnopompic) hallucinations also occur while waking up or falling asleep. They are described as vivid dream-like projections over awake perceptions. They manifest as visual or auditory aspects of dreams overlapping with wake states, meaning that sufferers are literally dreaming while awake.

Narcoleptics also have higher incidence rates of obesity and depression, although it is debated why this is the case. Recent research has shown that sleep deprivation in mice models reduces symptoms of depression (Hines, Schmitt, Hines, Moss, and Haydon, 2013). This raises the possibility that too much sleep could result in depression, but this conclusion is not currently supported by research. The hypocretin pathway itself has also been implicated in boosting metabolism and emotional reward pathways. The loss of such pathways could plausibly result in more difficulty losing

weight and less motivation (a key symptom of depression). Also, the hypocretin pathway has a metabolic function. Hypocretin receptors can be found in the islets of the pancreas, adrenal gland, bones, and adipose tissue, but experimental results probing into the functional changes when hypocretin binds have been inconsistent. However, it has been implicated in glucose metabolism, obesity, enhancement of sympathetic tone, and changes in bone mass. Narcoleptics who were not obese (BMI < 30) lower basal metabolic rates when compared to healthy subjects with similar BMIs (Funato, 2015). Alternatively, the mental toll of not having control over sleep-wake cycles may cause narcoleptics to become depressed. Sleep intrusion into daytime and fear of embarrassment if a sleep attack should strike often prevent narcoleptics from participating in physical activities, making obesity more likely (“Getting a Diagnosis”, 2013).

Narcolepsy and Cognition:

Executive function is a broad term that refers to cognitive control processes, such as organization, spatial reasoning, working memory, and concentration. Previous studies show narcoleptics exhibit impaired performance on some executive function tasks meant to test working memory and concentration (Naumann, Bellebaum, & Daum, 2006). By moving so quickly into REM, narcoleptics initially forego the earlier, less deep stages of sleep (“Narcolepsy Fact Sheet”, 2015). It is theorized that one of the critical functions of sleep is memory processing and storage. REM sleep has been implicated in processing declarative memory, while earlier stages of sleep seem to be important for storage of muscle memory tasks (“Sleep, Learning, and Memory”, 2007). The sudden bypass of other stages of sleep observed in narcolepsy patients could have

important effects on memory processing. Weinhold, Göder, and Baier (2015) linked the hypocretin pathway to memory by observing that during exploratory activity in mice, hypocretin pathways were maximally stimulated, they concluded the pathway is likely involved in memory of new spaces. More directly, selectively inactivating hypocretin receptors in mice caused memory impairments (Weinhold, Göder, & Baier, 2015).

Though mice and humans differ, this initial evidence is intriguing.

Additionally, the hypocretin pathway has been implicated in reward processing (Delazer *et al.*, 2011). One of the primary nuclei onto which the hypocretin-producing perifornical area neurons (Figure 2) project is called the paraventricular thalamus (PVT) (Hsu & Price, 2009). Huang, Ghosh, and Van den Pol (2006) found the density of hypocretin innervation in the PVT of mice is equivalent to the density observed in the locus coeruleus, a region previously identified as having the highest density of hypocretin innervation. The PVT in turn has many excitatory projections onto the ventral aspect of the medial pre-frontal cortex, specifically the infralimbic and prelimbic cortices, nucleus accumbens, and the amygdala. These areas are particularly important for limbic functions such as motivation and attention (Huang *et al.*, 2006). The PVT has been heavily studied for its applications in renewing drug addiction and reward seeking behaviors (Hamlin, Clemens, Choi, & McNally, 2009). Furthermore, the ventral parts of the medial pre-frontal cortex downstream from the PVT “play key roles in executive aspects of attention and a broad spectrum of limbic and associative functions” (Huang *et al.*, 2006, pg. 1656). With less excitatory input from perifornical area, the PVT excites reward pathways and the ventral parts of the medial prefrontal cortex less often. With the strong association between reward pathways and attention (Blum *et al.*, 2008),

it is probable that low hypocretin levels could explain the attention deficits of narcoleptics (Iatallese, Cremaschi, Coin de Carvalho, Tufik, & Coelho, 2015).

REM sleep physiology differs dramatically from the physiology of other stages. During non-REM sleep stages, similar to wake states, body temperature, blood pressure, heart rate, and breathing are maintained in regular patterns (Amlaner & Fuller, 2009). However, in REM sleep, core body temperature approaches ambient temperature, and blood pressure, heart rate, and breathing become irregular, thus undergoing dramatic dips and spikes in activity. The latter effects are seemingly due to up-regulation of sympathetic activity. These alterations to the normal, regular patterns of cardiorespiratory physiology make REM more physiologically stressful than other stages of sleep. By interrupting normally awake periods with REM sleep, narcoleptics are exposed to these irregular homeotic states during the daytime. This could have adverse effects on the mental comfort and wellbeing.

Finally, and perhaps most obviously, when a narcoleptic has a sleep attack, they are unable to learn or form new memories during the event. This is extremely disruptive for learning.

How is it treated?

The main symptoms of narcolepsy are each treated with different pharmaceuticals. Excessive daytime sleepiness (EDS) was historically treated with amphetamines developed for ADHD treatment. Today, however, the neurostimulant modafinil and its variations are commonly prescribed. More severe cases of narcolepsy, especially those with cataplexy, are often treated with antidepressants. Antidepressants are used in severe cases because they suppress REM sleep, reducing the instances of

sleep paralysis and hallucinations. Unfortunately, these medications must be taken daily for the rest of the patient's life and have many side effects. Some natural methods can be used to reduce excessive daytime sleepiness such as maintaining consistent sleep schedules with a at least eight hours of sleep a night and routinely taking short (30 minute) afternoon naps.

Classrooms and workplaces often demand long stretches of focus and passive listening, which are more difficult for narcoleptics. Additionally, side effects of narcolepsy medications can disrupt work and studies. Current recommendations for accommodating narcoleptics in these settings only address the mitigation of sleep attacks themselves (i.e. allowing a student to stand or walk around the room if they feel sleepy) and not the cognitive deficits observed ("Classroom Accommodations", 2013).

My experience

I was diagnosed with type II narcolepsy during my third year at University of Oregon in February 2015. Leading up to my diagnosis, regardless of the amount of sleep I got the night before, I was completely unable to stay awake while reading or sitting class. Even in small discussion courses I would nod off for part of the class, which caused me considerable embarrassment and social anxiety. After being lectured by one professor during their office hours about not falling asleep in class, I was too ashamed to ask my professors for help with class materials after sleeping through their initial explanation of the topic. Classmates I had never met knew me as the girl who fell asleep every day, making my sleepiness a running joke. Even my friends did not understand why I couldn't manage to stay awake and began to think of me as lazy. My

ability to study was affected not only by my sleepiness, but also by social consequences of appearing disinterested in class.

Driving was also a dangerous activity. Usually I can feel a sleep attack coming on and take preventative measures such as pulling over for a bit or doing something to startle myself, but occasionally I have microsleeps. Microsleeps are milder and shorter sleep attacks that come on so suddenly and subtly that the transition into unconsciousness isn't realized until after the microsleep is complete and wakefulness has returned. Often third parties cannot tell when microsleeps onset, as narcoleptics appear to be awake. Many people, myself included, actually continue to perform activities we were doing before the microsleep. I have continued to take notes during microsleeps in class, but the notes from these times are incoherent. Similarly, before diagnosis, I awoke from microsleeps while driving to find my car drifting slowly out of my lane. I am extremely fortunate that I never crashed as a result of my disorder. Many narcoleptics are not as lucky, as it is common for them to seek diagnosis only after they have had a vehicular accident as a result of their sleepiness.

I was inspired to write my thesis on narcolepsy when the UO accessibility center and other resources had little information about narcolepsy and how to accommodate it. Since I will be living with the disorder for the rest of my life, I want to know all I can about how to maximize my learning efficiency and I want future narcoleptics to have access to all the information they need.

Project Importance

Narcolepsy is more common than most people realize; it is the third most common neurodegenerative disease, affecting more than 1 in 2,000 Americans

(Thannickal, and Siegel, 2015). One of the most frustrating aspects of narcolepsy is the lack of public awareness and scientific understanding. This paper will help quantify the learning impairments of narcolepsy patients, aiding educators and students alike in determining the most effective accommodations to improve learning abilities, as well as illuminate areas where more research is needed. This topic applies to healthy individuals as well. A better understanding of sleep cycles, and their effect on mood, motivation, attention, and memory is applicable to all humans. Studying natural disorders and deficits provides unique insight on human physiology mechanisms.

Disabilities in Classroom Settings

Here at the University of Oregon, the process of disability accommodation begins with the disabled student making an appointment at the Accessible Education Center. The student then receives a personal consultation with one of the five access advisors who try to determine the areas in which the student needs extra help and work with the student to decide what accommodations are needed. After this consultation, the student is asked to submit medical records that document their disability. Once their records have been reviewed and approved, the student is affiliated with the Accessible Education center and will receive appropriate accommodations from the university. The personal tailoring of UO's educational accommodation is a commendable tactic, but it has some pitfalls. There is no feasible way the five access advisors can stay up to date on new research for all disabilities. This means that the advisors have can be ill-equipped to handle complex questions on more obscure disorders, like narcolepsy (Hilary Gerdes, Senior Director of UO Accessible Education Center, personal communication, May 18, 2016).

On a broader scale, a survey of US teachers in 2008 revealed that half of middle and high school teachers felt the learning abilities of their students were so varied that they could not teach them effectively. American educator's disability training requirements vary widely by state. As of 2011, some states do not require any special education coursework in preparation curriculum for general education teachers (Blanton, Pugach, & Florian, 2011). Compounded with inconsistent preparation for students with learning disabilities, there is little information on narcolepsy in the classroom when compared to ADHD. A quick search on Disability.gov reveals this disparity. Searching the term "narcolepsy" elicited a single two-sentence description of the Narcolepsy Network, a nonprofit committed to advocating, educating, and raising awareness of narcolepsy. Using the search term "ADHD" however resulted in 41 articles on research, advocacy, and specific accommodations for all grade levels and standardized tests. Recommendations for ADHD students are more nuanced and detailed than those for afforded for narcolepsy. For example, the Accessible Education Center here at UO offers accommodations to individuals with ADHD that meant to support executive function deficits. One accommodation some receive is weekly meetings with a graduate teaching fellow to ensure the student is budgeting their time wisely and is remaining on track for their class assignments. Such accommodation is not offered to narcolepsy students at UO (Hilary Gerdes, Senior Director of UO Accessible Education Center, personal communication, May 18, 2016). This difference in accommodations does not seem to be deliberate, rather it seems to stem from ignorance of studies on cognition and narcolepsy.

Interestingly, narcolepsy seems to share quantitative similarities with ADHD. Oosterloo, Lammers, Overeem, de Noord, and Kooij (2006) found considerable overlap in self-reported symptoms of inattention and sleepiness between adults with ADHD and narcoleptics.

Methods:

The interconnectivity of mood, sleep, attention, and memory is apparent to anyone who has studied the human brain. Drawing off of this relationship, informational resources on classroom accommodations for narcolepsy patients often compare narcolepsy to ADHD (“Resources for Students”, 2016 and “Classroom Accommodations”, 2013). These comparisons are meant to help educators frame this rare sleep disorder in a familiar light, as it is likely that educators have experience with students with ADHD but not narcolepsy. Due the qualitative overlap of attentional symptoms, I hypothesized that ADHD individuals, especially those with ADHD-I (the inattentive subtype), would perform similarly on cognitive measures of attention, alertness, and memory.

The similarities between attention and concentration abilities of those with these disorders can be difficult to qualitatively distinguish. Similar to Fulda and Schulz’s (2001) comparison of cognitive dysfunction in different sleep disorders, I performed a literature review examining cognitive deficits in narcoleptics. Furthermore, I performed statistical analyses to test quantitatively whether comparisons drawn between cognitive deficits in narcoleptics and ADHD are justified. The studies used were found from extensive searching on PubMed, PsycNet, Web of Science, ScienceDirect, and Google

Scholar for primary research aimed at quantifying narcoleptics' executive function and cognition abilities.

This search yielded four primary research studies: Bayard, Langenier, De Cock, Scholz, and Dauvilliers (2012); Naumann, Bellebaum, and Daum (2006); and Rieger, Mayer, and Gauggel (2003), and two clinical reviews: Rieger (2006) and Fulda and Schulz (2001). A full detailed comparison of the subject demographics can be found in Table 1. Bayard *et al.* had entirely un-medicated and medication-naïve patients, while Rieger *et al.* (2003) had 13 of 19 subjects with narcolepsy un-medicated. Naumann *et al.* only had 4 un-medicated narcoleptic subjects out of 15, but no significant difference in the task performance was observed between medicated and un-medicated narcoleptics through the course of the study. They all focused on adults with a median age in their late 30s. Across studies there were more female than male subjects, but since the control groups had the same gender composition, this likely did not affect the results. Finally, the studies tended to focus on narcolepsy with cataplexy (the most common type of narcolepsy). Naumann *et al.* utilized only subjects with cataplexy, while Bayard *et al.* found equal numbers of both types of narcoleptics. Rieger *et al.* (2003) did not specify whether subjects had cataplexy.

After exploring the specific tests used in these studies, I was able to search for studies containing data from the same tests from samples of adults with ADHD. It proved more difficult than expected to find studies on ADHD in adults as much of the research focuses on children. However, one primary research study fit my criteria; Tucha, Tucha, Laufkotter, Walitza, Klein, and Lange (2008). A clinical review of cognitive abilities in ADHD across the lifespan was also identified: Seidman (2006).

Tucha et al (2008) had 94 research subjects and Seidman (2006) used 33 studies. Both focused on European adults who were around the same age as the narcolepsy studies' subjects. Tucha et al (2008) additionally divided subjects into the three ADHD subtypes: ADHD-I (inattentive), ADHD-H (hyperactive/impulsive), and ADHD-C (combined).

Table 1: Subject demographics of all studies examined in this review of cognitive deficits in ADHD and narcoleptics. Studies ordered alphabetically by primary author's last name.

<i>Study Authors and Year</i>	<i>Disorder Studied</i>	<i>Number of Subjects</i>	<i>Subject Age (yrs ± SD)</i>	<i>Subject Gender</i>	<i>Subject Medication Status</i>	<i>Subject Nationality</i>
Bayard <i>et al.</i> (2012)	Narcolepsy	44 Total 22 w/ cataplexy 22 without	range 15-74	59% M 41% F	29 med naive, 15 unmed	France
Fulda and Schulz (2001)	Narcolepsy	Clinical review 14 studies	-	-	-	-
Naumann <i>et al.</i> (2006) Part 1	Narcolepsy	15 w/ cataplexy	38.3 ± 15.9	40% M 60% F	4 unmed, 11 med	Germany
Naumann <i>et al.</i> (2006) Part 2	Narcolepsy	21 w/ cataplexy	35.9 ± 12.7	19% M 81% F	6 unmed, 15 med	Germany
Rieger <i>et al.</i> (2006)	Narcolepsy	Clinical review 6 studies	-	-	-	-
Rieger <i>et al.</i> (2003)	Narcolepsy	19 (cataplexy unspecified)	39.9 ± 11.5 range 23-57	47% M 53% F	13 unmed, 6 med	Germany
Seidman (2006)	ADHD	Clinical review 33 studies on adults	-	-	-	-
Tucha <i>et al.</i> (2008)	ADHD	94 Total 19 ADHD-I 12 ADHD-H 63 ADHD-C	ADHD-I: 36.84 ± 2.40 ADHD-H: 33.17 ± 2.66 ADHD-C: 33.00 ± 0.97	53% M 47% F	94 med naive	Germany

The following is a description of the results of these studies on cognitive abilities of narcoleptics and ADHD patients divided by task type. These results are organized by task are listed in Table 2. Table 3 is a condensed tally of the number of times a deficit was observed within each category of cognitive ability in either ADHD individuals or narcoleptics. When possible, I statistically compared the published data between the equivalent studies: these comparisons are represented by Figures 3-6.

Results:

Phasic Alertness

First, I looked at the phasic alertness task. For this test subjects are asked to click a button when a stimulus (an 'x') appears on the screen in front of them. During the tonic condition of the task the 'x' would appear without warning, but in the phasic condition a tone preceded the stimulus. Reaction times (RT) were used to measure test performance. The narcolepsy studies found different results with this test. While Naumann *et al.* (2006) found no significant difference between narcoleptics and controls, Rieger *et al.* (2003) and Bayard *et al.* (2012) both found narcoleptics (only those with cataplexy in the case of Bayard *et al.*) to have significantly slower and more variable RTs compared to healthy controls, with patient's performance deteriorating over time. Fulda and Schulz (2001) described similar findings in the existing literature, with two of the four studies finding that narcoleptics had reduced alertness. But, the other two studies found no difference between narcoleptics and controls in either the tonic or the phasic portion of the test. It is important to note that Fulda and Schulz (2001) selected papers with slightly different tasks, which were also designed to

measure alertness. Tucha *et al.* (2008) found ADHD-I and ADHD-C had significantly more variable RT than controls during the phasic portion, but not the tonic portion of the task. As there is no forewarning, the phasic task creates a condition that is more likely to yield divergent results from healthy controls. ADHD subjects only performed differently in this condition, with performance varying far more than controls (Tucha *et al.*, 2008). Narcoleptics seemed to perform poorly on this alertness task, indicating that narcolepsy may have more of an effect on ability to sustain vigilance than ADHD.

Visual Scanning (Focused Attention)

I also examined the visual scanning task, which is designed to test focused attention. In this task the subject is presented with a display of 5 rows and 5 columns of squares each with an open side except for one, the critical stimulus, which was a square with the top open. Subjects were asked to press a button if the critical stimulus was present. RTs and errors (both false alarms and misses) were used to examine test performance. Rieger (2003) found that narcoleptics had the same search strategy and similar number of errors as controls, but narcoleptics had longer and more variable RTs. Fulda and Schulz (2001) found eight studies that measured focused attention all with different tasks, three of which found significant deficits in different ways, with one of these three finding worse task performance all around and the other two finding increased errors but not RT. Tucha *et al.* (2008) did not find significant differences in RT or RT variability for any types of ADHD, but ADHD-H showed significantly more errors compared to controls. These results again point to the possibility that narcoleptics are less able to maintain attention/alertness than ADHD individuals. However, the

increased errors seen in ADHD-H but not narcoleptics indicate narcoleptics retain control of impulsivity and in this manner are distinct from ADHD.

Dual Task (Divided Attention)

Dual task, which measures divided attention, is another measure of cognition that was used in multiple studies. For this task, both visual and auditory stimuli were presented simultaneously. The subject is asked to click a button when a critical stimulus is presented either visually or auditorily. The critical stimuli were a change in a simple alternating high-low tone pattern, or the appearance of four adjacent *x*'s forming a square amongst a display of 16 dots and *x*'s. RTs and error rates are used to determine test performance. Rieger *et al.* (2003) and Naumann *et al.* both found narcoleptics to have significantly slower RTs, but Rieger *et al.* (2003) also observed more variable RTs and more errors, while Naumann *et al.* did not. Fulda and Schulz (2001) combined divided attention and mental tracking into one category. They summarized four different studies with seven tasks that tested these cognitive abilities. Three tasks found impairment, while four did not find any impairment. Overall, Fulda and Schulz concluded acute sleepiness was the cause of the reduction in divided attention. Tucha *et al.* (2008) found ADHD-H and ADHD-C types had slower RTs, while ADHD-I and ADHD-C had more omission errors, and ADHD-I had more commission errors. All of these ADHD findings had large to medium effects. Both disorders showed decreases in performance on this more complicated task.

Alternating Reactions (Flexibility of Attention)

Next, the alternating reactions task also known as a test for flexibility of attention was compared. This test consists of two stimuli presented simultaneously (one on each side of the screen display); one stimuli is a letter and the other a digit. The subject is instructed to press a button that corresponds to the side of the critical stimulus, which is either the letter or digit depending on the trial, with RT and error rates indicating test performance. Rieger *et al.* (2003) found slower and more variable RTs with more errors in narcoleptics. Bayard *et al.* (2012) observed similar results in narcoleptics with cataplexy. Narcoleptics without cataplexy, however, did not show significantly slower RTs but still had significantly higher RT variability and errors. Fulda and Schulz (2001) only briefly mention flexibility of attention, but Rieger *et al.*'s (1997) study, which is discussed in Fulda and Schulz, also found reduced task performance in narcoleptics. All types of ADHD also showed slower RTs, higher RT variability, and more errors with large effects in Tucha *et al.*'s (2008) study. Narcoleptics and ADHD both show clear deficits in flexibility of attention.

Incompatibility (Focused Attention)

The test type with the least compatible results between ADHD and narcoleptics was ironically the incompatibility task. Like the visual scanning task, the incompatibility task measures focused attention. Subjects are presented with an arrow pointing either left or right; they must indicate the direction the arrow is pointing regardless of the physical location of the arrow on the screen. Naumann *et al.* (2006) found no significant deficits in narcoleptics on this task. Fulda and Schulz (2001) did not specifically describe incompatibility test results, but their conclusions on focused

attention are presented in the section on the visual scanning test. Tucha *et al.* (2008) found all types of ADHD resulted in slower RTs and ADHD-I and ADHD-C types had significantly more variable RTs, but ADHD error rates were the same as healthy controls. All of Tucha *et al.*'s results had medium to large effect sizes.

Stroop Test (Inhibition)

Additionally, I found some comparable tasks using the studies described within the clinical reviews. One such task is the Stroop test which measures inhibition by requiring subjects to read the names of colors whose letters are a different color than the word indicates (i.e. RED written in green letters) or they are asked to state the color of the letters not the one that is written. In order to correctly read the word and score well on the task the participant must inhibit the urge to say the color they see rather than the one that is written or vice versa. Fulda and Schulz (2001) found a single study that showed no difference between narcoleptics and controls while Seidman (2006) found 11 out of 15 studies resulted in significantly lower performance in ADHD adults. More data is needed on narcoleptic performance to draw any conclusions about their inhibition abilities.

Trail Making Test (Focused Attention)

The Trail Making Test, a measure of focused attention, consists of a series of numbered circles that the subject is asked to draw a line through in numerical order—like a connect the dots coloring book. There are two tests Test A consists of only numbers. Whereas in Test B, each dot has either a letter or number and the subject is asked to connect them in order alternating numbers and letters (i.e. 1 → A → 2 → B →

3). Narcoleptics and controls did not differ on this task in Fulda and Schulz (2001). However, ADHD adults showed performance deficiencies in 7 out of 10 studies examined by Seidman (2006) with Trails B showing a slightly larger effect. With only one study on narcoleptics, it is hard to say whether a deficit would be observed with this task with more trials, but perhaps the excitement and activeness of this task allows narcoleptics to overcome any issues with drowsiness.

Controlled Oral Word Associated Test (Verbal Fluency)

Controlled Oral Word Associated Test (COWAT) measures verbal fluency. Participants are given one minute to recite as many words as they can that begin with a certain common letter or that fit into a specific category (i.e. animals). Better task performance is marked by more words recalled. Fulda and Schultz (2001) found only one out of three narcoleptic studies demonstrated decreased performance. Naumann *et al.* (2006) found decreased performance compared to healthy controls in both tasks. Seidman (2006) found seven ADHD adult studies showed decreased performance compared to controls while only one did not. It is interesting that individuals with ADHD consistently showed deficits in this task, while only half of the narcoleptic studies showed deficits. Similar to the Trail Making Test, the excitement of this task could help narcoleptics with mild symptoms stay awake and perform normally this task.

Digit Symbol Substitution Test (Focused Attention)

To take the Digit Symbol Substitution Test, the subject sees a display of digit-symbol pairs that function as a key. It is followed by a list of digits that the subject must write the correct corresponding symbol next to as if they are translating the digits into

symbols. Task performance is measured by how many symbols are correct by the end of two minutes. Fulda and Schultz (2001) found one study that used this task, in which narcoleptics had decreased performance when in a state of low arousal but performed the same as controls when alert. Seidman (2006) found deficits in performance of adults with ADHD but did not specify how many studies contributed to this conclusion. It makes sense that low arousal states would decrease task performance, I would imagine this would affect performance on all of the tasks analyzed. Without much information on task performance it is hard to draw any conclusions from the Digit Symbol Substitution Test.

Continuous Performance Test (CPT) (Sustained Attention)

Finally, the Continuous Performance Test (CPT) is actually the general name for any number of variations of a task consisting of a repetitive boring task that requires focus. For example, one version of this task the subjects must click the mouse when presented with the number one but not click when presented with a number two. Fulda and Schultz (2001) found no significant difference on test performance for narcoleptics. Seidman (2006) found ADHD adults performed significantly worse in 13 of 17 studies, many with different versions of the CPT. It is surprising to me that narcoleptics would not have decreased performance with this task since it is designed as a condition with little stimulation. Once again, with only one study reporting results on narcoleptic task performance, it is not clear if the results are replicable.

Table 2. Summary of parallel results from studies of cognitive function in ADHD and narcolepsy.

<i>Task</i>	<i>Narcoleptic Studies</i>	<i>Result</i>	<i>ADHD Studies</i>	<i>Result</i>
Phasic Alertness (Alertness)	Naumann <i>et al.</i> (2006)	n.s.	Tucha <i>et al.</i> (2008)	ADHD-I and C variable RT in Phasic only
	Rieger <i>et al.</i> (2003)	Slow and variable RT		
	Bayard <i>et al.</i> (2012)	Slow and variable RT		
	Fulda and Schultz (2001)	2/4 decreased performance*		
Visual Scanning (Focused Attention)	Rieger <i>et al.</i> (2003)	Slow and variable RT	Tucha <i>et al.</i> (2008)	ADHD-H more errors
	Fulda and Schultz (2001)	3/8 decreased performance*		
Dual Task (Divided Attention)	Rieger <i>et al.</i> (2003)	Slow and variable RT, more errors	Tucha <i>et al.</i> (2008)	ADHD-H slow RT, ADHD-C slow RT and more omission errors, ADHD-I more omission and commission errors
	Naumann <i>et al.</i> (2006)	Slow RT		
	Fulda and Schultz (2001)	3/7 decreased performance*		
Alternating Reactions (Flexibility of Attention)	Rieger <i>et al.</i> (2003)	Slow and variable RT, more errors	Tucha <i>et al.</i> (2008)	All ADHD types: slow and variable RT, more errors
	Bayard <i>et al.</i> (2012)	Slow (only cataplectics) and variable RT, more errors		
	Fulda and Schultz (2001)	Decreased performance		
Incompatibility (Focused Attention)	Naumann <i>et al.</i> (2006)	n.s.	Tucha <i>et al.</i> (2008)	All ADHD types: slow RT, ADHD-I and C variable RT
	Fulda and Schultz (2001)	3/8 decreased performance*		
Controlled Oral	Fulda and	1/3 decreased	Seidman	7/8 decreased

Word Associated Test (Verbal Fluency)	Schultz (2001)	performance*	(2006)	performance*
	Naumann <i>et al.</i> (2006)	Decreased performance		
Stroop Test (Inhibition)	Rieger (2006)	n.s.	Seidman (2006)	11/15 decreased performance*
	Fulda and Schultz (2001)	n.s.		
Trail Making Test (Focused Attention)	Fulda and Schultz (2001)	n.s.	Seidman (2006)	7/10 decreased performance*
Digit Symbol Substitution Test (Focused Attention)	Fulda and Schultz (2001)	Decreased performance with low arousal conditions	Seidman (2006) [Hervey et al (2004)]	Decreased performance*
Continuous Performance Test (CPT) (Sustained Attention)	Fulda and Schultz (2001)	n.s.	Seidman (2006)	13/17 decreased performance*

*Results based on more than the specified task, often making results more variable n.s.

– No Significance RT – Reaction Time

Table 3. Summary of the total number of tasks that observed deficits for various cognitive abilities in both narcoleptics and ADHD individuals. If any difference was found in a task, it was counted in the “Deficit” category.

<i>Cognitive Ability</i>	<i>Narcoleptic Deficit</i>	<i>ADHD Deficit</i>	<i>No Narcoleptic Deficit</i>	<i>No ADHD Deficit</i>
Alertness	4	0.66*	3	0.33*
Focused Attention	8	2.33*	12	0.66*
Divided Attention	5	1	4	-
Flexibility of Attention	3	1	-	-
Sustained Attention	-	13	1	4
Verbal Fluency	2	7	2	1
Inhibition	-	11	1	4

*Fractions represent different ADHD subtypes (0.33 for deficit in only one subtype)

Direct Comparison of ADHD and Narcoleptic Task Performance

Not all the studies made reaction times and other task result values available. For example, Bayard *et al.* (2012) only presented their data in graphs and provided values of their statistical analysis; Naumann *et al.* (2006) presented their results from the Dual Task and the Incompatibility task in the same manner. Obviously, the clinical reviews also did not present any actual task performance values. This limited my access to data I could statistically compare across disorders. Additionally, I needed to select tasks that showed the same overall deficit or lack thereof as the others were already clearly distinguished as different. Using these restrictions, I selected two tasks: Alternating Reactions (Flexibility of Attention) and Dual Task (Divided Attention).

If you recall, in the Alternating Reactions task, Rieger *et al.* (2003) and Bayard *et al.* (2012) both found slower, more variable RTs, and more errors in all narcoleptics subjects with the exception of narcoleptics without cataplexy who did not show slower RTs but agreed on all the other measures. Bayard *et al.* did not provide data tables, so I was unable to use their values for my analysis. Tucha *et al.* (2008) found all subtypes of ADHD to have slower, more variable RTs and more errors than controls. Rieger *et al.* (2003) and Tucha *et al.* (2008) provided the most thorough data for both these tasks, but their presentations differed slightly.

For the Alternating Reactions tasks Tucha *et al.* (2008) presented the mean RT, variability, and number of commission errors, all with standard error mean (SEM) values, for each ADHD sub type and all of the separate sub type matched control groups. Rieger *et al.* (2003) presented the data more expansively, dividing the means and errors into two categories each: same hand and other hand (referring to whether the

critical stimulus was presented on the same side or the opposite side of the screen from the previous trial). Rieger *et al.* (2003) also used standard deviation (SD) rather than SEM and did not explicitly provide variability values. I consolidated Rieger *et al.*'s data into single mean RT and error values with corresponding SEM values so that it could be properly compared to the data from Tucha *et al.* For the mean RT and errors, I took a simple mean. My justification for this was that, as stated in the methods, same hand and other hand instances were both presented an equal number of times during the task and I assumed that all subjects completed all trials within the task (since not otherwise specified). Determining each value's accompanying SEM was more complicated. First I determined the mean SD. This is calculated by squaring each SD separately, adding them, and then taking the square root of that value. I then used that value as my SD in the SEM equation and the number of test subjects as n . The SEM is represented by the error bars on the graphs. Figure 3 shows reaction times while Figure 4 shows errors. I then performed separate unpaired two-tailed t -tests comparing each ADHD subtype to narcolepsy. Significance was found only when narcoleptics were compared to ADHD-C RTs where narcoleptics had significantly slower RTs ($p < 0.001$) and ADHD-H was found to have significantly more errors than narcoleptics ($p < 0.05$). All p -values are presented in Table 4. This indicates that in these two instances, Rieger *et al.*'s narcoleptic subjects performed differently than Tucha *et al.*'s ADHD subjects, but in all other instances, the task performance distribution overlapped enough to not reject their similarity.

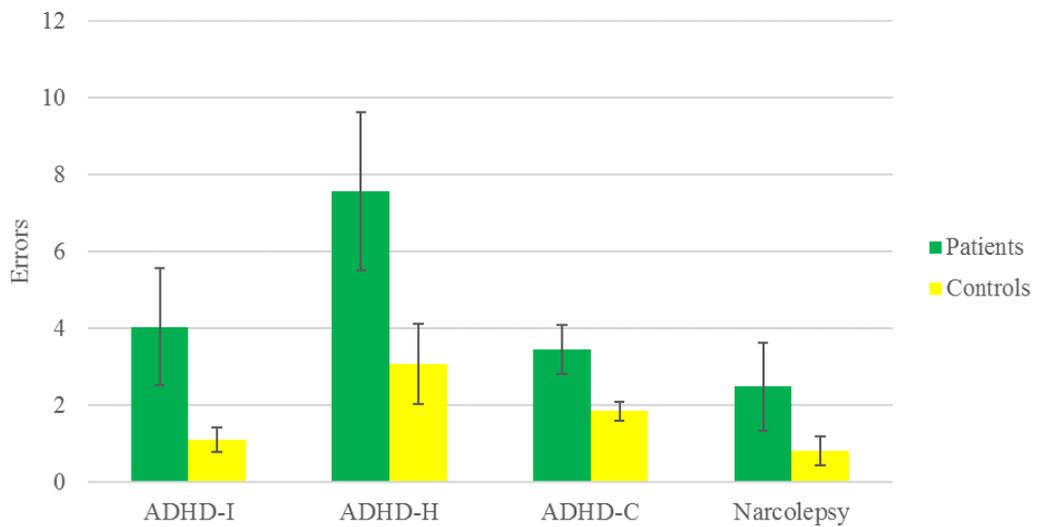
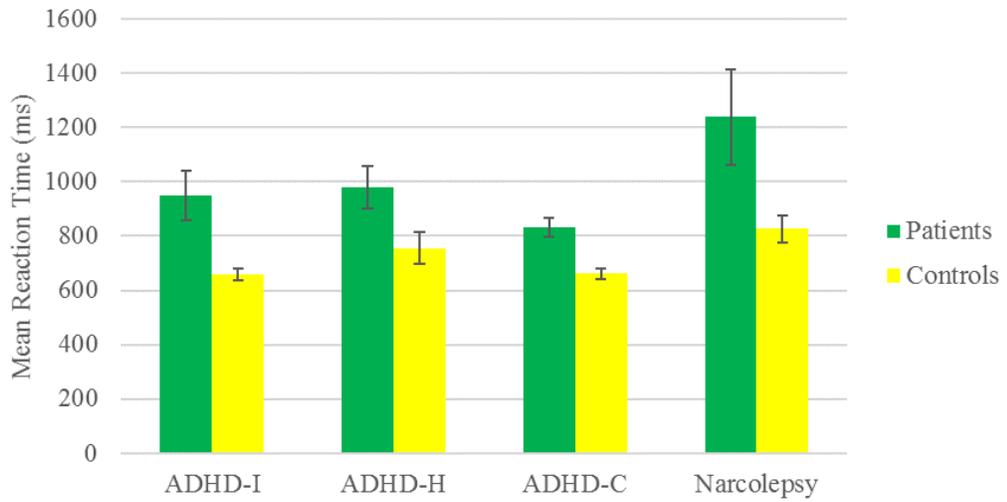


Figure 3. Alternating Reaction task RTs in ADHD and narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM. Only ADHD-C was found to differ significantly ($p < 0.001$) from narcolepsy, see Table 4 for a complete report of p -values.

Figure 4. Alternating Reaction task errors in ADHD and narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM. Only ADHD-H was found to differ significantly ($p < 0.05$) from narcolepsy, see Table 4 for a complete report of p-values.

For the Dual Task, Rieger *et al.* (2003) and Naumann *et al.* (2006) both found slower RTs in narcoleptics. Additionally, Rieger *et al.* observed more variable RTs and more errors in narcoleptics. Tucha *et al.* (2008) found ADHD-H and ADHD-C had slower RTs and more errors, additionally, ADHD-I had more errors. The Dual Task had similar data presentation incongruence as Alternating Reactions. Tucha *et al.* (2008) provided mean RTs, variability, omission and commission errors each with their own SEM for each of the ADHD subtypes and their control groups. Once again Rieger *et al.* (2003) divided the data up to present more detailed breakdown of the RTs and errors, although oddly only provided errors of omission and not commission as well. Rieger *et al.* presented the RTs and omission errors of each phase of the task condition separately (single visual, dual visual, single auditory, and dual auditory). I used the same calculation technique used for the alternating reaction task data with these values. For the presented mean RT and errors, I found the simple mean. For the standard deviations I squared each, added them together and took the square root of that value, and then divided that new SD value by the square root of n (the number of subjects, in this case 19 narcoleptics or 20 controls) to find the SEM. Figure 5 displays the RT values while Figure 6 shows the errors.

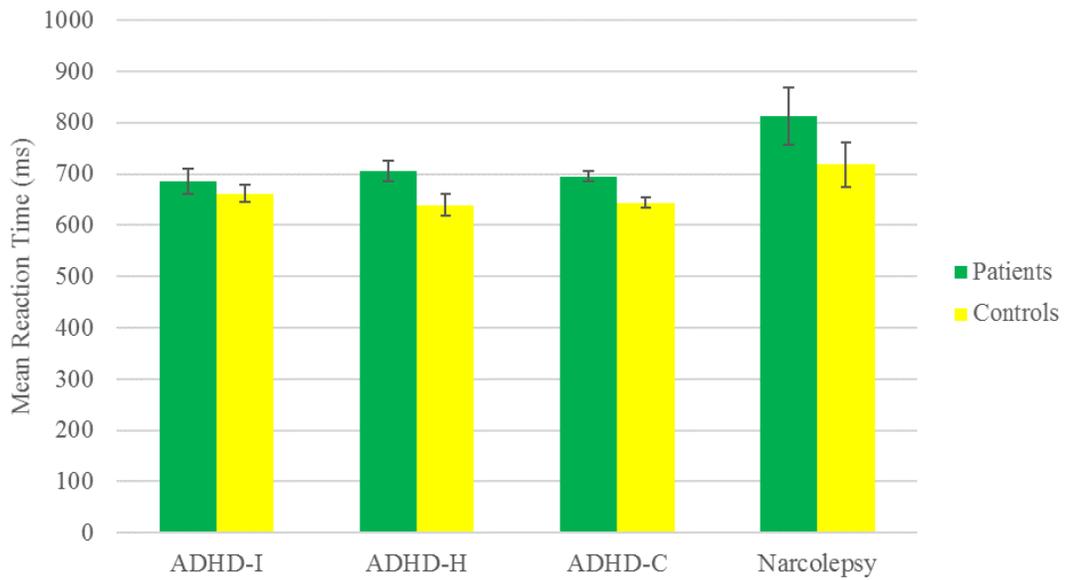


Figure 5. Dual Task RTs in ADHD and narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM. ADHD-I and ADHD-C were found to differ significantly ($p < 0.05$), showing faster RTs compared to narcoleptics, see Table 4 for a complete report of p-values.

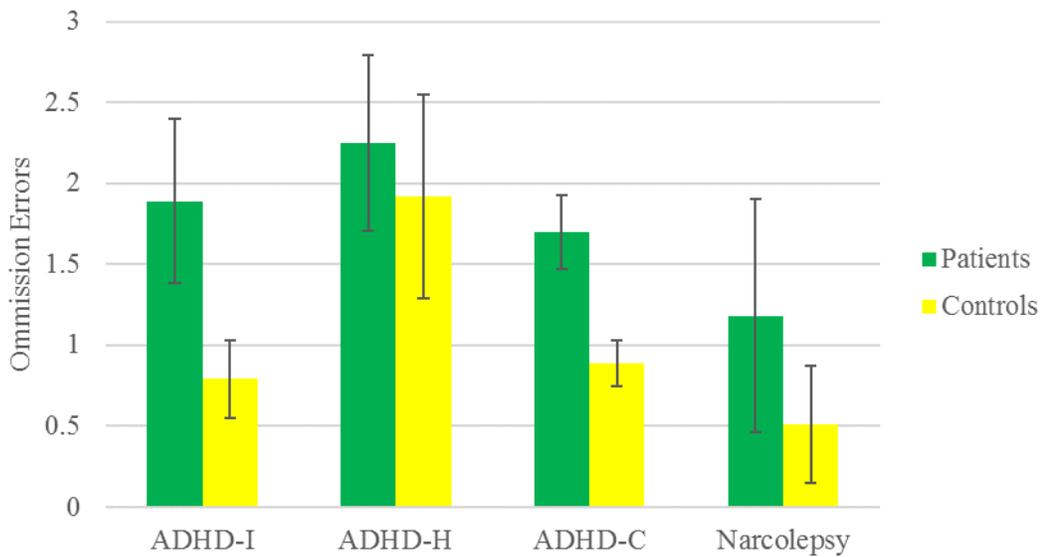


Figure 6. Dual Task errors in ADHD and Narcoleptics. ADHD values from Tucha et al (2008) and narcoleptic values from Rieger et al (2003). Error bars represent SEM. No significant difference was found between narcolepsy and any of the ADHD subtypes, see Table 4 for a complete report of p-values.

Like I did for the Alternating Reactions, I performed three unpaired two-tailed *t*-tests comparing narcoleptics to each of the ADHD subtypes. For RTs, ADHD-I and ADHD-C were found to have significantly faster RTs than narcoleptics. For error rates, no ADHD subgroups were found to differ significantly from narcoleptics. All *p*-values are presented in Table 4. It is important to note that I have not proved that the data sets are the same, just provided evidence that they are not significantly different.

To better assess the significance of the similarities and dissimilarities observed, I decided to compare the narcolepsy data from the Alternating Reactions and the Dual Task to the values produced by healthy controls from each ADHD subgroup. I found narcoleptics had significantly slower RTs than all ADHD subgroups on both tasks. Conversely, narcoleptics errors did not differ from any of the ADHD subtypes in either task.

Table 4. P values from unpaired two-tailed *t*-Tests comparing narcolepsy to each ADHD subtypes and their respective controls in the Alternating Reactions and Dual Task.

<i>Group compared with narcolepsy</i>	<i>Alternating Reactions RT p-value</i>	<i>Alternating Reactions Errors p-value</i>	<i>Dual Task RT p-value</i>	<i>Dual Task Errors p-value</i>
ADHD-I	0.1505	0.418	0.0444	0.4263
ADHD-I Controls	0.0023	0.2481	0.0137	0.6105
ADHD-H	0.2719	0.026	0.1474	0.2962
ADHD-H Controls	0.0422	0.7292	0.0238	0.4815
ADHD-C	0.0006	0.4702	0.0016	0.3672
ADHD-C Controls	<0.0001	0.4005	<0.0001	0.5357

Cells containing non-significant *p*-values while the equivalent controls were significantly different have been highlighted in yellow. These values represent more supported similarities.

Discussion:

With the notable exception of the CPT, narcoleptics seemed to be more likely to show deficits in tasks that were repetitive, i.e. the phasic alertness task and alternating reactions task. Narcoleptic task performance did not show the strong similarities to ADHD-I that I predicted it would. ADHD and narcolepsy had similar deficits on only a few of the tasks. When statistically compared, even the alternating reactions and dual task, the tests that appeared to share the most similarity, showed ADHD subtypes that were significantly different from narcolepsy. In fact, no one ADHD subtype stood out as having narcolepsy matching deficits.

At first glance, it would appear ADHD-C was least similar to narcolepsy, but when narcoleptic performance was compared with the performance of ADHD-C's healthy controls, the same differences were found. Notably, when the comparisons with the ADHD controls are considered, no important conclusions can be drawn from the error data as none of the ADHD control groups differ significantly from narcoleptics. The most important results are the similarities between narcolepsy and ADHD-I RTs in the Alternating Reactions task and RTs of ADHD-H in both Alternating Reactions and Dual Task (highlighted in yellow in Table 4). In these cases, the controls were significantly different from narcoleptics but the subjects with ADHD were not significantly different. Only in these cases I feel I have a strong foundation for claiming similarity.

Limitations

The lack of research on narcolepsy and cognitive deficits combined with little replication of study results presented the most substantial limitation to my conclusions.

Similar pleas for more research can be found in the discussions of all of the narcolepsy papers I examined for this project. Fulda and Schultz (2001) made a notable assertion on this idea.

“In particular ‘higher-order’ functions like concept formation, reasoning and executive function are underrepresented in the literature. Further research is needed, especially as the available evidence suggests that sleep-disordered patients might experience considerable difficulties in these areas.” (pg. 439)

Furthermore, the existing studies focus on adults, while these results are likely applicable to college age adults, they do not transcend all classroom age children. Younger individuals may show a different pattern of cognitive deficits that has yet to be revealed. Seidman (2006) found unexpected incongruences between child and adult performance on the Wisconsin Card Sorting Test (WCST). When administered to children with ADHD, the WCST consistently shows deficits, but when administered to adults the test does not distinguish ADHD subjects from healthy controls (Seidman, 2006). It is quite possible that similar incongruences exist in narcoleptics, but children with narcolepsy are extremely under-researched. I recommend that future research probe the idea of how narcoleptic children may differ in their cognitive abilities.

Additionally, as Bayard *et al.* (2012) pointed out, the cognitive deficits of narcolepsy with cataplexy seems to differ significantly from those without cataplexy. Much of the existing research focuses on narcolepsy with cataplexy, neglecting nearly one third of narcoleptics who do not have cataplexy (Bayard *et al.*, 2012). Even more concerning is when studies, like Rieger *et al.* (2003), do not specify whether their subjects had cataplexy or not. The composition of narcoleptic study subjects type is extremely important part of any research on this disorder and should always be

reported. Similarly, hypocretin levels (which are usually lower in narcoleptics with cataplexy than those without) of test subjects are rarely reported. Hypocretin levels were only known for 11 out of 44 subjects in Bayard *et al.* (2012). None of the other narcolepsy studies I examined reported hypocretin levels. This may be due to researchers' apprehension to perform lumbar punctures (as CSF is needed to determine hypocretin levels) on test subjects. This information is needed to unravel whether observed cognitive deficits are from damage to the hypocretin pathway or simply general sleepiness.

Another possible source of error is my interpretation of Rieger's (2006) clinical review. The only version of this document I could locate was entirely written in German except for the abstract. However, as the paper was extremely relevant to my topic, I enlisted the help of my friend John David Cross IV who has studied German to translate the data table presented in the paper. It is possible that the information was altered by translating, but I mitigated this error by choosing the data table, and not the text as my informational source because any large translation errors would likely not make logical sense and would therefore be easy to spot. In choosing this method, however, I exposed myself to the possibility that the text contains information that affects interpretation of the data table.

Also, both Fulda and Schultz (2001) and Rieger (2006) cited the same Smith paper but attributed it with different years. I initially had cited the Smith study as two separate pieces of evidence, but I noticed the titles of the publications were the same: "Can we predict cognitive impairments in narcolepsy?". I searched online and found only one paper with that title so I concluded it was a single publication from 1992. This

small problem resulted in a cross-comparison of all the studies used by clinical reviews with the primary studies used in this paper. If one of my primary studies were used to draw conclusions in one of my clinical studies, citing them separately would give disproportionate weight to the results of the primary study. No additional duplications were found upon review.

Finally, conclusions across different tasks intending to measure the same cognitive ability are unreliable. For example, despite both Stoop and the Go/No Go tasks being measures of inhibition, they possess only a weak correlational relationship (Morooka, Ogino, Takeuchi, Hanafusa, Oka, and Ohtsuka, 2012). As a result, I decided not to include Bayard *et al.*'s (2012) findings of poor Go/No Go task performance in narcoleptics with Stroop test findings from Rieger (2006), Fulda and Schultz (2001) and Seidman (2006). This incompatibility across different tasks meant to quantify the same aspect of cognition is likely an issue in many other instances. This is one explanation of the inconsistent results Fulda and Schulz (2001) found regarding cognitive deficits in narcolepsy because they combined results from many different tasks into larger categories of cognition. Many tasks administered to narcoleptics have only one study's results associated with them, sensitivity is low, making overall understanding of narcoleptic deficits foggy at best.

Future Research Directions

There are large gaps in our understanding of narcolepsy and its effects on cognition and more research is needed in all areas of this topic. However, I think cognition in narcoleptics of different ages should be a future research priority. Little to nothing is known about how narcolepsy affects cognition in school age children, and if

we hope to help these children succeed in their academic careers, we must understand the specific challenges they face, we should not continue to allow research performed only on adults to influence our policies on child accommodations. Ideally, longitudinal studies on narcoleptics cognition from shortly after diagnosis through adulthood would show how the disorder effects cognition at different important life stages. It would be especially fascinating to compare strength of cognitive deficits to age of narcolepsy onset.

I would also like to encourage more studies like Bayard *et al.* (2012) that compare narcolepsy with cataplexy to narcolepsy without. As I am a narcoleptic who does not have cataplexy (type II), I am personally invested in knowing whether studies performed solely with type I narcoleptics are applicable to type II narcoleptics as well. Non-cataplectics should not be ignored because we represent a minority of narcoleptics.

More generally, replication of cognitive task results and more subjects are needed to determine what deficits are most common and dramatic. It is also important to remember that the goal of these studies is to improve individual lives of those suffering from narcolepsy, so I would love to see studies on the relation of task performance on specific cognitive tests and their implications for the daily functions of people with narcolepsy.

Conclusion:

Narcoleptics showed few quantitative alignments with ADHD. While it may be practical to suggest the two disorders be accommodated similarly in the classroom, the actual underlying cognitive abilities of the disorders do not seem to show substantial overlap. However, in a practical setting, the degree with which the difference in

cognitive deficits between narcoleptics and ADHD students is distinguishable upon interaction with a student may be so small that this approximation is reasonable. There is simply not enough research on the topic.

Every paper I read on narcoleptics lists lack of data (and therefore statistical power) as a major limiting factor. I recognize that pleas for further research into topics is a staple of scientific literature, but in this case it is merited. Fulda and Schultz (2001) found that most cognition tasks had only been performed once with narcoleptics. Without replication, results are much less meaningful. Additionally, hypocretin levels of subjects are rarely reported (Bayard *et al.*, 2012). If we ever hope to distinguish the root cause of the cognitive deficits observed in narcolepsy, this information needs to be reported. With more cognition studies the correlations between task performance and hypocretin levels versus task performance and sleepiness scale rating could reveal which factor influences cognition more; the hypocretin pathway destruction or physical sleepiness symptoms. But, without data on subjects hypocretin levels, and more studies on cognition in general, this sort of conclusion is not possible. I think the underlying cause of cognitive deficits are likely caused by a combination of interesting neurochemical and behavioral changes, not simply one or the other, but data is needed to support this idea.

It is clear that narcolepsy and the symptoms associated with it causes cognitive deficits and pose additional challenges to classroom performance. It is important that we recognize these disadvantages and provide narcoleptics with access to information they need to make informed decisions about their education. I propose that the UO Accessible Education Center have some sort of database with links to pertinent research

and reliable sources and advocacy groups (like Narcolepsy Network) that students can access if they have more detailed questions about their disability. I plan to encourage the UO Accessible Education Center director to work more closely with the UO Health Center to understand medical underpinnings of the disorders accommodated. Finally, I feel that executive function support programs should be offered to narcolepsy students as well if they feel they need them.

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