

Learning Second Languages with ADHD: The Role of Memory Systems

BY

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LIST OF ABBREVIATIONS

ADHD	Attention-Deficit Hyperactivity Disorder
L2	Second Language
DM	Declarative Memory
PM	Procedural Memory
WM	Working Memory
SRT	Serial Reaction Time Task
MLAT	Modern Language Aptitude Test

SUMMARY

This study examined whether memory systems that are assumed to influence second language L2 (L2) learning in adults with neurotypical cognition influence L2 learning in adults with ADHD. Participants were asked ($N = 116$) to complete a) L2 training and testing with an artificial language with complex analogical and simple affixation rules; b) cognitive measures of working, declarative, and procedural memory; c) ADHD and depression questionnaires. We predicted that adults with ADHD would not have a statistically different performance on the L2 learning task than the neurotypical adults. We also expected that memory systems might play a different role in L2 learning based on the participants' ADHD severity symptomatology (as measured by BAARS-IV). The results of our study supported our first hypothesis — individuals with ADHD did not perform differently than the neurotypical controls; but did not support the second one — memory systems that are associated with L2 learning are not influenced by the ADHD symptomatology. Overall, we also found a facilitative role of declarative memory on learning of the complex analogical rules and facilitative role of working memory on learning of the simple affixed rules.

INTRODUCTION

Learning Second Languages with ADHD: The Role of Memory Systems

All adults should be given an equal opportunity to learn an additional language. However, certain categories of people with neurocognitive individual differences are sometimes advised against taking language classes. Specifically, there are assumptions (e.g., as mentioned in Sparks et al., 2004) that second language (L2) learning might be difficult for adults diagnosed with attention-deficit hyperactivity disorder (ADHD). Whereas such ideas might still be common in certain institutional settings, they do not seem to have a lot of evidence in the scientific world. However, the evidence for the opposite view, that is, that ADHD does not impact L2 learning, is also not ample (e.g., Sparks et al., 2004; Sparks et al., 2005). Research that focuses on ADHD and L2 learning tends to concentrate on the methodology of language teaching that might be more favorable for the students with ADHD (e.g., Leons et al., 2009; Castro, 2002). Although the product of this work could indeed facilitate L2 learning, it does not provide enough information to understand what purportedly makes L2 harder for those diagnosed with ADHD. Importantly, research also does not explain how cognitive abilities in memory systems that support L2 learning could interact or mediate learning in individuals with the disorder. Specifically, there are currently no studies that have looked at the relationship between L2 learning in individuals with ADHD and cognitive abilities in working memory (WM) and two long-term memory systems – declarative and procedural memory (DM and PM respectively), even though these types of memory are known to have a facilitative effect on L2 acquisition (e.g., Wen, 2015; Ullman, 2020). In the remainder of the study, I will first provide an overview of ADHD and its relationship with L2 learning as well as an overview of each memory system with its relation to L2 learning and ADHD. Second, I will introduce our research questions and

hypotheses. Third, the methods and the results of the study will be discussed, along with the interpretation of the findings.

ADHD and its Symptoms

ADHD is the most widely found behavioral disorder in children that often also persists in adolescents and adults. The worldwide prevalence for ADHD is 3-10% for children of the school age and 2-7% for adults (McGough, 2014). Specifically, it is a neurodevelopmental disorder that involves impaired attention, lack of the organizational skills, and/or hyperactivity-impulsivity (American Psychiatric Association, 2013). The primary symptoms of the impaired attention and lack of organizational skills include problems completing tasks, seeming not to listen, and misplacing objects. Some symptoms stemming from hyperactivity-impulsivity include having troubles with remaining seated, being overactive, fidgeting, and being not able to wait. As for the cognitive deficits, it has been shown that individuals diagnosed with ADHD usually have impairments in various cognitive domains, which include (a) attention, where one can observe issues with monitoring attentional sources, (b) memory, where the greatest impairments are found in the WM domain, and (c) executive functions, which, for example, might be manifested in poor inhibitory control (e.g., Gupta & Kar, 2010; Fuermaier et al., 2015; Alderson et al., 2013).

To test for ADHD in adults, clinicians usually conduct clinical interviews with the patient, reviewing their performance at school, conducting neuropsychological testing, and utilizing various rating scales to assess current and previous functioning of a person (Maniadaki & Kakouros, 2017). An example of such a rating scale is Barkley Adult ADHD Rating Scale-IV (BAARS-IV; Barkley, 2011), which includes questionnaires about both current (experienced within the last 6 months) and childhood symptoms of ADHD that need to be completed by a

person being tested and by an observer who knows this person well. The questions should be answered on a 4-point Likert scale and ask about the following symptoms: inattention, hyperactivity, impulsivity, and sluggish cognitive tempo (childhood symptoms only focus on inattention and hyperactivity-impulsivity). BAARS-IV is known to be a reliable and valid measure of ADHD. It yields substantial internal consistency of the results, test-retest reliability, convergent validity as compared with other measures of the disorder, and divergent validity (Silverman, 2012). Whereas rating scales give a good overview of the ADHD symptoms experienced in childhood and adulthood, neuropsychological testing reveals more details about the cognitive abilities of the patients. Neuropsychological tests could focus either on one of the cognitive domains or include a whole battery of measures that assess multiple cognitive functions (e.g., Mindstreams; Schweiger et al., 2007).

Finally, it should be noted that ADHD symptoms such as lack of concentration, distractibility, inattentiveness, and forgetfulness (Skodzik et al., 2017) might cause students to face difficulties in the academic settings, including L2 classes. Leons et al. (2009) also explain that students' struggles might be attributed to the association between the deficits in the core academic skill (e.g., spelling, reading) and the related cognitive abilities (e.g., poor memory or attention). Whereas these problems could significantly complicate L2 learning, they could also make any type of learning more difficult. Nevertheless, students with ADHD are not usually discouraged from taking classes in mathematics or history, even though they may be advised not to take a L2 class or even request a waiver for the L2 class if it is required (e.g., Sparks et al., 2004).

ADHD and L2

Unfortunately, research on ADHD and L2 learning is rare, and studies that have focused on this relationship have yielded conflicting results (Sparks et al., 2003; Sparks et al., 2005; Sparks et al., 2004; Leons et al., 2009; Ferrari & Palladino, 2007; See Appendix A). For example, by analyzing teachers' and parents' evaluation of school students who had low achievements in L2 learning, Ferrari and Palladino (2007) found that these students were frequently distracted and had difficulties controlling their attention. The researchers mentioned that the frequency of such behavior could be potentially associated with a risk of ADHD. Nonetheless, ADHD was not assessed directly by qualified professionals, and evaluations done by teachers and parents could have been influenced by subjective factors (Gupta & Kar, 2010). Thus, it is impossible to make any causal conclusions about the relationship of L2 struggles of these students and ADHD. This study also does not shed light on L2 and ADHD in adults.

Another study that looked at L2 learning and ADHD focused on students with either learning disabilities or ADHD who studied at an institution designed for students with these disorders (Leons et al., 2009). In this study, the authors observed improvement in the students' L2 level of proficiency. However, such findings could not be generalized to other settings because students who were enrolled in the institution already faced academic difficulties and were also instructed in a specific manner that took into account these particular groups of students' needs.

In the series of studies by Sparks and colleagues (Sparks et al., 2003; Sparks et al., 2005; Sparks et al., 2004), the researchers worked specifically with a group of participants who were officially diagnosed with ADHD. The results of their investigations, however, did not reveal any difficulties associated with L2 language learning in students with the disorder. For example, it

was found that students who have comorbid ADHD/LD could pass a L2 course (Sparks et al., 2003). Moreover, in their another study that looked at the performance of students with ADHD in the L2 class (Sparks et al., 2004, with results consistent with Sparks et al., 2005), the researchers found that students with ADHD did not have struggles with L2 learning and actually achieved grades that were within the average or higher than average range (83% of average or higher grades, 10% of below average grades, 2% failing grades). Although the authors did not compare their scores with the scores of students not classified as having ADHD, they still concluded that it seems like students with ADHD performed on a similar level with others. Interestingly, some students with ADHD also majored or minored in a foreign language. Finally, it was also found that only 32% of students utilized learning accommodations in the L2 class, which suggests that students with ADHD might not exhibit great difficulties in L2 learning.

However, although these studies (Sparks et al., 2003; Sparks et al., 2005; Sparks et al., 2004) provide some data that show that students with ADHD do not have impairments in L2 learning, they also require further investigations. For example, the authors did not actually include any comparison control group and did not more thoroughly control L2 learning in the experimental settings. Particularly, it might be beneficial to expose students to L2 learning where language acquisition begins at the same level of proficiency (e.g., by using an artificial language) and is compared to the performance of the participants without ADHD.

Therefore, taken together, the studies reviewed above (see also Appendix A) provide mixed data concerning the relationship between L2 and ADHD. Importantly, they also do not explain what cognitive mechanisms contribute to L2 performance of students diagnosed with ADHD, regardless of whether that performance differs from L2 learning in neurotypical populations. To investigate this question, we will look at the potential interactions between

ADHD and the memory systems that are known to play a role in L2 learning: WM, DM, and PM.

Working Memory and L2

First, WM and its relationship with ADHD and L2 will be considered. WM is generally defined as a system that includes storage and processing of the information needed to perform a wide range of cognitive tasks (Baddeley, 2007). Whereas there are different types of WM models, a commonly used model in L2 and ADHD research is the multi-component model offered by Baddeley (e.g., Kasper et al., 2012). This model consists of the following components: (a) phonological loop, which is responsible for storing and manipulation of speech-related and possibly acoustic only information; (b) visuospatial sketchpad, which bears the same functions for visual and spatial type of the information; and (c) central executive, an attentional control system that controls both phonological loop and visuospatial sketchpad (Baddeley, 2007). The forth component, that was added to the model later, is the episodic buffer which is “a temporary storage system that is able to combine information from the loop, the sketchpad, long-term memory, or indeed from perceptual input, into a coherent episode” (Baddeley, 2007, p. 148). In terms of its functionality, WM accounts for complex cognitive tasks, including remembering a phone number when calling someone, planning strategies when playing chess, multiplying digits, etc. (Williams, 2011).

WM is considered to play a significant role in language learning. Specifically, it is assumed to facilitate consolidation of information and its transformation into long-term memory, underpin vocabulary learning and grammar development, and facilitate language comprehension and production in “post-interpretive” processes (e.g., processing subject-verb agreement errors) (Wen, 2015). The evidence in support of WM underpinning L2 learning comes from numerous

sources. For example, by conducting a meta-analysis, Linck et al. (2014) found that WM has a positive relationship with both L2 processing and levels of proficiency ($p = .255$). Wen (2015) reviewed studies from the field of second language acquisition that focused on WM and found that WM has a facilitative effect on both L2 vocabulary and grammar learning. Specifically, WM appears to predict acquisition of the new phonological forms (L2 vocabulary learning) and facilitate storage of the morphosyntactic forms (L2 grammar). Interestingly though, not all the studies find a connection between WM and L2 learning. For instance, in an artificial language learning study, Antoniou et al. (2016) failed to observe any association between WM and L2 grammar learning. However, overall, WM is expected to have a small but robust effect on all aspects of L2 learning (e.g., Shen & Park, 2020). Due to WM's facilitative role on L2 acquisition, it would be important to learn the impact of ADHD on this memory system to better understand the influence of ADHD on L2 learning.

Working Memory and ADHD

The results of different meta-analyses suggest that ADHD might be associated with poor WM performance in people of different age groups. Specifically, Kasper et al. (2012) observed that compared to the neurotypical children, children with ADHD exhibited poorer performance on tasks that involved different components of WM, including phonological and visuospatial storage/rehearsal subsystems of the WM. Similar findings were reported in meta-analysis conducted by Martinussen et al. (2005) who investigated pre-school children and adolescents with ADHD and found impairments associated with WM in ADHD participants as compared to controls. Moreover, it was found that deficits in WM do not disappear in adulthood. Particularly, the meta-analysis by Alderson et al. (2013) found that the adults over the age of 18 who were diagnosed with ADHD performed moderately worse on the phonological and visuospatial WM

tasks than the healthy controls. However, difficulties in certain components of WM might become less severe with the increasing age. Ramos et al. (2020) conducted a meta-analysis of studies that focused on children (from 6 years of age) and/or adolescents (up to 18 years of age). They found that the difficulties associated with verbal WM performance (as measured exclusively by the digit span backwards task) lessened with the increase of the participants' age. At the same time, participants with ADHD were also found to have lower scores as compared to the neurotypical controls. Overall, given the evidence of WM impairment in ADHD (which might decrease with age), and the attested role of WM in L2 learning, it is possible that WM deficits may mediate any learning effect for L2.

Declarative Memory and L2

Now, DM in both its relation to L2 and ADHD will be described. DM refers to the capacity to learn and remember idiosyncratic information (Eichenbaum, 1997). It is a type of long-term memory that supports knowledge about facts and events that are related to the world and to oneself, including: (a) semantic memory, which is knowledge about general facts that are not connected to the experience the person had, and (b) episodic memory, which is knowledge about information tied to a specific learning context: knowledge about personal experiences (episodic memory) (Tulvig, 1983, as cited in Squire, 2004). As an example, due to the episodic memory system, we might remember falling off the bike, and due to the semantic memory, we might know that a bike is a vehicle that has two wheels. To put it shortly, DM could be described as the knowledge of “what”. DM underlies both explicit and implicit knowledge.

According to Ullman's (2020) declarative/procedural (DP) model, the DM system is involved in learning idiosyncratic pieces of the information in L2. Hence, it should be responsible for learning of vocabulary items (both their meaning and phonological form),

irregular grammatical forms (which include inflectional and derivational morphology), proverbs, and idioms. Besides that, Ullman (2020) mentions that DM is flexible in nature, which could make it suitable for learning “non-idiosyncratic, rule-governed aspects of language” as well (p. 140). Therefore, at least some of the rule-governed grammatical forms could also be acquired in this long-term memory system even though they are mostly learned by PM. The reliance of these rule-governed forms on DM is claimed to be more prominent at the early stages of L2 development.

There have been multiple studies that looked at the relationship between DM and L2 learning. For example, to support predictions made by the DP model concerning the role of the DM in particular systems of L2, one could refer to the meta-analysis by Hamrick et al. (2018) which observed a positive relationship between DM and grammar, particularly at lower learning stages (mean weighted $r = .455$, $p = .002$). The systematic review by Morgan-Short et al. (2022) expanded these findings by revealing the links between DM memory and L2 vocabulary, phonology, and particular aspects of grammar, including syntax (early learning stages), morphophonology, and morphosyntax (although the authors mention that the observed relationship was weak and could have been influenced by the specific features of the learning contexts, e.g., explicit classroom instructions). Separate empirical studies also lend support to the ideas offered by DP model and show the facilitative role of DM in the explicit contexts (e.g., Saito, 2017) and at an early learning stage (e.g., Hamrick et al., 2019; Walker et al., 2020).

It is also important to look at the results of the study conducted by Antoniou et al. (2016), which is the paradigm that will be replicated in this paper. Antoniou et al. found that DM facilitated learning of complex analogical forms of grammar, which required an irregular change of the vowels in the word as well as the rule-governed addition of the affix to the stem of the

word. This again underlines the importance of DM not only for learning lexical items but also for learning certain grammatical forms.

Declarative Memory and ADHD

Because DM plays a role in L2 learning, it would be helpful to know how it may or may not be impacted in ADHD in order to understand how ADHD impacts L2 learning that relies on DM. Studies of DM and ADHD are scarce, and some are not directly relevant as to whether DM is impaired in ADHD. For example, Prehn-Kristensen et al. (2011a) examined how sleep can benefit the consolidation of DM in children with ADHD and found that children with ADHD showed reduced sleep-associated consolidation of DM memory (based on the picture recognition task) in comparison with the controls. Verster et al. (2010) investigated how particular medical treatment can influence DM in patients with ADHD and observed that DM performance (particularly on a delayed recall task, but not on an immediate recall or delayed recognition tasks) was affected in ADHD individuals who did not take the studied medication when compared to those who did.

Other studies have more directly examined DM in ADHD. García (2001) focused on the relationship between DM and ADHD and found that adolescents with ADHD exhibited deficits in DM as compared to the controls. In the recent study conducted by Sindiani et al. (2022), the researchers explored whether the time of the day affects recall of the text in participants with ADHD and neurotypical controls. Although the study showed that controls outperformed participants with ADHD in recalling items from text, the researchers emphasized that their results do not support a simple idea that DM is worse in people with ADHD. Hence, while the research on DM and ADHD is not abundant, there is some evidence of potential deficits in DM in individuals with ADHD, which may in turn affect L2 learning.

Procedural Memory and L2

The last section of the paper considers PM and its relationship with L2 learning and ADHD. PM is a long-term memory system that supports cognitive and motor skills that are learned with experience (Knowlton et al., 2017). It also underlies learning of sequences and rules that cannot be described verbally. For example, a person can know how to ride a bicycle but might not be able to verbally describe the muscle coordination of doing that. Hence, it supports only implicit knowledge. To put it briefly, PM could be described as the knowledge of “how”.

Ullman’s DP model (Morgan-Short et al., 2022) posits that in L2 acquisition, PM is supposed to be responsible for learning of sequences and rules that are implicit in their nature. Therefore, Ullman (2020) comes to the conclusion that PM should account for grammar acquisition. Besides that, other types of implicit language learning that do not involve grammar could also depend on the PM system, e.g., learning word boundaries in a continuous speech stream. The role of PM is expected to be more prominent at later stages of L2 learning.

There are several studies that lend support to Ullman’s (2020) predictions about PM in L2, including the meta-analysis by Hamrick et al. (2018) who found a relationship between PM and L2 grammar learning at higher levels of experience (mean weighted $r = .548$, $p < .001$) and the systematic review by Morgan-Short et al. (2022) who reported links between PM and such forms of grammar as syntax (later learning stages), morphophonology (affixational forms), and morphosyntax. Consistent with these findings, specific empirical studies also provide evidence for a role of PM in L2, especially at later stages of learning and in the immersion contexts (Hamrick, 2015; Brill-Schuetz & Morgan-Short, 2014; Faretta-Stutenberg & Morgan-Short, 2018; Antoniou et al., 2016). Of note, Antoniou et al. (2016) found that PM was predictive of

simple affixed grammar learning in L2, which involves the addition of the affix to the stem of the word in a rule-governed manner.

Procedural Memory and ADHD

Because PM facilitates L2 learning, it is also important to understand the impact of ADHD on PM, which could provide us with more details about the influence of ADHD on L2. There is only a handful of research studies on PM and ADHD, and the obtained results are somewhat ambiguous. For instance, by investigating the relationship between WM and PM in young adults (a complex span task that concentrated on both PM and WM was used), Fabio et al. (2020) revealed that participants with ADHD exhibited deficits in both systems, which were found to be related and influence each other. Merikanto et al. (2019) observed that elevated ADHD symptoms based on the self-reported scale could be linked to poor performance on overnight procedural learning as measured by a mirror-tracing task.

However, there is also evidence that individuals with ADHD have preserved PM. For example, Sanjeevan et al. (2020a) meta-analyzed seven studies that examine procedural sequence learning by referring to the serial reaction time tasks (SRT) in individuals with ADHD in comparison with neurotypical controls. No significant difference in performance of both groups was found, regardless of the participants' age group (either children or adults). The authors also mentioned that mixed findings of the previous research could be attributed to different measures of PM or insufficient statistical power of the study. Besides that, by conducting a neuroimaging study, Sanjeevan et al. (2020b) also discovered no differences in the neural structures that underpin PM in children with and without ADHD. Takács et. al (2017) revealed that not only children with ADHD but also those who have ADHD and comorbid Tourette syndrome have preserved PM sequence learning (assessed by the alternating serial

reaction time task or ASRT). García (2001) also did not find any difference in the PM learning ability in the adolescents with ADHD and controls. Another interesting finding was observed in a sleep-oriented study by Prehn-Kristensen et al. (2011b) who found the positive effect of sleep on PM (assessed by the button-box task) in children with ADHD, which was surprisingly not present in the neurotypical controls. Although the results largely suggest that PM is not impaired in ADHD, this is still an under researched topic, and potential relationship between PM and ADHD could also have an effect on L2 learning. Therefore, it might be important to explore the association between PM, ADHD, and L2 learning in a greater detail.

Motivation for the Study and Research Questions

Based on the fact that WM and two long-term memory systems play a significant role in adult L2 acquisition, and that adults with ADHD seem to have impaired DM (e.g., Verster et al., 2010) and WM (e.g., Martinussen et al., 2005), and might have impaired PM (Fabio et al., 2020), it is important to investigate the role that individual differences in these memory systems play in L2 learning in individuals with ADHD. In this way, we should gain a more specific understanding of the nature of ADHD and its impact on L2 learning. Specifically, it would be important to answer the following research questions:

First, we would like to look at whether ADHD has effects on L2 learning (as compared by the performance of participants with ADHD and controls). Thus, our first research question (RQ1) is: *Does ADHD influence L2 learning?*

Regarding this research questions, it is possible that I would not find any difference between the two groups (i.e., participants with ADHD and controls) or that the difference in performance might be minimal (with controls scoring slightly higher than participants with ADHD). My prediction is based on the fact that most of the studies that looked at L2 learning

and ADHD did not find impaired L2 learning in students with ADHD (e.g., Sparks et al., 2003; Sparks et al., 2005; Sparks et al., 2004) and those studies that found impaired performance either assessed ADHD only based on the teachers' and parents' evaluations (Ferrari & Palladino, 2007) or concentrated on the performance of the students who already had difficulties with learning (Leons et al., 2009). Thus, I believe that in a more controlled experimental setting in which ADHD is measured, differences between the two groups may not be observed. However, given that previous research on L2 and ADHD is still scarce, I do not consider this to be a strong prediction. Perhaps differences will be found.

Another question that we are interested in is whether memory systems that influence L2 learning have similar contributions in L2 learning in participants with ADHD in comparison with controls. Thus, our second research question (RQ2) is: *Does the role of WM, DM, and PM for L2 learning differ in learners with ADHD compared to neurotypical learners?*

Regarding this research question, I predict that memory will be associated with L2 learning but that it may have a different role for learners with ADHD and neurotypical controls. Specifically, I assume that neurotypical learners may rely more on WM and DM (but also on PM), especially for complex, analogical structures. However, since these memory systems (WM and DM) might be impaired in ADHD (e.g., Kasper et al., 2012; Alderson et al., 2013; García, 2001), the learners with a disorder may not rely on WM and DM to the same extent, and they may compensate their L2 learning by relying more on PM, which may potentially be not impaired in ADHD (Sanjeevan et al., 2020a). This potential increased reliance on PM should be evident especially for simple, affixed structures. Note that this compensatory role of PM might also explain the results I could obtain for the first question (that there might be no meaningful difference in performance of ADHD learners and neurotypical controls). I also admit that this

particular study may not show this clearly as we are not testing participants at later stages of learning where PM is predicted to play a larger role (Ullman, 2020).

METHODS

Participants

Based on the results of the study (Antoniou et al., 2016) that applied the identical language task and found the significant difference in performance between two groups with 36 participants in one group and 25 participants in the other group, we aimed to have at least 36 participants for each group (ADHD and control). We believed that this number would be sufficient to detect the learning effect. Data from both ADHD participants and neurotypical controls was collected over the course of the spring 2023 and fall 2024 semesters until both groups had at least 36 participants.

Overall, 116 participants from a large Midwestern university participated in the study. Participants were recruited either from the Psychology subject pool for a class credit (mostly control participants and 17 ADHD participants) or were monetarily compensated (ADHD participants only) for their participation. All participants had to sign a consent form prior to the participation in the study. Participants from both groups had various native languages with the majority of participants reporting prevailing English as their L1. Most of the participants also reported being bilingual.

The control group consisted of 80 participants (M age = 20.30, SD = 3.22) who did not report being clinically diagnosed with ADHD. Fifty-three participants from the group identified themselves as males and 27 as females. All control participants were undergraduate students. Control participants' scores on BAARS-IV were: M = 33.20, SD = 9.67, 95% CIs [31.05; 35.35]. Their PHQ scores were: M = 10.14, SD = 6.23, 95% CIs [8.75; 11.52].

The ADHD group consisted of 36 participants (M age = 20.60, SD = 3.64) who self-reported being clinically diagnosed with ADHD. Twenty-one of the ADHD participants were females, 11 males, and 4 preferred not to reveal their sex. Most of the participants were undergraduate students, with the exception of 2 PhD students, 1 student in a Master's program, and 1 participant who was not enrolled in college but was a high school graduate. The ADHD group had the following scores on BAARS-IV: M = 46.67, SD = 9.97, 95% CIs [43.29; 50.04]. Their PHQ scores were: M = 10.58, SD = 4.87, 95% CIs [8.93; 12.23]. As can be seen, the BAARS-IV scores were higher for the ADHD group, and they fell within the range for the clinical diagnosis based on the BAARS-IV scale.

Materials and Procedure

First, participants signed an informed consent form and then proceeded working on the verbal DM task and then on the language training. This was followed by a non-verbal DM task and a background survey. Then, participants completed a depression questionnaire and worked on a PM task, followed by the ADHD questionnaire. The session ended after participants finished working on the WM tasks and were debriefed about the purpose of the study. Each task is described in more detail below.

L2 Learning Task

As mentioned by Brill-Schuetz & Morgan-Short (2014), artificial languages have been shown to have ecological validity in relation to L2 acquisition. Thus, in order to measure L2 learning, an artificial language paradigm was used (Antoniou et al., 2016). Specifically, participants learned the morphophonology of an artificial language that consists of 12 nouns denoting animals. In this language, all the nouns are monosyllabic and have the following structure: consonant-vowel-consonant (e.g., [gif], “horse”). Each noun can be used in four

forms, including singular, diminutive, plural, and diminutive plural forms. There are two types of rules that participants need to learn. In the simple affixed type (found in words with *i*- and *a*-stems), a new word is formed by the addition of affixes (either the suffix [-il], to indicate the plural form, and/or prefix [ka-], to indicate the diminutive form) to the stem of the word without any other changes (e.g., the singular word [gif], “horse” becomes [gif-il], “horses”, [ka-gif], “little horse”, or [ka-gif-il], “little horses”). This type of simple affixation rule is posited to rely on PM (Antoniou et al., 2016). In the complex analogical type (found in the words with *e*-stems), a new word is produced by the addition of an affix and a change of the vowel in both the stem and affix in the diminutive forms (e.g., the singular word [mez], “cow”, becomes [mez-el], “cows”, [ka-maz], “little cow”, or [ka-maz-el], “little cows”). Because of the complexity of these combined rules, these forms are assumed to be learned by analogy, which is posited to rely on DM (Antoniou et al., 2016). See Appendix B for the whole list of stimuli.

To train participants in the artificial language, we exposed them to the picture-spoken word pairings without giving them any specific instructions about the rules of the language. In other words, they solely saw a picture of an animal and heard a noun that denotes it. All 12 nouns were presented in their 4 possible forms (which constitutes 1 block of 48 items), where half of the nouns were of the simple affixed type, and half of the nouns were of the complex analogical type. The block of nouns was repeated 4 times for a total of 192 trials overall (12 nouns * 4 forms * 4 repetitions = 192 trials). A picture denoting a noun was shown on the screen for 3 s. The spoken word corresponding to the name of the noun appeared 500 ms after the picture was displayed. The picture remained on the screen for 3 s, and participants saw a blank screen for 500 ms before the next picture-noun pair was introduced.

Later, participants were tested on untrained words that followed the morphophonology of the trained rules. Here, the participants needed to respond to a forced choice task where they had to choose between one of the two forms of the new words depending on the picture they saw. In particular, participants were presented with a picture of a new animal or object that remained on the screen for 1.5 s. They also heard the name of the animal in its singular form (500 ms after the presentation of the picture). After that, the picture disappeared from the screen and a new picture of the same animal was shown again in a new configuration (e.g., seeing many pictures of the same animal, which indicates a plural form). As the new picture remained on the screen, two spoken words were also produced sequentially, and participants were instructed to choose the correct one. They were given up to 5s to make their decision. Accuracy of the responses was analyzed.

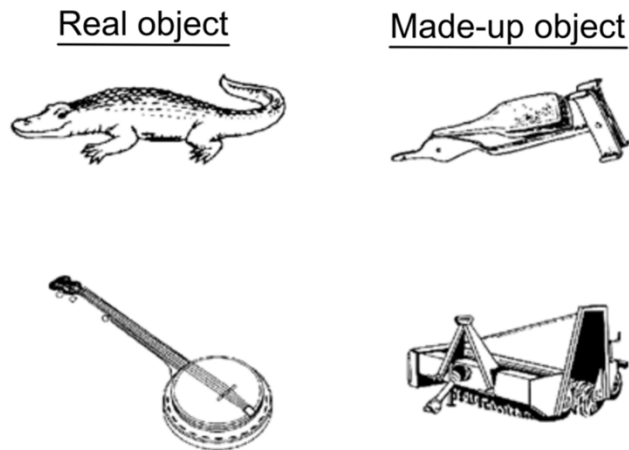
Declarative Memory Task - Declearn

In order to assess participants' DM learning ability, the Declearn task (Hedenius et al., 2013) was used. As mentioned in Hedenius et al. (2013), similar tasks have shown to “engage the network of brain structures underlying declarative memory” (p. 50). Moreover, in the study by Buffington et al. (2021), Declearn was found to be positively correlated with other DM learning ability measures.

Declearn is a nonverbal task, which means that the links between the score on it and L2 can be associated exactly with the domain-general DM learning abilities (Buffington et al., 2021). The task consists of two stages. On the first stage (incidental encoding), participants are presented with a set of black-and-white images of real and made-up objects (see Figure 1, 64 trials total) and are asked to decide whether the object is real or not. After that, participants take a 10-minute break. On the second stage (recognition), they are shown the same set of objects

including the new ones and need to indicate whether they have seen them before or not (128 trials total). During both stages, participants were given 500 ms to view each image and up to 4500 ms to make their response. The d -prime score for the recognition block was computed. In other words, a score based on the difference between the relative rate of hits (correct answers) and the relative rate of false answers was calculated.

Figure 1. Examples of real and made-up objects



Note. Retrieved from Hedenius et al. (2013)

Declarative Memory Task - MLAT

To assess participants' verbal DM learning ability, we used the Part V of the Modern Language Aptitude Test (MLAT), (Carrol & Sapon, 1959), which reliability was found to be "above the acceptable threshold" in previous research (Buffington et al., 2021, p. 648). In this task, participants had to memorize 24 Kurdish words that were presented with the English

equivalents. They were given 2 minutes to learn the words and 2 minutes to practice using the words. Particularly, during practice, participants were presented with 24 words in English and were asked to write their corresponding Kurdish equivalents. When working on this activity, participants could look at the handout that had the words in both English and Kurdish. After participants finished practice, they were given 4 minutes to work on a multiple-choice test (find an English equivalent to a Kurdish word), which included all 24 items. Each question had 5 options. The accuracy score was analyzed.

Procedural Memory Task

Participants' PM learning abilities was assessed using the Serial Reaction Time (SRT) task (Nissen & Bullemer, 1987; Lum et al., 2012), which was found to have acceptable reliability and positive association with another PM learning task, ASRT (Buffington et al., 2021). Here, participants were presented with a smiling face image positioned in one of the four squares on the screen. Their job was to press the button corresponding to the location of the smiling face as quickly as they could. Specifically, participants were instructed to "press the button on the game pad that matches the location of the smiley face on the computer screen."

When working on SRT, participants were not told that the sequence in which the stimulus appears on the screen followed the same order. Thus, they repeated the same sequence over four blocks over 60 trials each. However, on a fifth final block, a new sequence was introduced. This task is considered to measure PM learning ability since participants' responses become faster and more accurate with practice, which shows that they have learned the sequence successfully even though they might be not aware of that. However, when a novel sequence is introduced, the response rate becomes slower again. Similar response rate across trials indicates that no learning took place (Walker et al., 2020). In order to calculate the PM score from SRT, the median

response time score obtained from the final block of the repeating sequence was subtracted from the one obtained from the new block. The larger the score, the more learning occurred.

Working Memory Tasks

Shortened versions of the complex WM span tasks (Oswald et al., 2015) that were shown to be both valid and reliable measures of WM will be utilized in the current study. These tasks include Operation-Span, Reading-Span, and Symmetry-Span tasks (see Appendix C for the examples of each of these tasks).

Operation-Span. When working on the O-Span task, participants are presented with simple math equations and solutions to them (e.g., $(1*2) + 1 = 3$). The participants' task is to identify whether the provided solution is correct or wrong. After being presented with each math problem, they are also shown a letter that they will need to recall at the end of the set of trials (sets could consist of 3-7 trials). A set of each length is administered 3 times, which results in 75 trials in total.

Reading-Span. In the R-Span task, participants are presented with logical and illogical sentences that contain 10-15 words. The participants' task is to decide whether the sentences they see make sense or not (e.g., "Andy was stopped by the policeman because he crossed the yellow heaven" or "During winter you can get a room at the beach for a very low rate"). After making their decision on each sentence, participants are presented with a letter that they are instructed to remember and are asked to recall at the end of each trial set. The list length of letters in each set ranged from 3-7 letters (the letters were not related). A set of each length is administered 3 times, which results in the presentations of 75 letters in total (or 75 trials).

Symmetry-Span. When working on this task, participants are shown 8*8 grids of black and white squares. Their task here is to judge whether the grids are symmetrical about the

vertical axis. After symmetry judgment is made, participants are presented with a 4*4 grid that contains a red square. Here, their task is to memorize where the red square is located. The sets of the symmetry judgment and red square presentation occur from 2-5 times, after which participants have to recall each position of the squares. A set of each length is administered 3 times, which results in the presentations of 42 locations in total (or 42 trials).

For assessing WM, first, an absolute accuracy score that is based on the correct responses for both types of questions for each span task (Oswald et al., 2015) was analyzed. Second, a composite WM score was calculated. The overall WM composite score consisted of the averaged z-scores from the accuracy score on each task.

ADHD Measure

To measure the degree of reported ADHD symptoms, participants completed the BAARS-IV questionnaire, which has been shown to be a reliable and valid measure of ADHD (Silverman, 2012). For the purpose of this study, only the self-report form of the scale was utilized. It includes 30 items, 27 of which are evaluated on a 4-point Likert scale, where participants indicate the frequency of the ADHD symptoms they experienced during the last 6 months. Here, the scale is divided into four sections with the focus on inattention (9 statements, e.g., “easily distracted by extraneous stimuli or irrelevant thoughts”), hyperactivity (5 statements, e.g., “fidget with hands or feet or squirm in seat”), impulsivity (4 statements, e.g., “have difficulty awaiting my turn”), and sluggish cognitive tempo (9 statements, e.g., “underactive or have less energy than others”). The possible answers include the following: never (1), sometimes (2), often (3), very often (4). The last three questions evaluate the onset of the symptoms and spheres that are the most affected by them. For the purpose of the current study, we looked at the total number of symptoms only on the inattention, hyperactivity, and impulsivity scales. A total

score that falls within 93 percentile or higher (39-72 total points on three symptoms) is considered to be indicative of ADHD (Barkley, 2011).

Depression Measure

Since depression might often be comorbid with ADHD, participants completed a PHQ-9 questionnaire that evaluates depressive symptoms (Kroenke & Spitzer, 2002). Here, they were asked about nine problems they might have experienced during the last 2 weeks (e.g., “Little interest or pleasure in doing things”, see Appendix D for the full questionnaire). The occurrence of each problem had to be indicated based on the 4-item scale: not at all (0), several days (1), more than half the days (2), nearly every day (3). If there are at least four “more than half the days” or “nearly every day” responses (or “several days” to the following problem: “Thoughts that you would be better off dead, or of hurting yourself”), depression could be considered. The total score indicates the severity of depression, where 1-4 points are indicative of minimal depression, and 20-27 points could indicate severe depression.

Analysis

To answer the first research question, particularly “Does ADHD influence L2 learning?”, a *t*-test was conducted. Here, performance on the L2 task of the participants with self-reported diagnosis of ADHD and controls was compared. ADHD was quantified categorically and performance on the L2 task was presented as a continuous variable.

To answer the second research question, specifically “Does the role of WM, DM, and PM for L2 learning differ in learners with ADHD compared to neurotypical learners?”, two linear mixed effect models were run — one for simple affixed structures and one for complex analogical structures. Each model had the accuracy score on the L2 learning task as a dependent variable. ADHD and individual differences in WM, DM, and PM were treated as predictor

variables. The models also contained interactions between ADHD and each of the individual difference measures. Finally, the score on the depression measure was entered as a covariate.

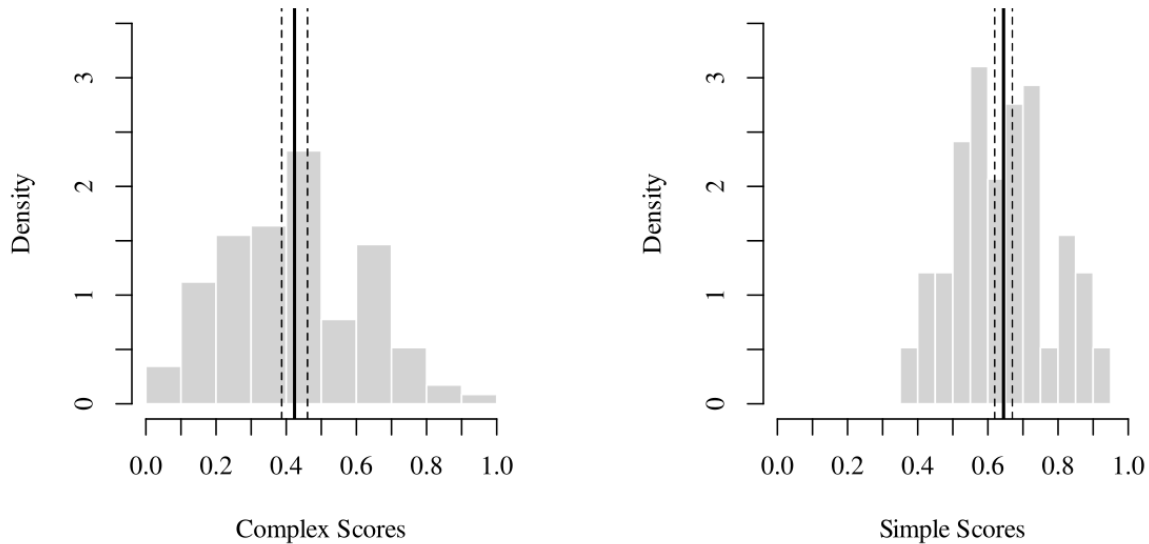
RESULTS

First RQ

Our first research question was: *Does ADHD influence L2 learning?*

First, learning on the artificial language task was examined (see Figure 2 and Table I). Participants performed above chance (i.e., 50%) on simple affixed forms. However, their performance on the complex analogical forms was below chance. Table VI and Table VII, Appendix E show separate L2 descriptive scores for ADHD and control participants.

Figure 2. Histograms of the score distributions for complex analogical and simple affixed forms



Note. Solid lines represent means, and dashed lines represent 95% confidence intervals.

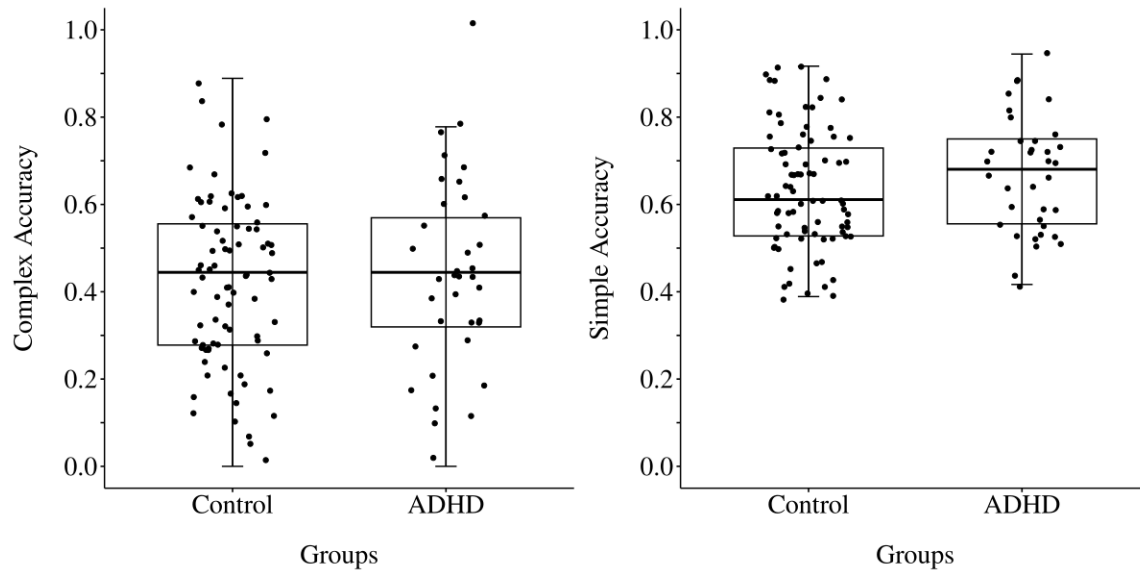
TABLE I

DESCRIPTIVE SCORES ON THE ARTIFICIAL LANGUAGE TASK FOR COMPLEX
ANALOGICAL AND SIMPLE AFFIXED FORMS

L2 form	<i>M</i>	<i>SD</i>	95% CI	
			LL	UL
All	0.53	0.13	0.51	0.56
Complex	0.42	0.49	0.40	0.45
Simple	0.64	0.48	0.62	0.67

Then, we ran two Welch two-sample t-tests with the continuous accuracy score on the complex analogical forms and the simple affixed forms (see Figure 3). The groups were divided based on the self-reported ADHD questionnaire. A Welch two-sample t-test showed that for complex analogical forms the difference in L2 learning between the ADHD ($N = 36$, $M = 0.44$, $SD = 0.22$, 95% CIs [0.36; 0.51]) and the control group ($N = 80$, $M = 0.42$, $SD = 0.19$, 95% CIs [0.38; 0.46]) was not statistically significant, $t(59.81) = 0.44$, $p = .66$, $d = .09$. For simple affixed forms, the difference in L2 learning between the ADHD ($N = 36$, $M = 0.67$, $SD = 0.13$, 95% CIs [0.36; 0.71]) and the control group ($N = 80$, $M = 0.64$, $SD = 0.14$, 95% CIs [0.60; 0.67]) was also not statistically significant, $t(69.64) = 1.14$, $p = .26$, $d = .23$. Thus, no differences between the ADHD and control groups were detected on the measures of L2 learning.

Figure 3. Box plots of the scores for complex and simple forms for ADHD and Control Groups



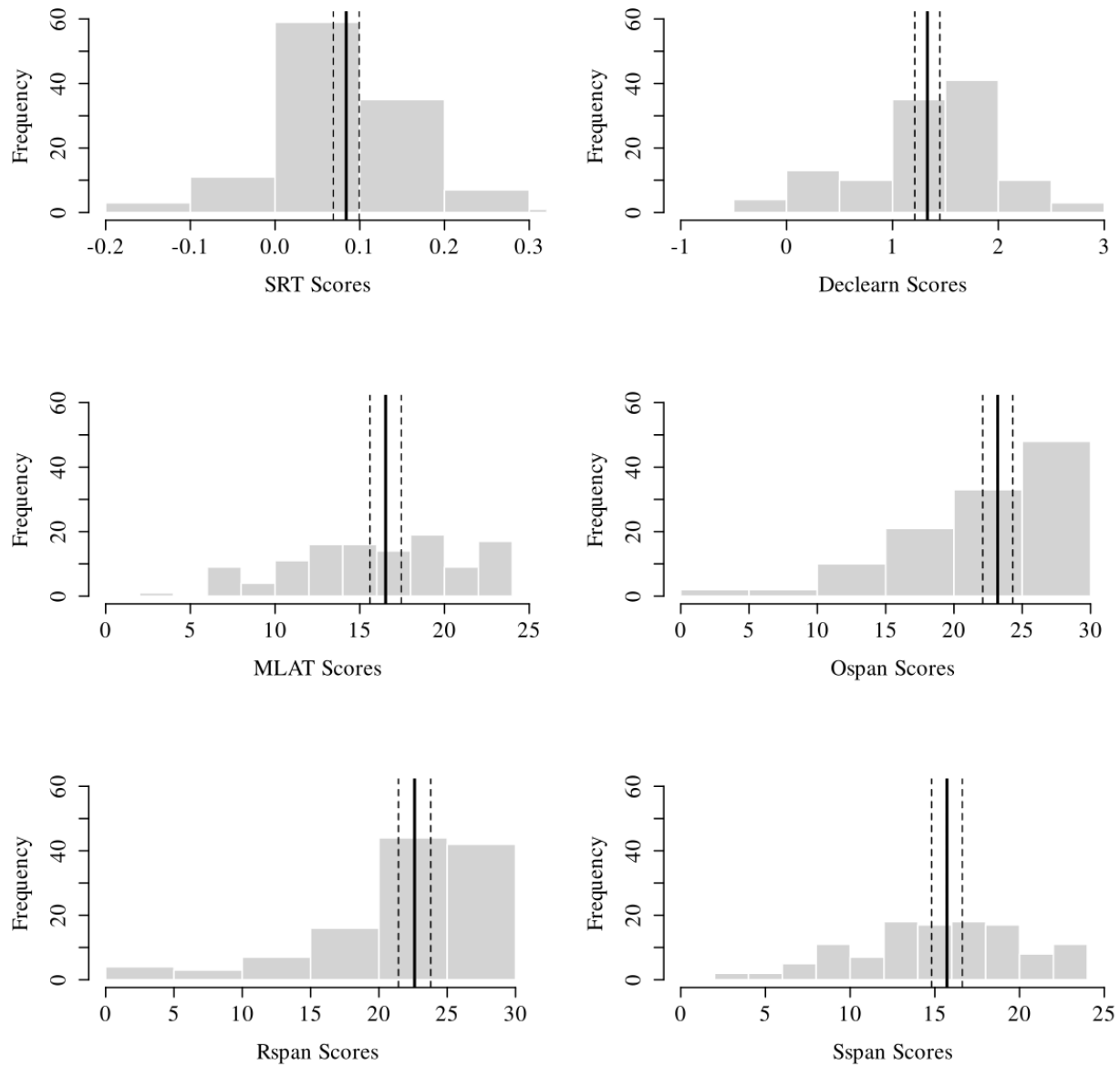
Note. Each dot represents a score for an individual participant.

Second RQ

Second, we examined the models that addressed our second research question: ***Does the role of WM, DM, and PM for L2 learning differ in learners with ADHD compared to neurotypical learners?***

Before doing the inferential analysis, we looked at the learning effects on the cognitive tasks. Learning was observed on each task (see Figure 4, Table II, and Table VIII and IX, Appendix F for separate descriptive scores for ADHD and control participants), with above-chance performance on Declearn, MLAT, and SRT. Participants' performance on the WM tasks was also satisfactory and showed variation. For all the cognitive tasks, we examined outliers above 3 *SD*. Two outliers were identified on the SRT task, and thus these scores were removed from the analysis.

Figure 4. Histograms of scores on the cognitive task distributions



Note. Solid lines represent means, and dashed lines represent 95% confidence intervals.

TABLE II
DESCRIPTIVE SCORES ON THE COGNITIVE TASKS

Memory	<i>M</i>	<i>SD</i>	95% CI	
			LL	UL
DM composite (standardized)	0.00	0.80	-0.15	0.15
Declearn	1.33	0.64	1.21	1.45
MLAT	16.53	5.02	15.60	17.45
SRT	0.08	0.07	0.07	0.10
Span task (standardized)	0.00	0.82	- 0.15	0.15
Ospan	23.21	5.98	22.11	24.31
Rspan	22.61	6.41	21.43	23.79
Sspan	15.72	4.93	14.81	16.62

To observe general patterns of association in the data, a correlational analysis was run (see Table III and Table IV). The correlations showed that overall, there was a statistically significant small positive relationship between the accuracy score on the complex analogical forms and the composite DM score ($r(116) = .20, p = .04$) and a statistically significant small positive relationship between the accuracy score on the simple affixed forms and the WM score ($r(116) = .25, p = .01$). ADHD symptomatology also seemed to have a statistically significant small positive association with the composite DM score ($r(116) = .19, p = .045$), MLAT ($r(116) = .19, p = .09$), and WM ($r(116) = 0.19, p = .04$). Separate correlations for ADHD and control participants are provided in Table X and Table XI, Appendix G.

TABLE III**CORRELATIONS BETWEEN SIMPLE AND COMPLEX ANALOGICAL SCORES AND COGNITIVE TASKS (ALL PARTICIPANTS)**

Task	Simple	Complex	SRT	DM	Declearn	MLAT	WM	BAARS
SRT	-0.01	0.06						
DM	0.16	0.20*	0.06					
Declearn	0.15	0.16	0.05	0.80*				
MLAT	0.10	0.16	0.04	0.80*	0.30*			
WM	0.25*	0.13	0.01	0.42*	0.23*	0.46*		
BAARS	0.08	0.05	-0.04	0.19*	0.11	0.19*	0.19*	
PHQ	0.09	-0.05	0.02	0.13	0.02	0.19*	0.12	0.44*

* $p < .05$

To answer the research question more comprehensively, we also used generalized mixed-effect models by running the *glmer* function (Bates et al., 2015) in R. The accuracy score on the Ettlinger task was a dependent variable. Fixed factors included a reaction time score for PM (which was grand-mean centered), a composite standardized score for DM, a composite standardized score for WM, a continuous ADHD symptomatology score, depression, age, sex, and interactions between each memory type and ADHD. An intercept of a participant served as a random factor.

For simple affixed rules (see Table IV), we found a significant effect of WM ($\beta = 0.23$, $z = 2.71$, $p = .01$), see Figure 5, showing that participants with higher WM scores got higher scores on the simple affixed rules. For complex analogical rules (see Table V), no significant effects were observed. However, there seems to be a trend in the main effect of the composite DM ($\beta = 0.23$, $z = 0.13$, $p = .06$), see Figure 5, showing that participants with higher DM score seemed to get higher scores on the complex analogical rules. No other significant main effects or

interactions were found. Thus, the results indicated some role for individual differences in memory in L2 learning, but no interaction with ADHD symptomatology was detected.

TABLE IV

MIXED-EFFECTS MODEL

[ACCURACY_SIMPLE ~ PHQ + AGE + SEX + DM*BAARS + PM*BAARS + WM*BAARS
+ (1|PARTICIPANT)]

Fixed effects	β	SE	z	p
(Intercept)	0.65	0.10	6.50	<.001***
DM	-0.005	0.09	-0.06	.95
PM	-0.004	0.06	-0.07	.94
WM	0.23	0.09	2.71	.007**
BAARS	0.006	0.07	0.09	.93
PHQ	0.03	0.06	0.54	.59
Sex	-0.03	0.12	-0.27	.78
Age	-0.04	0.06	-0.73	.46
DM*BAARS	-0.12	0.08	-1.45	.15
PM*BAARS	-0.01	0.06	-0.22	.83
WM*BAARS	0.15	0.09	1.64	.10
Random effects	Variance	SD		
Intercepts Participant	0.24	0.49		

** $p < .01$, *** $p < .001$

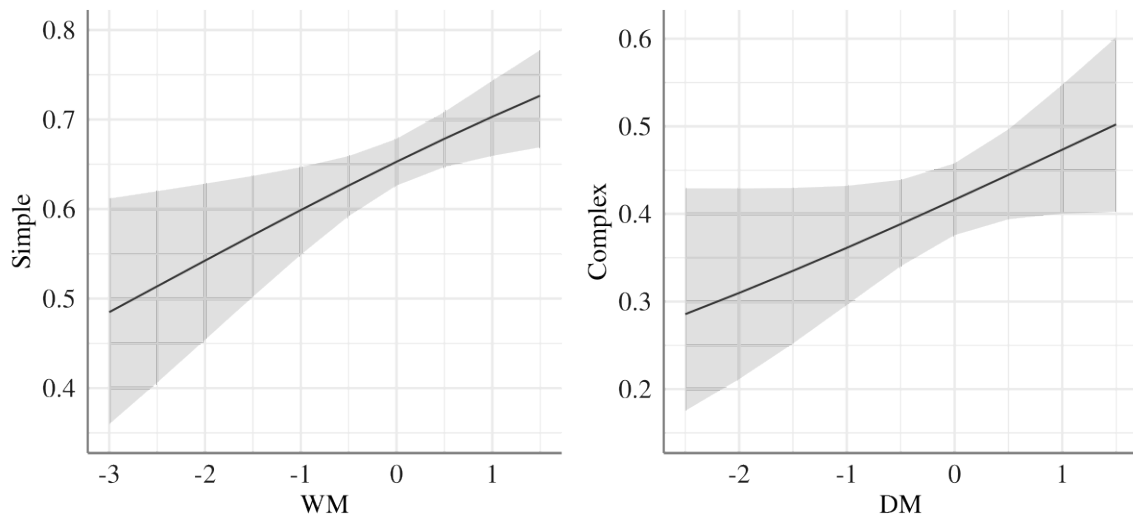
TABLE V

MIXED-EFFECTS MODEL
 [ACCURACY_COMPLEX ~ PHQ + AGE + SEX + DM*BAARS + PM*BAARS +
 WM*BAARS + (1|PARTICIPANT)]

Fixed effects	β	SE	z	p
(Intercept)	-0.47	0.15	-3.17	.002**
DM	0.23	0.12	1.85	.06
PM	0.03	0.09	0.29	.78
WM	0.04	0.12	0.34	.73
BAARS	0.07	0.10	0.66	.51
PHQ	-0.10	0.10	-1.05	.29
Sex	0.18	0.17	1.08	.28
Age	-0.02	0.09	-0.27	.78
DM*BAARS	-0.05	0.12	-0.38	.70
PM*BAARS	0.01	0.09	0.12	.90
WM*BAARS	-0.01	0.14	-0.06	.95
Random effects	Variance	SD		
Intercepts Participant	0.54	0.74		

*** $p < .001$

Figure 5. Graphs of the main effect of WM in the simple affixed forms and main effect of the DM for the complex analogical forms



Note. Gray shaded areas represent confidence intervals.

DISCUSSION

Our study aimed to investigate the relationship between ADHD and memory systems in L2 learning. Overall, in the L2 task, we found that both ADHD and control participants evidenced learning in simple affixed forms, but not in the complex analogical forms. Both groups learned in the memory tasks.

Research Questions

In regard to our first research question that looked at whether ADHD affects L2 learning, we did not find any difference between ADHD participants and controls for both types of the forms. Thus, we did not find any evidence that ADHD might affect L2 learning: both control and ADHD groups seem to learn simple affixed forms (their performance was above chance) and did not seem to learn complex analogical forms (their performance was below chance).

Such results support our original hypothesis and are consistent with previous research (Sparks et al., 2005; Sparks et al., 2004; Sparks et al., 2003; and Leons et al., 2009). Previous studies showed that L2 learning in individuals with ADHD may be intact, which was evident in ADHD students' ability to pass L2 classes (Sparks et al., 2005; Sparks et al., 2004; Sparks et al., 2003) or improve L2 proficiency as measured by the oral proficiency test (Leons et al., 2009). Our results also extend these previous findings by not finding any influence of ADHD on L2 learning in the controlled laboratory settings, when comparing performance of both the ADHD participants and controls.

However, our findings do not align with the results obtained by Ferrari and Palladino (2007) who found that students from a junior high school who had a lower achievement level of L2 learning potentially had ADHD. Nevertheless, such discrepancies in findings could be explained by the fact that Ferrari and Palladino (2007) did not look at students who were

clinically diagnosed with ADHD and solely relied on the subjective teachers' and parents' perceptions, whereas we looked at the participants who were diagnosed with ADHD by a clinician.

In regard to the second research question that investigated whether the role of WM, DM, and PM for L2 learning differs in learners with ADHD compared to neurotypical learners, we did not find any evidence that these memory systems have a different role for students with a disorder and neurotypical ones. This was the case for both complex analogical and simple affixed rules. These results do not support our hypotheses that predicted that neurotypical learners may rely more on WM, DM (memory systems that might be impaired in individuals with ADHD, e.g., Kasper et al., 2012; Alderson et al., 2013; García, 2001) and PM, especially for complex, analogical structures. We also expected that ADHD learners may rely more on PM (a memory system that is potentially sparse in the ADHD individuals) especially for simple, affixed structures. However, we did not find any relationship between memory systems and ADHD symptomatology in L2 learning. Unfortunately, we were not able to compare our results to the previous findings because, to our knowledge, no studies have examined the interaction between these memory systems and ADHD in L2 learning.

Other Findings

Overall, whereas we did not find any relationship between memory and ADHD in L2 learning specifically, we did observe some more general relationships between (a) memory and ADHD symptomatology and (b) memory and L2 scores.

We did find that DM and WM independently showed a relationship with ADHD symptomatology. First, for DM and ADHD, we found that higher composite DM scores and higher scores on MLAT seem to be related to higher ADHD symptomatology. These results are

surprising considering that previous research studies reported that people with ADHD might have impaired DM (e.g., García, 2001/Verster et al., 2010). It should be noted though that although García (2001) used a verbal DM task, it was auditory in nature, whereas the MLAT test that we used is designed in a written modality. Also, although Verster et al. (2010) mentioned that individuals with ADHD have worse performance on the DM tasks, this was observed only on the delayed recognition tasks, but not on the immediate recall. In contrast, our study utilized DM tasks (both MLAT and Declearn) that probed immediate recognition. Thus, our contradicting finding might be explained by the nature of the task, which could suggest that people with ADHD have intact verbal DM as measured by the immediate recognition tasks.

Second, we found that higher composite WM scores were associated with higher ADHD symptomatology. This result is surprising and does not corroborate the findings of the previous studies that found that ADHD is associated with poor WM performance in different age groups (e.g., Martinussen et al., 2005; Alderson et al., 2013). It is possible that this finding is influenced by the population we studied, specifically, college students with ADHD. To explore this possibility, we conducted an additional post-hoc search for the articles that focused on WM and ADHD in college students. Gropper & Tannock (2009) found that college students with ADHD had worse scores on the WM tasks, measured by the auditory-verbal WM tasks and a visual-spatial task. However, Kim et al. (2014) did not find any behavioral differences in performance on the digital span task and spatial WM tasks, but found a significant difference in the neural processes, measured by ERP (lower P3 – component associated with WM functioning – during WM encoding). Gabay et al. (2022) also did not find that participants with ADHD had lower WM compared to controls on the N-back task. Thus, it may be that college students might either

not exhibit any differences in WM when measured by behavioral methods or might show them in specific WM domains which were not accounted for in this study.

As for the relationship between memory and L2, we found an association between DM and complex analogical forms. Specifically, although this effect seemed only to approach significance in the mixed model, a correlational analysis revealed that higher scores on the complex forms were associated with higher scores on DM. Such findings are consistent with the previous literature that found that DM correlates with complex analogical rule learning (e.g., Antoniou et al., 2016; Ettlinger et al., 2014). However, even though there seems to be a relationship between DM and ADHD and DM and L2 learning, we did not find evidence that ADHD symptomatology moderates the role of DM in L2 learning.

We also found that better WM predicts better scores on the simple affixed rules as shown by the mixed model analysis. This is a novel finding for this paradigm because the previous studies that implemented WM did not find any relationship between L2 learning for both types of the rules and WM (e.g., Antoniou et al., 2016; Ettlinger et al., 2014). However, they used an auditory WM task, which is different from the complex span WM tasks that we utilized. Nevertheless, such findings support a facilitative role of WM in L2 learning, as attested to in a previous meta-analysis (Linck et al., 2014). Altogether, our findings about WM suggest that whereas it plays a role in L2 learning and has a relationship with the ADHD, we do not have evidence to suggest that the role of WM in L2 learning is moderated by the ADHD symptomatology.

Limitations

It is also important to mention limitations that our study might have had. First, it is likely that our results might have been influenced by the tasks that we used. Whereas it is good to

explore different parts of the memory domains (looking at different modalities), it is also possible that we have missed something by not exploring the others. For instance, to measure WM, it might be useful to utilize an auditory task, especially since it was shown that the same population of the participants had an impaired performance on such a task. Second, our results might be applicable only to Midwestern college students from diverse linguistic backgrounds and mostly females. Thus, further research with different participants should be conducted to improve the generalizability of the findings. Third, even though we did not see a statistically significant difference between the groups, our analyses do not allow us to claim that the groups equivalently relied on WM, DM, and/or PM. In order to establish equivalence, we would need to run additional statistical tests that are designed to confirm the null hypothesis, e.g., the two one-sided t-tests procedure (TOST). Finally, the levels of L2 learning of our participants were not high. Thus, future analysis might also benefit by looking at the quadratic relationship between the variables in addition to the linear relationship, as such a relationship has been evidenced in previous research (Ettlenger et al., 2012). It would also be beneficial to conduct a post-hoc power analysis to determine whether we had enough participants to find any effect.

Conclusion

In conclusion, our findings show that there is no evidence that students with ADHD perform differently from neurotypical students in the L2 task. They also did not show evidence that the memory systems that seem to influence L2 learning and moderated by ADHD symptomatology. However, more generally, our study revealed that DM may facilitate learning of the complex analogical forms, and WM may facilitate learning of the simple affixed forms. Our findings could help us to build our overall knowledge about L2 learning with ADHD. From the practical perspective, since our results suggest that adults with ADHD do not seem to

perform differently from the neurotypical adults, it could imply that they should not be treated differently in the L2 classes.

REFERENCES

- Alderson, R. M., Kasper, L. J., Hudec, K. L., & Patros, C. H. G. (2013). Attention-deficit/hyperactivity disorder (ADHD) and working memory in adults: A meta-analytic review. *Neuropsychology*, 27(3), 287–302. <https://doi.org/10.1037/a0032371>
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). <https://doi.org/10.1176/appi.books.9780890425596>
- Antoniou, M., Ettlinger, M., & Wong, P. C. M. (2016). Complexity, training paradigm design, and the contribution of memory subsystems to grammar learning. *PLoS ONE*, 11(7), <https://doi.org/10.1371/journal.pone.0158812>
- Baddeley, A. (2007). Working memory, thought, and action. Oxford University Press. <https://doi.org/10.1093/acprof:oso/9780198528012.001.0001>
- Barkley, R. A. (2011). *Barkley Adult ADHD Rating Scale-IV (BAARS-IV)*. Guilford Press.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Brill-Schuetz, K., & Morgan-Short, K. (2014). The Role of Procedural Memory in Adult Second Language Acquisition. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 36. Retrieved from <https://escholarship.org/uc/item/0dc7958r>
- Buffington, J., Demos, A. P., & Morgan-Short, K. (2021). The Reliability and Validity of Procedural Memory Assessments Used in Second Language Acquisition Research. *Studies in Second Language Acquisition*, 43(3), 635–662. <https://doi.org/10.1017/S0272263121000127>

- Gabay, L., Miller, P., Alia-Klein, N., & Lewin, M. P. (2022). Circadian Effects on Attention and Working Memory in College Students with Attention Deficit and Hyperactivity Symptoms. *Frontiers in Psychology, 13*, 851502–851502. <https://doi.org/10.3389/fpsyg.2022.851502>
- Carrol, J. B., & Sapon, S. M. (1959). *Modern language aptitude test*. Psychological Corporation.
- Castro, O. (2002). The Changing Demographic Panorama of Student Populations in Language Departments: Effective Solutions at the University Level and Recommendations for Their Implementation at the Secondary School Level. *Hispania, 85*(1). <https://doi.org/10.2307/4141205>
- Eichenbaum, H. (1997). Declarative memory: Insights from cognitive neurobiology. *Annual Review of Psychology, 48*(1), 547–572. <https://doi.org/10.1146/annurev.psych.48.1.547>
- Ettlinger, M., Bradlow, A. R., & Wong, P. C. M. (2014). Variability in the learning of complex morphophonology. *Applied Psycholinguistics, 35*(4), 807–831. <https://doi.org/10.1017/S0142716412000586>
- Fabio, R. A., Rizzotto, C., & Colombo, B. (2020). The analysis of the independence hypothesis: Working and procedural memory in young adults with Attention Deficit and Hyperactivity Disorder. Cognition, Brain, Behavior. *An Interdisciplinary Journal, 24*(3), 255–270. <https://doi.org/10.24193/cbb.2020.24.14>
- Faretta-Stutenberg, M., & Morgan-Short, K. (2018). The interplay of individual differences and context of learning in behavioral and neurocognitive second language development. *Second Language Research, 34*(1), 67–101. <https://doi.org/10.1177/0267658316684903>

- Ferrari, M., & Palladino, P. (2007). Foreign Language Learning Difficulties in Italian Children: Are They Associated with Other Learning Difficulties? *Journal of Learning Disabilities*, 40(3), 256–269. <https://doi.org/10.1177/00222194070400030601>
- Fuermaier, A. B. M., Tucha, L., Koerts, J., Aschenbrenner, S., Kaunzinger, I., Hauser, J., Weisbrod, M., Lange, K. W., & Tucha, O. (2015). Cognitive impairment in adult ADHD—Perspective matters. *Neuropsychology*, 29(1), 45-58. <https://doi.org/10.1037/neu0000108>
- García, C., Estévez, A., & Junqué, C. (2001). Perfil de memoria en el Trastorno por déficit de atención con hiperactividad. *Anuario de Psicología*, 32(4).
- Gropper, R. J., & Tannock, R. (2009). A Pilot Study of Working Memory and Academic Achievement in College Students With ADHD. *Journal of Attention Disorders*, 12(6), 574–581. <https://doi.org/10.1177/1087054708320390>
- Gupta, R., & Kar, B. R. (2010). Specific Cognitive Deficits in ADHD: A Diagnostic Concern in Differential Diagnosis. *Journal of Child and Family Studies*, 19(6), 778–786. <https://doi.org/10.1007/s10826-010-9369-4>
- Hamrick, P., Graff, C., & Finch, B. (2019). Contributions of episodic memory to novel word learning. *The Mental Lexicon*, 14(3), 381–398. <https://doi.org/10.1075/ml.19019.ham>
- Hamrick, P., Lum, J. A. G., & Ullman, M. T. (2018). Child first language and adult second language are both tied to general-purpose learning systems. *Proceedings of the National Academy of Sciences - PNAS*, 115(7), 1487–1492. <https://doi.org/10.1073/pnas.1713975115>

- Hedenius, M., Ullman, M. T., Alm, P., Jennische, M., & Persson, J. (2013). Enhanced recognition memory after incidental encoding in children with developmental dyslexia. *PloS ONE*, 8(5), <https://doi.org/10.1371/journal.pone.0063998>
- Kasper, L. J., Alderson, R. M., & Hudec, K. L. (2012). Moderators of working memory deficits in children with attention-deficit/hyperactivity disorder (ADHD): A meta-analytic review. *Clinical Psychology Review*, 32(7), 605–617. <https://doi.org/10.1016/j.cpr.2012.07.001>
- Kim, S., Liu, Z., Glizer, D., Tannock, R., & Woltering, S. (2014). Adult ADHD and working memory: Neural evidence of impaired encoding. *Clinical Neurophysiology*, 125(8), 1596–1603. <https://doi.org/10.1016/j.clinph.2013.12.094>
- Knowlton, B. J., Siegel, A. L., & Moody, T. D. (2017). Procedural Learning in Humans. In J. H. Byrne (Ed.), *Learning and Memory: A Comprehensive Reference* (2nd ed., pp. 295-312). <https://doi.org/10.1016/B978-0-12-809324-5.21085-7>
- Kroenke, K. & Spitzer, R.L. (2002). The PHQ-9: A new depression and diagnostic severity measure. *Psychiatric Annals*, 32, 509-52. <https://doi.org/10.3928/0048-5713-20020901-06>
- Leons, E., Herbert, C., & Gobbo, K. (2009). Students With Learning Disabilities and AD/HD in the Foreign Language Classroom: Supporting Students and Instructors. *Foreign Language Annals*, 42(1), 42–54. <https://doi.org/10.1111/j.1944-9720.2009.01007.x>
- Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review*, 21(4), 861–883. <https://doi.org/10.3758/s13423-013-0565-2>

- Lum, J. A. G., Conti-Ramsden, G., Page, D., & Ullman, M. T. (2012). Working, declarative and procedural memory in specific language impairment. *Cortex*, 48(9), 1138-1154.
<https://doi.org/10.1016/j.cortex.2011.06.001>
- Maniadaki, K., & Kakouros, E. (2017). The Complete Guide to ADHD: Nature, Diagnosis, and Treatment (1st ed.). Routledge. <https://doi-org.proxy.cc.uic.edu/10.4324/9781315316031>
- Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A Meta-Analysis of Working Memory Impairments in Children With Attention-Deficit/Hyperactivity Disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, 44(4), 377–384. <https://doi.org/10.1097/01.chi.0000153228.72591.73>
- McGough, J. J. (2014). *ADHD*. Oxford University Press.
- Merikanto, I., Kuula, L., Makkonen, T., Halonen, R., Lahti, J., Heinonen, K., Räikkönen, K., & Pesonen, A.-K. (2019). ADHD symptoms are associated with decreased activity of fast sleep spindles and poorer procedural overnight learning during adolescence. *Neurobiology of Learning and Memory*, 157, 106–113.
<https://doi.org/10.1016/j.nlm.2018.12.004>
- Morgan-Short, K., Hamrick, P., & Ullman, M. T. (2022). Declarative and procedural memory as predictors of second language development. In S. Li, P. Hiver, & M. Papi (Eds.), *The Routledge handbook of second language acquisition and individual differences* (pp. 67-81). Routledge. <https://doi.org/10.4324/9781003270546-6>
- Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology*, 19(1), 1-32.
[https://doi.org/10.1016/0010-0285\(87\)90002-8](https://doi.org/10.1016/0010-0285(87)90002-8)

- Oswald, F. L., McAbee, S. T., Redick, T. S., & Hambrick, D. Z. (2015). The development of a short domain-general measure of working memory capacity. *Behavior Research Methods*, 47(4), 1343–1355. <https://doi.org/10.3758/s13428-014-0543-2>
- Prehn-Kristensen, A., Göder, R., Fischer, J., Wilhelm, I., Seeck-Hirschner, M., Aldenhoff, J., & Baving, L. (2011). Reduced sleep-associated consolidation of declarative memory in attention-deficit/hyperactivity disorder. *Sleep Medicine*, 12(7), 672–679. <https://doi.org/10.1016/j.sleep.2010.10.010>
- Prehn-Kristensen, A., Molzow, I., Munz, M., Wilhelm, I., Müller, K., Freytag, D., Wiesner, C. D., & Baving, L. (2011). Sleep restores daytime deficits in procedural memory in children with attention-deficit/hyperactivity disorder. *Research in Developmental Disabilities*, 32(6), 2480–2488. <https://doi.org/10.1016/j.ridd.2011.06.021>
- Ramos, A. A., Hamdan, A. C., & Machado, L. (2020). A meta-analysis on verbal working memory in children and adolescents with ADHD. *The Clinical Neuropsychologist*, 34(5), 873–898. <https://doi.org/10.1080/13854046.2019.1604998>
- Redick, T. S., Broadway, J. M., Meier, M. E., Kuriakose, P. S., Unsworth, N., Kane, M. J., & Engle, R. W. (2012). Measuring Working Memory Capacity With Automated Complex Span Tasks. *European Journal of Psychological Assessment: Official Organ of the European Association of Psychological Assessment*, 28(3), 164–171. <https://doi.org/10.1027/1015-5759/a000123>
- Saito, K. (2017). Effects of Sound, Vocabulary, and Grammar Learning Aptitude on Adult Second Language Speech Attainment in Foreign Language Classrooms. *Language Learning*, 67(3), 665–693. <https://doi.org/10.1111/lang.12244>

- Sanjeevan, T., Cardy, R. E., & Anagnostou, E. (2020). Procedural Sequence Learning in Attention Deficit Hyperactivity Disorder: A Meta-Analysis. *Frontiers in Psychology, 11*, 560064–560064. <https://doi.org/10.3389/fpsyg.2020.560064>
- Sanjeevan, T., Hammill, C., Brian, J., Crosbie, J., Schachar, R., Kelley, E., Liu, X., Nicolson, R., Iaboni, A., Day Fragiadakis, S., Ristic, L., Lerch, J. P., & Anagnostou, E. (2020). Exploring the Neural Structures Underlying the Procedural Memory Network as Predictors of Language Ability in Children and Adolescents with Autism Spectrum Disorder and Attention Deficit Hyperactivity Disorder. *Frontiers in Human Neuroscience, 14*, 587019–587019. <https://doi.org/10.3389/fnhum.2020.587019>
- Schweiger, A., Abramovitch, A., Doniger, G. M., & Simon, E. S. (2007). A clinical construct validity study of a novel computerized battery for the diagnosis of ADHD in young adults. *Journal of Clinical and Experimental Neuropsychology, 29*(1), 100–111. <https://doi.org/10.1080/13803390500519738>
- Silverman, S. B. (2012). *Assessing attention-deficit/hyperactivity disorder in adults: A review of rating scales*. ProQuest Dissertations Publishing. Retrieved from: <https://digitalcommons.pepperdine.edu/etd/251>
- Sindiani, M., Korman, M., & Karni, A. (2022). Time-of-day matters in text learning and recall: Evening lessons are advantageous for adults with ADHD though not for typical peers. *Learning and Instruction, 80*, 101630. <https://doi.org/10.1016/j.learninstruc.2022.101630>
- Shen, W., & Park, H. (2020). Working Memory and Second Language Learning: A Review of the Past Twenty Years' Research in China. *Journal of Pan-Pacific Association of Applied Linguistics, 24*(1), 85–106. <https://doi.org/10.25256/PAAL.24.1.5>

- Skodzik, T., Holling, H., & Pedersen, A. (2017). Long-Term Memory Performance in Adult ADHD: A Meta-Analysis. *Journal of Attention Disorders*, 21(4), 267–283.
<https://doi.org/10.1177/1087054713510561>
- Sparks, R. L., Javorsky, J., & Philips, L. (2005). Comparison of the Performance of College Students Classified as ADHD, LD, and LD/ADHD in Foreign Language Courses. *Language Learning*, 55(1), 151–177. <https://doi.org/10.1111/j.0023-8333.2005.00292.x>
- Sparks, R. L., Javorsky, J., & Philips, L. (2004). College Students Classified with ADHD and the Foreign Language Requirement. *Journal of Learning Disabilities*, 37(2), 169–178.
<https://doi.org/10.1177/00222194040370020701>
- Sparks, R. L., Philips, L., & Javorsky, J. (2003). College Students Classified as Having Learning Disabilities and Attention Deficit Hyperactivity Disorder and the Foreign Language Requirement. *Foreign Language Annals*, 36(3), 325–338.
<https://doi.org/10.1111/j.1944-9720.2003.tb02117.x>
- Squire, L. R. (2004). Memory systems of the brain: a brief history and current perspective. *Neurobiology of Learning and Memory*, 82(3), 171–177.
<https://doi.org/10.1016/j.nlm.2004.06.005>
- Takács Á., Shilon, Y., Janacsek, K., Kóbor, A., Tremblay, A., Németh, D., & Ullman, M. T. (2017). Procedural learning in Tourette syndrome, ADHD, and comorbid Tourette-ADHD: Evidence from a probabilistic sequence learning task. *Brain and Cognition*, 117, 33–40. <https://doi.org/10.1016/j.bandc.2017.06.009>
- Ullman, M. T. (2020). The Declarative/Procedural Model: A Neurobiologically-Motivated Theory of First and Second Language. In B. VanPatten, G. D. Keating, & S. Wulff

(Eds.), *Theories in Second Language Acquisition* (3rd ed., pp. 128-161). Routledge.

<https://doi.org/10.4324/9781003270546-6>

Verster J. C., Bekker, E. M., Kooij, J. J. S., Buitelaar, J. K., Verbaten, M. N., Volkerts, E. R., &

Olivier, B. (2010). Methylphenidate significantly improves declarative memory functioning of adults with ADHD. *Psychopharmacology*, 212(2), 277–281.

<https://doi.org/10.1007/s00213-010-1952-2>

Walker, N., Monaghan, P., Schoetensack, C., & Rebuschat, P. (2020). Distinctions in the Acquisition of Vocabulary and Grammar: An Individual Differences Approach.

Language Learning, 70, 221-254. <https://doi.org/10.1111/lang.12395>

Wen, Z. (2015). Working memory in second language acquisition and processing: The phonological/executive model. In Z. Wen, B. Mailce, & A. McNeill (Eds.), *Working memory in second language acquisition and processing* (pp. 41–62). Multilingual Matters. <https://doi.org/10.21832/9781783093595-007>

Williams, J. N. (2012). Working memory and SLA. In *The Routledge Handbook of Second Language Acquisition* (1st ed., pp. 427–441). Routledge.

<https://doi.org/10.4324/9780203808184-32>

APPENDICES

Appendix A

Studies that focused on the relationship between ADHD and L2 learning

Reference	Participants	Assessment of ADHD	Control group?	L1/L2	Context in which L2 was learned	Measures of L2 Learning	Main finding for ADHD participants	No difficulty in L2 learning?
Sparks, Philips, and Javorsky (2003)	College students from a midwestern university composed mostly of undergraduates	Evaluated by a qualified professional, some were evaluated by a psychiatrist for diagnosis of ADHD	No control group; compared performance of the students with LD vs ADHD/LD (who either petitioned/not petitioned to take a FL course)	L1: NR, L2: NR	Foreign language (FL) classroom	Grades on a foreign language course	Students classified as ADHD/ LD can pass FL courses; MLAT scores are not predictive of L2 performance (ADHD/LD students with low MLAT scores got passing grades in FL courses) Petition students were more likely to receive WF or F grades, nonpetition students were more likely to receive A/B grades	Yes (students with ADHD/LD can pass FL course)
Sparks, Javorsky, and Philips (2005)	Undergraduate college students from a midwestern university	Diagnosed by qualified professionals + got help from the university's Office of Learning Assistance	No control group; compared performance of the students with ADHD vs LD vs ADHD/LD	L1: NR, L2: NR	FL classroom	Grades on a foreign language course	Large number of average and above-average grades; Students classified as ADHD and as LD can pass FL courses	Yes (students with ADHD can pass FL course)
Sparks, Javorsky, and Philips (2004)	College students from a midwestern university composed mostly of undergraduates	Diagnosed by qualified professionals	No control group	L1: NR, L2: Spanish, French, Italian, German, Latin, Russian, Portuguese, Japanese	FL classroom	Grades on a foreign language course	83% of average or higher grades, 10% of below average grades, 2% failing grades; Students classified as ADHD and as LD can pass FL courses; only 32% of students requested instructional accommodations	Yes (students with ADHD/LD can pass FL course)
Leons, Herbert, Gobbo (2009)	Students from Landmark College (a 2-year college for students	Had documented diagnosis	No control group, looking at students with ADHD & LD	L1: NR, L2: Spanish (level 101, 102, 201, 202)	FL classroom	Level of the oral proficiency, measured by the	79.3% of students improved one or more level in proficiency	Yes (students with ADHD can pass FL course)

	with LD and ADHD) who previously had difficulty with academics and probably struggled with FL learning at academic settings		(without dividing into separate groups)			ACTFL Oral Proficiency Interview		
Ferrari and Palladino (2007)	Students from a public junior high school in Italy	Attention and self-regulation control scales completed by teachers (SDAI) and parents (SDAG)	Low achievement (LA) FL learners vs high achievement (HA) FL learners	L1: Italian, L2: English	FL classroom	English Learning Task (battery of FL learning tests): dictation + multiple choice test; Teachers' evaluation based on the FL learning difficulty	Participants classified as LA FL learners had problems controlling their attention (as indicated by teachers and parents). The frequency of their behavior could be indicative of ADHD.	No

Appendix B

List of stimuli from the L2 learning task

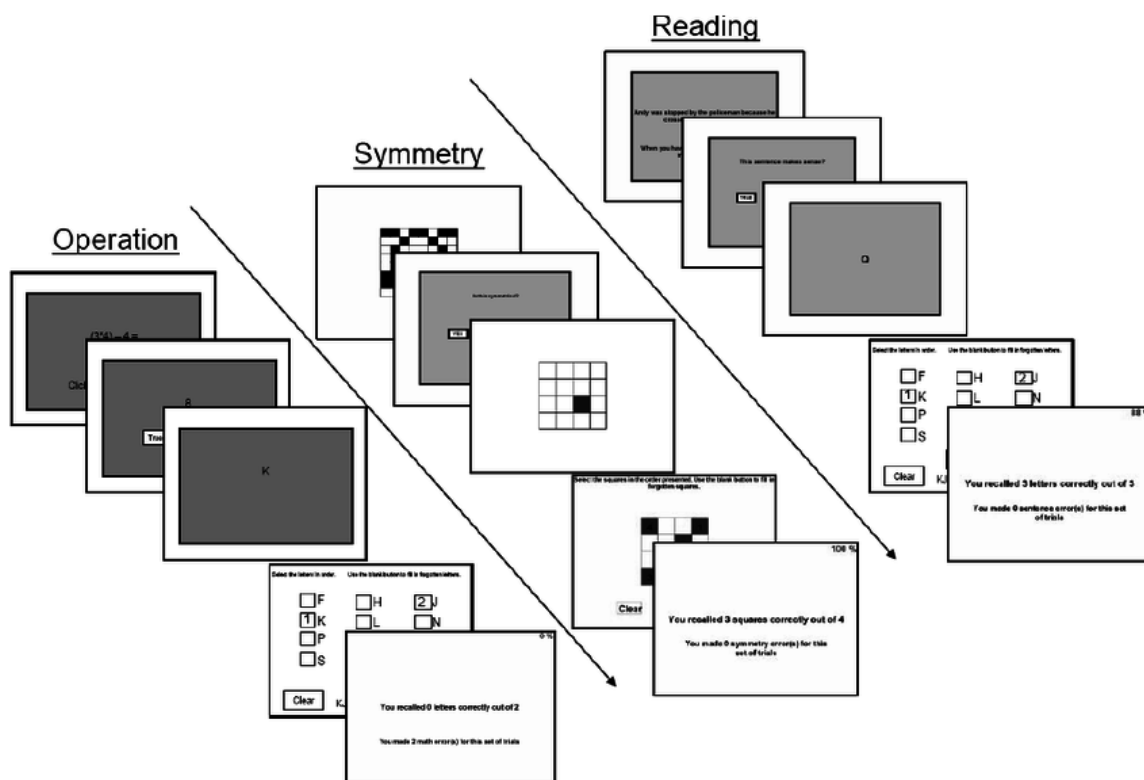
Trained Items							
Singular	Diminutive	Plural	Dim. Plural				Meaning
Vab	Kavab	Vabil	Kavabil				Bear
Tach	Katach	Tachil	Katachil				Bird
Waj	Kawaj	Wajil	Kawajil				Butterfly
Lam	Kalam	Lamil	Kalamil				Cat
Pel	Kapal	Pelel	Kapalel				Chicken
Mez	Kamaz	Mezel	Kamazel				Cow
Bes	Kabas	Besel	Kabasel				Alligator
Fen	Kafan	Fenel	Kafanel				Dolphin
Kit	Kakit	Kitil	Kakitol				Duck
Dig	Kadig	Digil	Kadigil				Elephant
Nik	Kanik	Nikil	Kanikil				Fish
Gif	Kagif	Gifil	Kagifil				Horse

Test Items							
Singular	Diminutive	Plural	Dim. Plural	Dim. Foil	Plural Foil.	Dim. Plural Foil.	Meaning
Shang	Kashang	Shangil	Kashangil	Kashang	Shangel	Kashangel	Anchor
Thad	Kathad	Thadil	Kathadil	Kathad	Thadel	Kathadel	Coat
Pag	Kapag	Pagil	Kapagil	Kapag	Pagel	Kapagel	Dog
Rash	Karash	Rashil	Karashil	Karash	Rashel	Karashel	Elbow
Waf	Kawaf	Wafil	Kawafil	Kawaf	Wafel	Kawafel	Frog
Nav	Kanav	Navil	Kanavil	Kanav	Navel	Kanavel	Glove
Sep	Kasap	Sepel	Kasapel	Kasep	Sepil	Kasapil	Guitar
Ched	Kachad	Chedel	Kachadel	Kached	Chedil	Kachadil	Kangaroo
Zek	Kazak	Zekel	Kazakel	Kazek	Zekil	Kazakil	Sheep
Thep	Kathap	Thepel	Kathapel	Kathep	Thepil	Kathapil	Elk
Yef	Kayaf	Yefel	Kayafel	Kayef	Yefil	Kayafil	Pig
Geth	Kagath	Gethel	Kagathel	Kageth	Gethil	Kagathil	Pigeon
Hik	Kahik	Hikil	Kahikil	Kahak	Hikel	Kahikel	Pillow
Jit	Kajit	Jitil	Kajitil	Kajat	Jitel	Kajitel	Pumpkin
Kij	Kakij	Kijil	Kakijil	Kakaj	Kijel	Kakijel	Rooster
Pish	Kapish	Pishil	Kapishil	Kapash	Pishel	Kapishel	Boat
Tib	Katib	Tibil	Katibil	Katab	Tibel	Katibel	Tiger
Fis	Kafis	Fisil	Kafisil	Kafas	Fisel	Kafisel	Worm

Appendix C

Examples of the Operation-Span, Symmetry-Span, and Reading-Span Tasks

(Redick et al., 2012)



Appendix D

PHQ-9 Questionnaire

PATIENT HEALTH QUESTIONNAIRE-9 (PHQ-9)

Over the <u>last 2 weeks</u> , how often have you been bothered by any of the following problems? (Use "✓" to indicate your answer)	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

FOR OFFICE CODING 0 + + +
=Total Score:

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all Somewhat difficult Very difficult Extremely difficult

Developed by Drs. Robert L. Spitzer, Janet B.W. Williams, Kurt Kroenke and colleagues, with an educational grant from Pfizer Inc. No permission required to reproduce, translate, display or distribute.

Appendix E

TABLE VI

DESCRIPTIVE SCORES ON THE ARTIFICIAL LANGUAGE TASK FOR COMPLEX ANALOGICAL AND SIMPLE AFFIXED FORMS FOR ADHD PARTICIPANTS

L2 Form	<i>M</i>	<i>SD</i>	95% CI	
			LL	UL
All	0.55	0.18	0.49	0.61
Complex	0.44	0.22	0.36	0.51
Simple	0.66	0.13	0.62	0.71

TABLE VII

DESCRIPTIVE SCORES ON THE ARTIFICIAL LANGUAGE TASK FOR COMPLEX ANALOGICAL AND SIMPLE AFFIXED FORMS FOR CONTROL PARTICIPANTS

L2 Form	<i>M</i>	<i>SD</i>	95% CI	
			LL	UL
All	0.53	0.17	0.49	0.57
Complex	0.42	0.19	0.38	0.46
Simple	0.64	0.14	0.60	0.67

Appendix F

TABLE VIII

DESCRIPTIVE SCORES ON THE COGNITIVE TASKS FOR ADHD PARTICIPANTS

Memory	<i>M</i>	<i>SD</i>	95% CI	
			LL	UL
DM Composite (standardized)	0.00	0.80	-0.27	0.27
Declearn	1.50	0.51	1.33	1.67
MLAT	17.11	4.26	15.67	18.55
SRT	0.08	0.08	0.05	0.10
Span Task (standardized)	0.00	0.79	-0.27	0.27
Ospan	25.11	4.55	23.57	26.65
Rspan	23.92	5.35	22.11	25.73
Sspan	16.31	4.77	14.69	17.92
BAARS	46.67	9.97	43.29	50.04
PHQ	10.58	4.87	8.93	12.23

TABLE IX

DESCRIPTIVE SCORES ON THE COGNITIVE TASKS FOR CONTROL PARTICIPANTS

Memory	<i>M</i>	<i>SD</i>	95% CI	
			LL	UL
DM Composite (standardized)	0.00	0.80	-0.18	0.18
Declearn	1.25	0.69	1.10	1.40
MLAT	16.26	5.36	15.07	17.45
SRT	0.09	0.07	0.07	0.10
Span Task (standardized)	0.00	0.83	-0.18	0.18
Ospan	22.35	6.36	20.93	23.77
Rspan	22.02	6.79	20.51	23.54
Sspan	15.45	5.01	14.33	16.57
BAARS	33.20	9.67	31.05	35.35
PHQ	10.14	6.23	8.75	11.52

Appendix G

TABLE X
CORRELATIONS BETWEEN SIMPLE AFFIXED AND COMPLEX ANALOGICAL
SCORES AND COGNITIVE TASKS FOR ADHD PARTICIPANTS

Task	Simple	Complex	SRT	DM	Declearn	MLAT	WM	BAARS
SRT	-0.10	0.20						
DM	0.07	0.00	0.04					
Declearn	0.22	-0.03	0.01	0.80*				
MLAT	-0.10	0.04	0.06	0.80*	0.29			
WM	0.19	-0.08	-0.18	0.69*	0.54*	0.58*		
BAARS	-0.05	0.15	-0.14	0.26	0.13	0.28	0.10	
PHQ	0.01	-0.05	-0.07	0.02	0.08	-0.04	-0.10	0.44*

* $p < .05$

TABLE XI
CORRELATIONS BETWEEN SIMPLE AFFIXED AND COMPLEX ANALOGICAL
SCORES AND COGNITIVE TASKS FOR CONTROL PARTICIPANTS

Task	Simple	Complex	SRT	DM	Declearn	MLAT	WM	BAARS
SRT	0.03	-0.01						
DM	0.17	0.27	0.07					
Declearn	0.11	0.23*	0.08	0.80*				
MLAT	0.15	0.20	0.05	0.80*	0.29*			
WM	0.26*	0.21	0.10	0.34*	0.12	0.42*		
BAARS	0.07	-0.03	0.04	0.07	-0.03	0.14	0.12	
PHQ	0.11	-0.05	0.06	0.16	0.00	0.25*	0.17	0.52*

* $p < .05$

Appendix H

Approval Notice

This research was approved by the University of Illinois Human Subjects Institutional Review Board under protocol 2008-0496-MOD006.

IRB APPROVAL

August 21, 2023

Kara Short
karams@uic.edu

Dear Dr. Kara Short:

On 8/21/2023, the IRB reviewed the following submission:

Type of Review:	Modification / Update
Study Title:	The Cognition of Language Acquisition and Processing
Investigator:	Kara Short
Study ID:	STUDY2008-0496-MOD006
Expedited Review Category(ies):	4,6,7
Funding:	None
IND, IDE, or HDE:	None
Documents Reviewed:	None

The IRB approved the Modification on 8/21/2023.

In conducting this protocol, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

Sincerely,

Office for the Protection of Research Subjects

Office for the Protection of Research Subjects

201 AOB, M/C 682
1737 W. Polk St | Chicago, IL
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VITA

Maryna Ridchenko

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Education

- August 2021 - Present* **Doctoral Program: Cognitive Psychology**
University of Illinois Chicago
Research Assistant at Cognition of Second Language Acquisition Lab
Advisor: Dr. Kara Morgan-Short
- May 2021* **Master of Arts: Teaching English as a Second Language**
Kent State University, Kent, OH
Research Assistant at Language and Cognition Research Laboratory
Advisor: Dr. Phillip Hamrick
Graduate Assistant at the ESL Center
- January 2017* **Master of Arts: Language and Literature (English)**
Minor: German language
Bohdan Khmelnytsky National University of Cherkasy, Ukraine
- May 2015* **Bachelor of Arts: Language and Literature (English)**
Minor: German language
Bohdan Khmelnytsky National University of Cherkasy, Ukraine

Publications

- 2020* Zhang, Y., **Ridchenko, M.**, Hayashi, A., & Hamrick, P. (2021). Episodic memory also predicts higher proficiency second language lexical abilities. *Applied Cognitive Psychology*, 35, 1356-1361.
- 2014* **Ridchenko, M.** (2014). Realization of the concept “friend or foe” in the novel “Shampoo Planet”, written by Douglas Coupland. *Rodzynka-2014*. Cherkasy, Ukraine: Brama.
- 2013* **Ridchenko, M.** (2013). Symbolism and the meaning of numerals in phraseological units, *Eurolanguages-2013: Innovations and Development: Collection of Scientific Students' Abstracts*. Dnipropetrovsk, Ukraine: Litograf.

Presentations

- 2024* Hernandez, V., **Ridchenko, M.**, Morgan-Short, K. (scheduled for August 2024). *The Relationship Between Loneliness and Working Memory among Neurotypical Adults & Adults with ADHD* [Poster presentation]. American Psychological Association 2024 Annual Convention, Seattle, Washington
- 2024* **Ridchenko, M.**, Hernandez, V., Morgan-Short, K. (scheduled for August 2024). *Second Language Learning & Memory Systems in Neurotypical Adults and Adults*

- with *ADHD* [Poster presentation]. American Psychological Association 2024 Annual Convention, Seattle, Washington
- 2024 Hernandez, V., **Ridchenko, M.**, Morgan-Short, K. (scheduled for April 2024). *The Relationship Between Working Memory and Loneliness Among College Students*. The 96th Annual Meeting of the Midwestern Psychological Association, Chicago, Illinois
- 2024 Rodriguez, A., Berles, A., **Ridchenko, M.**, Morgan-Short, K. (2024). Working memory and proficiency in adult second language neurocognitive processing: An ERP study. The 2024 Cognitive Neuroscience Society Annual meeting, Toronto, Canada
- 2023 **Ridchenko, M.**, Hernandez, V., Morgan-Short, K. (2023). *Second Language Learning with ADHD: The Role of Memory Systems*. [Poster presentation]. Psychonomic Society 64th Annual Meeting, San Francisco, California
- 2023 Berles, A., **Ridchenko, M.**, Buffington J., Morgan-Short, K. (2023). *Individual differences in adult Romance-like language learning and working memory in implicit and explicit contexts*. Hispanic Linguistics Symposium 2023, Provo, Utah
- 2023 Berles, A., **Ridchenko, M.**, Buffington J., Morgan-Short, K. (2023). *Individual Differences in Cognitive Control and Adult Language Learning*. The American Association for Applied Linguistics 2023 Conference, Portland, Oregon
- 2022 **Ridchenko, M.**, Berles, A., Buffington J., Morgan-Short, K. (2022). *Does Learning Context Modulate the Roles of Long-Term Memory in Adult Second Language Learning?* [Poster presentation]. Psychonomic Society 63st Annual Meeting, Boston, Massachusetts
- 2021 **Ridchenko, M.**, Corpening, K. (2021). *Exploring the connection between second language acquisition and personality*. The Graduate Student Association of Applied Linguistics, Northern Arizona University, Virtual Conference
- 2021 Corpening, K., **Ridchenko, M.** (2021). *Exploring the connection between second language acquisition and personality*. TESOL 2021, Virtual Graduate Student Research Forum
- 2021 Hayashi, A., **Ridchenko, M.**, Zhang, Y., & Hamrick. (2021). *Individual differences in episodic memory also influence higher level L2 lexical abilities*. American Association of Applied Linguistics, Virtual Conference
- 2020 Zhang, Y., **Ridchenko, M.**, Maiga, I., Lamb, M., Hayashi, A., Corpening, K., & Hamrick, P. (2020). *Individual differences in episodic memory abilities compensate for age effects in L2 lexical access*. Second Language Research Forum, Nashville, Tennessee, USA

Teaching Experience

September 2021 - Present **Graduate Teaching Assistant, University of Illinois at Chicago, IL**

Courses:

PSCH 242 (Intro to Research in Psychology);

PSCH 262 (Behavioral Neuroscience);

PSCH 366 (Cognitive Neuroscience);
 PSCH 367 (Laboratory in Cognitive Neuroscience);
 PSCH 353 (Laboratory in Cognition and Memory)

2020 - May
2021 **College Writing I Instructor, Kent State University, Kent, OH**

2019 - May
2021 **ESL Center Instructor, Kent State University, Kent, OH**

2021 **Graduate Teaching Assistant, Kent State University, Kent, OH**
Course:
 ENG 31003 (Linguistics)

2013 - 2018 **Individual Tutor of English and German, Cherkasy, Ukraine**

2016 **Teacher of English for children** at the courses held at Bohdan Khmelnytsky National University of Cherkasy, Ukraine

Mentoring Experience

Spring 2022 Erin Weller - undergraduate research assistant

Fall 2022 - Tay McDonald - undergraduate research assistant

Spring 2023 Poster presentation at the Undergraduate Research Forum 2023, UIC: *Examining the Relationship Between Individual Differences in Declarative Memory and Second Language Vocabulary Learning*
 Recipient: Chancellor's Undergraduate Research Award

Fall 2022 - Jessica Sakalas - undergraduate research assistant
 Present Poster presentation at the Undergraduate Research Forum 2024 (scheduled for April 2024), UIC: *ADHD Symptomatology Severity Impact on Implicit and Explicit Language Acquisition*
 UIC Honors College Capstone Project

Spring 2023 - Victor Hernandez - undergraduate research assistant, postbac research assistant
 Present Recipient: Chancellor's Undergraduate Research Award

Fall 2023 - Yael Lenga - undergraduate research assistant
 Present Poster presentation at the Undergraduate Research Forum 2024 (scheduled for April 2024), UIC: *Learning Languages with Attention Deficit Hyperactivity Disorder: The Role of Feedback*
 UIC Honors College Capstone Project

Fall 2023 - Morgan Chinski - undergraduate research assistant
 Present Poster presentation at the Undergraduate Research Forum 2024 (scheduled for April 2024), UIC: *Effects of Sex and Declarative Memory on L2 Vocabulary Learning*

Fall 2023 - Aarya Labade - undergraduate research assistant
 Present Poster presentation at the Undergraduate Research Forum 2024 (scheduled for April 2024), UIC: *Effects of Sex and Declarative Memory on L2 Vocabulary Learning*