

**IMPLICIT MEMORY IN YOUNG ADULTS WITH ADHD:
DOES IT INCLUDE A CONCEPTUAL PRIMING DEFICIT?**

A Senior Scholars Thesis

by

STEPHANIE REBECCA MURPHY

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2009

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Approved by:

Research Advisor:
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ABSTRACT

Implicit Memory in Young Adults with ADHD:
Does It Include a Conceptual Priming Deficit? (April 2009)

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This experiment explored the distinction between two implicit memory test paradigms: identification versus production processes and conceptual versus perceptual processes. These dimensions were crossed to produce four different types of implicit tests, consistent with current literature, in which each test differentially consisted of two of the four processes. The tests were then administered across two divergent subject populations of young adults: ADHD and non-ADHD. Participants studied semantic properties of words, performed a filler section to divert attention from the studied words, and then performed four memory tests to assess long term, implicit memory. There were no statistically significant differences in performance between subject populations for any of the tests. Participants with ADHD performed equally well compared to their non-ADHD peers. These results are inconsistent with other research suggesting that children with ADHD have reduced priming with conceptual-based tests. However, participants with ADHD that had more severe symptoms exhibited reduced priming in conceptual

tasks compared to other less symptomatic participants with ADHD, yet showed more priming in perceptual driven tasks.

ACKNOWLEDGMENTS

First and foremost, I would like to thank Dr. Terry Barnhardt. Your constant help and guidance pushed me to work harder and learn more than I ever imagined I would. No matter how complex my questions, or at times how irrelevant, you always patiently and enthusiastically enhanced my learning in any way that you could. Thank you for giving me the chance to work with you. It was a truly rewarding experience.

I would also like to thank my husband, Jesse, for putting up with my endless cognitive “lessons.” By now, you probably know enough to write a thesis all on your own. Thank you for your support during those weeks when I couldn’t have been busier. You made my life much easier.

Finally, I would like to thank my parents, Shirley and Kenneth, my aunt Carol, and my new mother, Cindy. You made the best support system I could have had. Thank you for being there for me, and believing in me.

NOMENCLATURE

AD	Alzheimer's Disease
ADHD	Attention Deficit Hyperactive Disorder
CAARS	Conners' Adult ADHD Rating Scales
CG	Category Generation
CPT	Continuous Performance Test
CV	Category Verification
LOP	Level of Processing
PAS	Personality Assessment Screener
PID	Perceptual Identification
RT	Response Time
SC	Stem Completion

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CHAPTER I

INTRODUCTION

Common vernacular implies that memory entails conscious retrieval, and that the person remembering is aware of the memory and its representation of something in the past.

However, studies in the last few decades show that long-term memory consists not only of explicitly retrieved information, but also memory in which conscious awareness is not necessary. These two forms of memory are distinguished by the terms *implicit memory* - when performance is facilitated in a task with absence of the participants' awareness of retrieval-- and *explicit memory*, when a task requires conscious recollection (Graf & Schacter, 1985).

In explicit memory tests, such as free recall, cued recall, and recognition, participants are instructed to deliberately recall information presented in an earlier study phase (Vaidya, Gabrieli, Keane, Monti, Gutierrez-Rivas, & Zarella, 1997). In contrast, participants are not told to consciously retrieve old material in implicit memory tests, yet prior exposure to stimuli still affects performance. This influence of past experience on current behavior, such as a change in speed or accuracy relative to a baseline condition, is referred to as repetition priming (Schacter, 1987).

This thesis follows the style of *Journal of Experimental Psychology: Learning, Memory, and Cognition*.

In priming tests, participants are exposed to stimuli in a study phase, and are then exposed at test to new, additional stimuli as well as some of the previously encountered stimuli (Roediger, 1990). Priming is then calculated as the difference between performance on the studied versus unstudied stimuli, where the effect is a facilitation on performing with the previously studied words (Fleischman & Gabrieli, 1998). Researchers commonly use repetition priming tests (e.g., stem completion, fragment completion, anagram solution) to assess implicit memory (Rajaram & Roediger, 1993). A multitude of experiments demonstrate the dissociation of explicit and implicit forms of memory. In these studies, a variety of experimental manipulations produce disparate performance on explicit and implicit memory tests (Schacter, Bowers, & Booker, 1989).

For example, Jacoby (1983) found that in an explicit test (i.e., recognition test), generated items at study are better recognized at test than those that were simply read, reiterating a generation effect found in earlier research. The results also revealed a higher performance for the read stimuli that had been studied in context. However, in an implicit test (i.e., perceptual identification), performance was higher for read words, thus dissociating implicit and explicit memory so completely that the effects were reversed across the two tests.

Often studies explore divergent human populations, by comparing those with some deficit to those with normal functioning in attempts to further dissociate types of

memory. In this way, much of the interest in implicit memory stems from research on amnesic patients. Amnesic populations perform similarly to normal populations on implicit memory tests, such as word fragment identification and word stem completion, showing no deficit in priming effects in relation to non-amnesic participants. However, amnesic populations showed impaired performance on explicit tests such as free recall and recognition (Warrington & Weiskrantz, 1970). Beyond the original studies of Warrington and Weiskrantz (1970), the retention of implicit memory in amnesics has been observed across multiple types of implicit memory tasks as well as across different amnesic populations (Cermak, Talbot, Chandler, & Wolbarst, 1985; Glass & Butters, 1985; Graf & Schacter, 1985; Shimamura, 1986).

Similarly, elderly populations show a deficit in explicit memory, but have no impairments on implicit memory tests relative to young healthy adults (Fleischman & Gabrieli, 1998). In fact, elderly populations have shown deficits in free recall, cued recall, and recognition tests, yet show intact priming effects in perceptual identification and word-stem completion tests compared to baseline populations (Light & Singh, 1987). Therefore, implicit tasks appear to underlie a separate form of memory than explicit tasks.

Perceptual-conceptual distinction

Earlier cognitive researchers argued that implicit memory was purely data-driven. That is, implicit memory was thought to rely on perceptual information as compared to

explicit memory that was thought to rely only on conceptual information, or stimulus meaning (Jacoby, 1983; Roediger, 1990). However, more recent studies show that implicit memory consists of two subtypes of processes, perceptual and conceptual (Blaxton, 1989).

Perceptual priming relies on perceptual information (e.g., auditory and visual) and is affected by changes in perceptual information; whereas, conceptual priming relies on stimulus meaning (i.e., semantic attributes) and is affected by changes in conceptual information. By manipulating perceptual relations of stimuli between study and test phases (e.g. study-test change) as well as conceptual elaboration (e.g. deep and shallow studied words), a dissociation of perceptual and conceptual forms of implicit memory can be observed. For instance, on pictorial tests, perceptual priming is reduced when picture *titles* are studied versus the pictures themselves (Srinivas, 1993). Also, perceptual priming is modality specific in that priming will diminish if the method of study does not match the method of test (e.g., visually presented at study, aurally presented at test); (Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995). However, perceptual priming is unaffected by the level of conceptual elaboration of stimuli at study (Weldon, 1991). Conversely, conceptual priming is not affected by changes in surface information or study-test modality shifts, but does show a levels-of-processing effect (Mulligan, Guyer, and Beland, 1999).

Identification-production distinction

Populations with Alzheimer's Disease (AD) show impaired explicit memory yet intact perceptual priming, much like amnesic populations. However, their conceptual test performance exhibits reduced priming (Monti, Gabrieli, Reminger, Rinaldi, & Wilson, 1996; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991). AD subjects also show additional deficits with word-stem completion priming (Bondi & Kaszniak, 1991). This deficit cannot be explained by either the explicit or conceptual deficits typically seen in AD subjects, because word-stem completion is a perceptual implicit test. It does not rely on explicit retrieval, and it is not affected by conceptual manipulations (Gabrieli, Vaidya, Stone, Francis, and Thompson-Schill, 1999).

AD patients have additionally demonstrated impaired word-stem completion priming while retaining intact word-identification priming (Keane et al., 1991). Both of these tasks rely on perceptual implicit processes. Therefore, the dissociation cannot be attributed to an explicit-implicit distinction, because both of the tasks are implicit. Moreover, the disparate performance cannot be attributed to a perceptual-conceptual distinction either because both tasks rely on perceptual processes.

Gabrieli, Keane, Stanger, Kjelgaard, and Corkin (1994) proposed a distinction between identification and production tasks which could account for the varied perceptual priming results in AD. In identification tasks, such as lexical decision, perceptual identification, or word fragment completion, participants engage in a search process

where there is only one correct answer. The stimuli may be presented normally or in degraded form where it may be very briefly flashed (e.g., flashing words task) or partially shown (e.g., fragment completion task); (Gabrieli et al., 1999). This identification of a cue depends on the stimulus matching an entry in our lexicon (i.e., our mental dictionary). On these tasks, the response is then correct if the subject responds with the cue rather than not responding at all, since there is only one possible solution (Barnhardt, 2005).

In contrast, producing the correct answer in a production task does not depend on identifying the cue in terms of a single lexical entry. Instead, the outcome, if using the cue to search lexical memory, is to yield many possible solutions (Gabrieli et al., 1999). Because the lexical match produces a large number of alternatives, a second competitive process follows resulting in the generation of a single answer (Barnhardt, 2005).

AD patients show impaired performance on production tasks such as word stem completion and category exemplar generation tasks (Carlesimo, Fadda, Marfia, and Caltagirone, 1995; Monti et al., 1996), yet maintain normal performance on identification tasks such as word or picture naming and lexical decision (Sullivan et al., 1995; Balota & Ferraro, 1996). Therefore, AD patients exhibit impaired production abilities, with spared identification abilities.

In addition to AD studies, experiments manipulating attention demands have provided evidence for the dissociation of identification and production tasks. Gabrieli et al. (1999) found that dividing a participant's attention at study affected a word stem completion task (i.e., a production task) but not a picture naming task (i.e. an identification task). This need for attention during production tasks may be due to the increased competition involved in the task.

Researchers have shown that an increase in competition within production tasks increases left frontal cortex activation (Thompson-Shill, D'Esposito, Aguirre, & Farah, 1997; Desmond, Gabrieli, & Glover, 1998). This supplements the earlier findings of Winocur, Moscovitch, and Stuss (1996) that found aging, when accompanied by frontal lobe impairment, resulted in impaired production performance relative to identification tasks. So, production tasks seem to be mediated by some frontal lobe activity, and damage to the frontal lobes impairs abilities on production tasks. Attention Deficit Hyperactivity Disorder (ADHD) is also often associated with frontal lobe deficits (e.g., Vaidya et al., 1999). These frontal lobe impairments may produce a deficit in production processes.

Present study

The goal of the present study is to further our basic knowledge of implicit memory with regard to the conceptual, perceptual, identification, and production subtypes. Burden and Mitchell (2005) found that the priming performance of children with ADHD, in

comparison to non-ADHD children, was impaired on a conceptual implicit memory test, yet spared on a perceptual implicit memory test. However, in using these types of tests, the perceptual-conceptual and identification-production subtypes of implicit memory were confounded. That is, Burden and Mitchell used a conceptual test, in which each test cue had many possible solutions, and a perceptual test with only a single solution. Thus, even though Burden and Mitchell attributed their result to conceptual priming deficit, it could just as easily been attributed to a production priming deficit.

Vaidya et al. (1997) have provided evidence that these two dimensions of implicit memory (i.e., perceptual vs. conceptual and identification vs. production) can be crossed to produce four different types of implicit tests (i.e., perceptual identification, conceptual identification, perceptual production, and conceptual production). Figure 1 displays these four types of tests. To better illustrate the existing confound, the red 'x' marks indicate the types of tests used by Burden and Mitchell. By examining the results of these four specific tests with ADHD and non-ADHD subjects, we effectively remove the confound as well as provide further understanding of the deficits in ADHD.

	Identification	Production
Perceptual	x Perceptual- Identification	Perceptual- Production
Conceptual	Conceptual- Identification	x Conceptual- Production

Figure 1. Classification of implicit memory tests according to the two orthogonal dimensions: identification-production and conceptual-perceptual

Our hypothesis was that the deficit observed by Burden and Mitchell could be attributed to a deficit in production, rather than conceptual processes, as this is one logical explanation for their pattern of results. If this were the case, ADHD participants should show a deficit in production tests regardless of whether those tests are conceptual or perceptual while at the same time displaying normal performance on conceptual identification and perceptual identification tests. However, if Burden and Mitchell are correct that people with ADHD have a conceptual priming deficit, then these participants should show a deficit in both conceptual tests, regardless of whether those tests are identification or production, while at the same time exhibiting normal performance on perceptual tests.

CHAPTER II

METHOD

Design

The design of the experiment included one between-subjects variable (ADHD vs non-ADHD groups) and two within-subjects variables (conceptual vs perceptual and identification vs production tests). The two test-type distinctions were crossed to produce four types of tests: perceptual-identification (i.e., flashing words test), conceptual-identification (i.e., category verification), perceptual-production (i.e., word stem completion), and conceptual-production (i.e., category generation).

The primary dependent variable was accuracy priming. In order to calculate an accuracy priming score for the stem completion test, for example, the proportion of correct target words said to baseline (unstudied) stems was subtracted from the proportion of correct target words said to stems of studied words. Response time priming in the category verification task will also be reported.

Participants

A total of 44 participants were tested. Eighteen of the participants were males (41 %), and twenty-six were females (59 %). Participants were introductory psychology students who received research credit that was required for course completion. All participants

were selected on the basis of their performance on a prescreening measure (i.e., the Conners' Adult ADHD Rating Scales; CAARS) that was adapted for online completion.

The CAARS provides numerous survey forms to choose from, depending on the context and situation of the analysis. The self report screening version (S:SV) served as the prescreening for this experiment, and it consists of three 10-item subscales of ADHD symptoms: inattentiveness, hyperactivity/ impulsiveness, and total symptoms. All items were created based on the DSM-IV criteria for ADHD diagnosis, and presented as questions on a four-point likert scale ranging from 0, not at all [like me], to 3, very much [like me]. Higher scores indicated more severe ADHD symptoms. Additional items were added to the pre-screening for our own knowledge and inquired information about personal experience with ADHD diagnosis. For example, one item questioned if the participant had ever been diagnosed with ADHD. The additional questions can be viewed in Appendix A. These questions were placed after the self report form and were not viewable before the CAARS form had been completed.

Scores on the total ADHD subscale, for all participating in the prescreening, were converted into a standardized score, a T-score, which accounted for age or gender differences typically found in ADHD. The cut-off for inclusion in the ADHD group was set at a T-score minimum of 66. According to the CAARS manual, an individual with this score would be considered "much above average," or at least in the 95th percentile for their own age and gender. The cut-off for inclusion in the non-ADHD group was set

at a T-score under 44, indicating a below average score, or that the individual fell lower than the 27th percentile for their own age and gender suggesting their lack of ADHD symptoms.

Materials

144 words served as the critical stimuli. No two stimuli shared word stems, so there were no repetition of word beginnings for any of the stimuli. There was also no overlap in categories. That is, a particular target word was a match only for its corresponding category and was not a match for any of the other 143 categories. For any particular participant, 72 of the items were studied, and the other 72 were unstudied. This was counterbalanced across participants. The studied and unstudied words were then distributed across the four tests so that each task had 18 studied critical items, and 18 unstudied critical items. For the category verification test, the items were further split into 9 matching items (e.g., the target word matched the category with which it was displayed) and 9 non-matching items (e.g., the target word did not match the category with which it was displayed). This was also counterbalanced across participants.

One of the unique features of this experiment was that all the critical stimuli rotated through each of the different tests. In most experiments that compare performance across a number of different types of implicit memory tests, (e.g., Geraci, 2006), each task would employ a different set of stimuli. Obviously, in such instances, it is impossible to know whether dissimilar patterns of performance in the different tests were due to the

nature of the tests or the nature of the stimuli. In order to obtain our 144 unique category-exemplar pairs, 51 of them were derived from Battig and Montague (1969). The target exemplars were chosen so that they made up no more than two-fifths of the first responses within the category. That is, if more than two-fifths of the participants generated a particular exemplar first for a category label, that word would not be used as a target word. To ensure that the target exemplar was suited for the category label, selected exemplars must have composed at least one-twentieth of the total responses. 97 additional category-word pairs were created and distributed to two classes of students. Normative data was collected for 30 students. The remaining 93 stimuli were chosen from this data based on the same criteria as that which was applied to the categories from Battig and Montague (1969).

In addition, there were other criteria that had to be met for the other tasks. For example, all stimuli had three letter word beginnings, stems, in which at least 10 other words besides the target also began with that stem to ensure that enough competition existed for the production tasks. Longer targets (i.e., greater than 8 characters) are easier to identify than shorter targets in the flashing words task and were therefore avoided.

Procedure

Stimuli were presented on a Windows computer, and responses were collected via the keyboard for all phases of the experiment except the category generation, perceptual identification, and stem completion tests. In these tasks, a tape recorder was used to

collect oral responses for later transcription and scoring. The stimulus presentation routines were constructed using E-Prime.

Participants were tested individually in 35 minute sessions which included 6 phases: titration, study, filler, stem completion (SC), category verification (CV), perceptual identification (PID), and category generation (CG). Two task orders were used: SC, V, PID, and CG, or V, SC, CG, and PID. These orders were used to minimize priming from one test to another. All critical words were unique, so critical word responses in one task could not act as a priming episode for later task performance. However, because all of the test tasks other than category verification are relatively open-ended, it would be possible that non-critical responses could affect, or prime, later responses. For instance, in the stem completion task, a participant could give a non-critical response, “bracelet,” to the stem, “bra.” This response could then be used later in the category generation task with the category, “a type of jewelry”.

In deciding upon the order of our tasks, it was reasoned that the less open-ended tasks should be presented first, in order to minimize the possibility of priming across tests. In the category verification test, participants make a yes-no (match-nonmatch) decision and hence are not producing any oral responses. Thus, because the CV test is a closed task, and as a result cannot produce test priming in our experimental procedure, it was obvious that it should occur early in the test order. The stem completion test, although very open-ended relative to CV, is less open-ended than either category generation or

perceptual identification. That's because, in either CG or PID, it is possible for a participant to respond with a critical target word on a trial in which that response counts as a non-target response. For example, let's say, for a particular participant, that "bread" is a critical target word for the category generation test. However, in the preceding PID test, the participant misperceives the cue "thread" and responds with "bread". Although "bread" counts as a non-target response for purposes of scoring PID performance, clearly the production of "bread" in that task creates the possibility of test priming in the ensuing CG test. The same holds true when category generation precedes PID. However, it is almost impossible that this scenario would occur when stem completion was the preceding test. This is because the stems for all of the critical target words in this experiment were unique. For example, it is highly unlikely that a participant would, when presented the cue "thr" for the target word "thread", respond with another target word like "bread." Thus, although it is still possible that a participant in the stem completion test could get the cue "thr" and respond with "throat" (a non-target response that could be generated in the CG task to the category "body parts"), the fact that no alternative critical target responses can be made means that the stem completion test is the least open-ended of the three remaining tests.

Titration

Before the study phase, each participant performed a pretest composed of 2 sets of perceptual identification trials for the purpose of placing each individual into an appropriate exposure duration tier. The computer monitor used to display the

experimental tasks, had a refresh cycle of 10 ms (100 Hz refresh rate). Three exposure durations were used: 20 ms, 30 ms, and 40 ms. Ideally, each participant was placed into the exposure duration tier in which 30% to 50% of their responses were correct. This was done in order to avoid floor or ceiling effects for the perceptual identification task presented later in the experiment. Participants were encouraged to guess as much as possible, even when not confident in their responses.

The perceptual identification titration trials began with a beep, followed by a mask of nine pound characters, 24 point font, presented for 600 ms. A word was then flashed briefly, at one of the three exposure durations, immediately after the mask but at a smaller font size (18 point). The smaller size for the stimuli was used so that the mask would cover any ascending or descending letter components in the word, as would be the case for the letters “h” or “y.” Immediately following the presentation of the word, a second mask was displayed for 600 ms, followed by a 900 ms blank screen. This was repeated with each target word through the entire trial. The responses were then checked by the experimenter and used to place the individual in the correct exposure duration tier for the actual perceptual identification test that would occur later in the experiment.

Study

The study phase consisted of judging the pleasantness of the meaning of words that were presented one at a time. Each trial began with a beep followed by a word presented on the screen for 1500 ms, after which the word self-terminated. During this time, the

participant would press “L” if they thought the word was pleasant, or “D” otherwise, indicating unpleasantness or neutrality. For example, the word “mustard,” would appear on the screen for 1500 ms, during which the participant might press “D” showing a dislike for mustard. This repeated through each stimulus for a total of 72 trials.

Filler

In order to distract participants from the previously studied words, thus ensuring that long-term memory as opposed to short-term memory was being assessed in the test phases, a filler phase lasting 10 minutes was included between study and test. In the first filler task, participants were asked to complete fragments of the names of famous people (e.g. C_in_Ea_tw__d). In the second task, they were to complete fragments of geographical entities (e.g., W__hi_gt_n).

Category verification

In the category verification task, participants determined whether a word was an exemplar of a particular category by pressing the “L” key on the keyboard if it was, and “D” if it was not. For example, if the word “apple” was presented with the category label, “a fruit,” the participant would be expected to press the “L” key, indicating that the word displayed was an exemplar of that category.

Each trial began with a beep followed by a 150 ms blank screen. The target stimulus was presented above the category label, and both were displayed at the same time for 1500

ms, or until the display was terminated upon the participant's keyboard response. A 250 ms blank screen ended each trial. The 1500 ms deadline insured a relatively low accuracy rate for this task. Thus, although response time was also recorded, it was intended that accuracy would serve as the main dependent variable for the CV test. There were 44 trials: 18 studied (9 matching and 9 non-matching), 18 baseline (9 matching and 9 non-matching), and 8 filler items presented at the beginning of the test (4 matching and 4 non-matching).

Stem completion

In this task, participants completed a series of word heads, strings of three letters that begin words. They were instructed to say the first word that came to mind. For instance, if the target presented on the screen was "tel," the participant should have completed the word with the first response they could think of that starts with "tel", such as the word "telephone."

Each trial began with a beep lasting 25 milliseconds, and was followed by a 150 ms blank screen. Then, the word head was displayed for 1250 ms, which was followed by a 250 ms blank screen. This was repeated for all trials, resulting in 44 displayed word heads (18 studied, 18 baseline, and 8 filler heads presented at the beginning of the task).

Category generation

In the category generation task, participants were instructed to generate one exemplar for each category label presented. For example, the category “a fruit” would be presented, and the participant might respond with “apple.” The trial began with a beep followed by a 100 ms blank screen. Each category, consisting of a short phrase, was then displayed and self-terminated after 1250 ms, followed by another blank screen lasting 250 ms. This was repeated for 42 critical stimuli, corresponding to 18 studied words, 18 baseline words, and 6 filler items presented at the beginning of the task.

Perceptual identification

The titration task before the study phase placed each participant in one of the exposure duration tiers. The procedure for each PID test trial was the same as during the titration phase except that all the words were presented at that single exposure duration. The participants were instructed to verbally indicate the word that was displayed and these responses were recorded for later transcription and scoring. There were 44 trials consisting of 18 studied words, 18 baseline words, and 8 filler items presented at the beginning of the task.

Questionnaire

An awareness questionnaire was given at the end of the experiment to determine how aware the participants were that they were performing memory tests. Participants were asked 8 questions regarding the “pleasantness words.” The questions progressed from

assessing lower levels of awareness to asking questions about intentional use of studied, or “pleasantness” words. For instance, the first question asks, “What do you think was the purpose of these tasks?” Yet, the last question asks, “If you noticed that you were saying pleasantness words in any of the last four tasks, did you become aware of this while you were responding with a particular word? If so, what was that word?” The complete questionnaire can be found in Appendix B.

CHAPTER III

RESULTS

For all statistical tests, the significance level was set at $p < .05$. Priming was examined as a function of test type, ADHD symptoms (as reported on the CAARS), and awareness. For all tests, accuracy was the main variable of interest, but response time for correct responses was also considered in the category verification task.

Of the 900 candidates who completed the CAARS prescreening, 24% of the males qualified for the ADHD group, compared to only 12% of the females. Furthermore, 27% of females and 19% of males qualified for the non-ADHD group. This is consistent with the notion that ADHD is more common among males (Gershon, 2002).

All 44 participants were included when analyzing results from the stem completion and category generation tests. However, in order to avoid floor and ceiling effects in the PID test, participant's results were not included in the analysis if they scored higher than 80% correct or lower than 20% correct. Using this criterion, 13 participants were excluded when analyzing the perceptual identification test.

Likewise, participants included in the accuracy priming analysis for the category verification test were required to score between 20% and 80% correct. Furthermore, when analyzing response time, only subjects that had 3 or more correct responses in each

of the four cells created by crossing studied vs. baseline and matching vs. non-matching were included (i.e., matching/studied, non-matching/studied items, matching/baseline, and non-matching/baseline). Response time was considered only for correct responses, whether those responses were for yes or no trials (i.e., matching target and category, non-matching target and category).

As indicated in Table 1, there was little difference between ADHD and non-ADHD populations in priming scores for any of the tests. None of the group differences were statistically significant. Although a conceptual or production deficit in the ADHD group was expected, this group did not show reduced priming in either dimension. This may have been due to the low numbers of participants. In fact, the ADHD group showed numerically higher priming scores in both the stem completion and the category generation tasks, compared to the non-ADHD group. Finally, the absence of both accuracy priming and RT priming in the category verification test made it difficult to make a full assessment of the potential differences between our ADHD and non-ADHD populations.

TABLE 1
Priming performance in accuracy as a function of population

<i>Population</i>	<i>SC</i>			<i>CV</i>			<i>PID</i>			<i>CG</i>		
	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>
ADHD	.126	.086	23	.022	.137	18	.118	.219	16	.065	.116	23
Non-ADHD	.082	.129	21	-.003	.135	17	.185	.175	15	.021	.107	21

Degree of symptoms

The data was also examined as a function of the severity of symptoms within the ADHD group. Within the ADHD group, subjects were categorized into a high ADHD group if their score for total ADHD symptoms on the CAARS prescreening placed them in the 99th percentile or higher for their age and gender (i.e., a score of 32 for total ADHD symptoms).

Of the 23 ADHD participants, 12 met the criteria for the high ADHD group and were compared to the 11 other less symptomatic ADHD subjects, who composed the low ADHD group. Taking into account eliminated subjects, 10 high ADHD subjects and 6 low ADHD subjects were analyzed in the PID test, while 10 high ADHD subjects and 8 low ADHD subjects were analyzed in the category verification test. As indicated in table 2, highly symptomatic individuals exhibited reduced priming in conceptual tasks, while showing more priming in perceptual driven tasks, compared to other less symptomatic participants with ADHD. For instance, in the perceptual identification task, for the high

ADHD group, $M = .16$ ($SD = .23$) and for the low ADHD group, $M = .06$ ($SD = .21$). In the stem completion test, for the high ADHD group, $M = .16$ ($SD = .05$) and for the low ADHD group, $M = .09$ ($SD = .10$). However, the low ADHD group showed more accuracy priming in both conceptual tests: category verification and category generation. For instance, in the category verification test, for the low ADHD group, $M = .06$ ($SD = .14$) and for the high ADHD group, $M = -.01$ ($SD = .14$). In the category generation test, for the low ADHD group, $M = .10$ ($SD = .13$) and for the high ADHD group, $M = .04$ ($SD = .10$). A repeated measures ANOVA indicated a statistically significant interaction between the high and low groups and the perceptual and conceptual tests, $F(1,2) = 8.17$, $MSE = .024$.

TABLE 2
Priming performance in accuracy as a function of
symptom severity within the ADHD group

<i>Population</i>	<i>SC</i>			<i>CV</i>			<i>PID</i>			<i>CG</i>		
	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>
High ADHD	.157	.052	12	-.006	.137	10	.156	.227	10	.037	.099	12
Low ADHD	.091	.103	11	.056	.140	8	.056	.211	6	.096	.129	11

Awareness

Results from the awareness questionnaire were used to quantify participants into three groups: unaware, aware, and intentionally retrieving. Subjects were placed in the unaware category if they said they did not recognize a relationship between studied words and words they responded with (or, in the case of category verification, were presented with) during the memory tests. Subjects were considered aware if they recognized that studied items were being represented later in the experiment in any of the four tests. Subjects were considered intentionally retrieving if they reported actively trying to use studied items as responses in any of the tests. Most commonly, subjects that were aware or intentionally retrieving recognized the relationship with the perceptual identification test, which was always presented as one of the last two tests.

Overall, there was no statistically significant patterns of results as a function of awareness (see Table 3). However, at least numerically, priming in every test did increase across the unaware and aware categories. For example, in the perceptual identification test, there was a large increase in priming from unaware subjects, $M = .068$ ($SD = .087$), to aware subjects, $M = .196$ ($SD = .214$).

TABLE 3
Priming performance in accuracy as a function of awareness

<i>Awareness</i>	<i>SC</i>			<i>CV</i>			<i>PID</i>			<i>CG</i>		
	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>
Unaware	.02	.167	13	-.01	.149	10	.03	.108	9	.00	.083	13
Aware	.02	.155	25	-.02	.101	20	.16	.242	17	.02	.138	25
Intentionally Retrieving	.06	.099	6	-.06	.168	5	.14	.218	5	.02	.130	6

CHAPTER IV

SUMMARY AND CONCLUSIONS

This study investigated the role that ADHD symptoms play in priming performance for young adults in implicit memory tests. Burden and Mitchell (2005) found that children with ADHD showed a conceptual priming deficit. Those children had deficits in a conceptual-production test, but maintained normal performance on a perceptual-identification test. Like Burden and Mitchell, this experiment explored priming performance across conceptual and perceptual tests but also included identification and production factors. If ADHD adults indeed have a conceptual priming deficit, then we would expect that priming in both category verification and category generation would be relatively impaired, while priming in both perceptual identification and stem completion would be relatively intact. On the other hand, if ADHD adults have a production deficit, we would expect that priming in both stem completion and category generation would be relatively impaired, while priming in both perceptual identification and category verification would be relatively intact.

It was hypothesized that individuals with ADHD would show some conceptual or production deficits. However, ADHD and non-ADHD populations, as defined by our measurements, did not produce significant differences on any of the memory tests. ADHD participants performed statistically equivalent to non-ADHD participants, and showed no implicit memory deficits. Some reasons for this, and some ways in which

future experiments might be altered in order to better examine these hypotheses will be discussed below.

However, participants in the ADHD group who fell in the 99th percentile or higher for ADHD symptoms showed a conceptual deficit when compared to others in the ADHD group. They showed reduced priming in both of the conceptual tests, the category verification and category generation tests. This pattern of results complements those found by Burden and Mitchell in that ADHD may correlate with reduced conceptual abilities.

The high ADHD participants also showed increased priming in the perceptual tasks compared to the low ADHD participants. This heightened perceptual ability may reflect a reliance on perceptual processing as an attempt to compensate for reduced conceptual ability. Little research focuses on enhance perceptual processing abilities in individuals with ADHD, yet recent literature reflects a focus on enhanced perceptual ability for a related disorder, Autistic Spectral Disorder (ASD). Several studies have found that individuals with ASD have superior perceptual skills (O’Riordan et al, 2001; Plaisted et al, 1998). Furthermore, Gadow, DeVincent, & Pomeroy (2006) found that over half of autistic people meet the DSM-IV criteria for ADHD. Perhaps this enhanced perceptual ability found in ASD is related to greater perceptual ability in ADHD.

The divergent priming performance on conceptual and perceptual tests between high and low ADHD groups does not reflect a need to adjust quantitative criteria for the ADHD group, because the low ADHD group did not resemble the non-ADHD group. If the low-ADHD group showed results similar to the non-ADHD group, it would have indicated that the cut-off for the ADHD group was too low. However, the low-ADHD group had a pattern of results very different from both the high-ADHD and non-ADHD groups. Moreover, the ADHD and non-ADHD groups were chosen to represent very divergent populations regarding ADHD symptoms. The non-ADHD group consisted of individuals who were much below average, where all males were in the 45th percentile or lower, and all females were in the 27th percentile or lower. So, had this group consisted of individuals that had average levels of symptoms, they may have shown a similar pattern as the low ADHD group.

Examining the correspondence between the CAARS and the additional 6 questions presented at the end of the pre-screening, showed that 14 subjects had consistent responses for ADHD. On the CAARS prescreening, these individuals scored in the appropriate range to be placed in the ADHD group and also answered “yes” to at least one of the questions regarding ADHD diagnosis in their individual experience. In addition, 20 subjects were correctly rejected and placed in the non-ADHD group. These subjects showed minimal ADHD symptoms on the CAARS prescreening and also said no to all 6 additional questions. However, about 25% of the participants had a lack in correspondence between the CAARS and the additional questions. In only one case, the

subject had personal experience with ADHD diagnosis, while the CAARS did not identify him or her as ADHD. All others had been placed in the ADHD group by their CAARS scores, yet had no personal experiences with ADHD diagnosis. This may indicate that some of our subjects in the ADHD group should be removed from the analysis, and additional criteria for the ADHD group should be defined on the basis of these questions. However, it could also indicate that these subjects actually have ADHD yet have gone undiagnosed. Although eliminating these subjects from the ADHD group may produce a different pattern of results, there are too few subjects to form any reasonable conclusions.

Future Research

A study evaluating the use of DSM-IV criteria when choosing college students as ADHD participants found that the hyperactive-impulsive subtype of ADHD was much more commonly reported among college men and women than the inattentive subtype (DuPaul, Schachar, Weyandt, Tripp, Kiesner, Ota & Stanish, 2001). Therefore, many of our subjects may not have had the attention deficits that are believed to be the root of conceptual deficits in people with ADHD. In addition, the subjects may have been reporting general maladjustment on the prescreening rather than specific ADHD symptoms. Hopwood & Morey (2007) found that general maladjustment and inability sustaining attention are both represented in the DSM-IV criteria for ADHD, but some performance-based assessments reflect more specific features of ADHD. For instance, the Continuous Performance Test (CPT) evaluates sustained attention performance.

Therefore, including a CPT test would be beneficial to ensure that participants in the ADHD group have attention deficits. In addition, a Personality Assessment Screener (PAS) could be used to eliminate people that were selected for the ADHD group that report high levels of general maladjustment.

Subjects showed little priming in the category verification test. This may be due to the predominant use of unconventional categories, with the exception of the Battig and Montague normalized categories. The critical stimuli are not typically organized on the basis of our ad-hoc categories; however, the items could be placed into a category after consideration. For instance, “square” is typically thought of as a “geometrical shape,” yet “balloon” does not have a correspondingly salient category. However, “balloon” can be placed in the ad-hoc category, “a birthday item.” Predominantly using the Battig and Montague category norms would ensure that the categories and targets are normal while providing an expected range of responses. Because stimuli were rotated through each task, critical items had extensive requirements to meet. So, category choices were very restricted. On future experiments, choosing the most suitable stimuli for each test could produce priming scores more representative of typical implicit tests.

In summary, the ADHD and non-ADHD group did not perform significantly different from one another. The ADHD group as a whole did not display either a conceptual or production priming deficit. However, ADHD subjects with high levels of symptoms did show a conceptual priming deficit compared to ADHD subjects with fewer total

symptoms. Future research is needed to explore this conceptual deficit in the high-ADHD group.

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APPENDIX A

ADDITIONAL PRESCREENING

1. Have you, your parents, or your teachers ever thought about you being tested for ADHD?
2. Have you ever been tested for ADHD?
3. Have you ever been diagnosed with ADHD?
4. If you have been diagnosed with ADHD, did you take ADHD medicine?
5. If you were diagnosed with ADHD in the past, do you currently consider yourself to still have ADHD?
6. Are you currently taking medications for ADHD?

APPENDIX B

AWARENESS QUESTIONNAIRE

1. What do you think was the purpose of the last four tasks you completed? The last four tasks you did were (1) say “yes” if the example was from the category, (2) complete the word beginnings, (3) produce an example for each category, and (4) identify words flashed very quickly.
2. What was your general strategy in trying to produce responses in these tasks?
3. While you were doing any of these tasks, did you notice any relationship between the words that were presented in the second task in the experiment (where you decided whether the meanings of words were pleasant) and the words you saw or said in the last four tasks?
4. If you did recognize a relationship between words in the pleasantness task and words you saw or said in the last four tasks, what was that relationship and in which of the last four tasks did you notice it?
5. At any time during the last four tasks, did you notice whether the words that were displayed (or that you produced) were the same as the words in the pleasantness task?
6. If you noticed that you were saying words from the pleasantness task in any of the last four tasks, did you continue to try to do your best on the task or did you start to try to use the pleasantness words?
7. If you tried to use pleasantness words as responses, in which of the last four tasks did you do this?
8. If you noticed that you were saying pleasantness words in any of the last four tasks, did you become aware of this while you were responding with a particular word? If so, what was that word?

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