

THE RELATION BETWEEN EPISODIC MEMORY AND
ARTIFICIAL GRAMMAR LEARNING

A Thesis

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ABSTRACT

Two artificial grammar learning experiments were conducted to study the acquisition of episodic and grammar knowledge with manipulations designed to enhance one or the other type of knowledge. The first experiment trained subjects to recognize specific exemplars (episodic emphasis) or to identify patterns of family resemblance (semantic focus), and then participants were given both an episodic (specific exemplar recognition) and grammar (valid string identification) test. The episodic emphasis training led to better episodic knowledge and equivalent grammar knowledge. The second experiment investigated the same training types over a longer training period and under presence or absence of interference from different study lists. The results confirmed that the two types of knowledge can be independently manipulated and that both types of knowledge are used together whether it is beneficial or not for overall performance. The results are not consistent with current exemplar models or single system abstraction models.

INTRODUCTION

Tulving proposed that episodic memory (remembering exact experiences) and semantic memory (recognizing categories) are two different cognitive systems (Tulving, 1972). The evidence supporting a difference between these two systems is both robust and immense in quantity (Tulving, 2002). Although in the past there has been disagreement from researchers who claim that the two systems are essentially the same (McKoon, Ratcliff, & Dell, 1986); the debate is primarily concerned with how to classify events according to the memory systems and where exactly the distinction should be made (Ratcliff & McKoon, 1986). The functional difference between the two systems is well supported. Research shows episodic and semantic memories being affected differently by aging (Allen, Sliwinski, & Bowie, 2002). Some types of brain damage can affect episodic memory greatly, while leaving semantic memory relatively intact (Wheeler & McMillan, 2001). Semantic knowledge can continue to be gained even when the cognitive facilities for episodic knowledge have been profoundly damaged (Kitchener, Hodges, & McCarthy, 1998). Differences in brain area activation between the two memory-systems have been firmly demonstrated with positron emission tomography (Lee, Robbins, Graham, & Owen, 2002). Episodic memory can also be traced specifically to the hippocampus, while the surrounding cortical areas are involved with both memory types (Mishkin, Suzuki, Gadian, & Vargha-Khadem, 1997). Thus, the neurological and clinical evidence that distinguishes episodic and semantic memory is strong.

Yet it is obvious that there must be some relation between the two systems. Given that we are not born with extensive semantic knowledge, semantic memories must come from experiences – that is semantic knowledge must be obtained from memories of events. The present paper explores two opposite extreme views, while considering one moderate view, of the relation between episodic and semantic memories based on theories of artificial grammar learning.

An artificial grammar is a system of rules that can be used for linking letters together such that artificial “words” are generated. These words are usually termed: “valid letter strings”.

Artificial grammar experiments provide a way of studying grammar learning (a type of semantic knowledge) without the confounding effects of, or individual differences in prior language learning in the participants being tested. Typically participants in an artificial grammar learning experiment are exposed to lots of valid letter strings and then later tested on their ability to discriminate valid from invalid strings (Reber, 1989). Thus, grammar knowledge (a type of semantic knowledge) develops from sufficient experience with individual valid strings (episodic knowledge). Two different theoretical approaches predict opposite types of relations between the episodic database of experiences with instances and the resulting semantic knowledge.

One view, originally proposed by Vokey and Brooks (1992), asserts that there is a positive relation between quality and quantity of instances stored in the experiential database and the ability to judge grammaticality. According to this view grammar knowledge is only derived at time of retrieval when new strings are compared to those in the episodic database. Acceptance of a string as grammatical depends on how close it matches one or more of the strings in the database. This type of instance theory of grammatical knowledge has also been popular in the categorization literature (Murphy & Medin, 1985). Clearly, this view suggests that more instances in the episodic database and more accurate episodic memory traces of instances in the database should have a strong positive correlation with grammar knowledge. Accuracy of grammaticality judgments should continue to improve as the episodic database becomes larger or more precise. In the current writing this will be termed the “exemplar model”.

The exact opposite view, a negative relation between acquisition of episodic and semantic knowledge, has been proposed by Mathews (1991). He suggested that interference from viewing many similar instances over time causes loss of unique episodic features in the episodic traces of individual items (decreasing exact episodic knowledge of instances) leaving only the more general characteristics that are typical of valid strings (semantic knowledge). For example, over time you might learn to recognize a penny from a nickel, but only at the expense of recalling exact details of

particular pennies you have seen before (since the generalization of categories has happened). Thus, in his view, episodic forgetting directly drives semantic learning. Therefore; this view predicts a strong negative relation between episodic and semantic knowledge. In the current writing, this view will be referred to as the “single system abstraction model”.

A milder version of the forgetting algorithm view would suggest that while forgetting drives learning in the semantic system, episodic memories are not directly affected because they are stored in a separate system. There exists a weaker version of the forgetting algorithm; weaker in the sense of predicting a much weaker relation between episodic and semantic memory. Perruchet et al. (2002) proposed that implicit learning happens when exemplars become grammar knowledge through a process of losing details in memory. According to this view, valid chunks of letters (knowledge of which represents grammar learning) becomes the basic perceptual unit rather than the individual letters over time through the operation of an “intrinsically unconscious mechanism”, which was “forgetting” according to Mathews (1991). Since Perruchet et al. (1997) asserts that grammar learning is the changing of how data is encoded, it is implied that episodic knowledge and grammar knowledge are different, at least functionally if not mechanistically. Thus this milder view suggests no strong relation between quality of episodic traces and resulting semantic knowledge. This is because any manipulation that might influence recall of instances after initial encoding (e.g., interference from seeing more exemplars) might not affect (already abstracted) semantic knowledge. This view would predict a weak positive relation between overall ability to recall instances and grammar knowledge because a good encoding of instances might increase both recall of the instances and such good encoding might also “feed” the semantic system. However this view predicts that it should be possible to independently manipulate quality of episodic and semantic knowledge through variables that affect episodic recall subsequent to initial encoding. As long as episodic memories are initially fairly accurately encoded to feed the semantic abstraction process,

the quality of the episodic database at time of retrieval is not important according to this view, which will be termed the “dual system abstraction model”.

According to the single-system abstraction model, the details of repeated events are forgotten while the central defining features are remembered. This notion is supported by research demonstrating that increased variability in stimuli becomes perceptually similar to noise, while the constant features of the stimuli become like a signal. Gomez (2002) demonstrated this very strongly by having participants listen to strings of ongoing syllables. Stimuli in this paradigm typically consist of long audio strings of syllables such as: “la”, “pa”, “da”, etc. These syllables form artificial words such as “lapa” or “daka”, which must be detected by the participant. This language is assumed to be learned by the likelihood of one syllable following another. Gomez however looked at non-adjacent dependencies, and how participants formed them. The irrelevant portions of the “grammar” had either high variation or low variation. The findings showed that participants learned better when variability of the irrelevant portion of the grammar was high.

Although many studies have compared AG learning under instructions to memorize sets of instances versus looking for rules (Domangue et al., 2004), they did not measure both episodic and grammar knowledge. A recent study using artificial grammar, Sallas et al. (2006) included an episodic memory test in addition to grammar discrimination tests and cued generation tasks. The episodic memory test consisted of 50% old items that were seen in the training phase, and 50% new items that were just valid letter strings. Participants were exposed to various types of training depending on group membership. Training sessions were long (20 minutes in length) and consisted of 88 trials. The exemplars were few (eleven) and were viewed many times (4 times per study phase). The exposure to these exemplars was meaningful in the sense that it was involved and engaging. The training task had participants correcting wrong letter strings, and then revealing the corrected letter strings. There were five of these training sessions, which took place over the course of one week. The tests were given on the final day of the experiment. An interesting finding was

that the episodic memory performance was at chance-level. Even after five sessions of meaningful and abundant exposure over the course of a week; coupled with above-chance performance on grammaticality judgment tests, participants were still unable to report which letter strings they had seen.

The present study consists of two experiments in which the quality of episodic and semantic knowledge of an artificial grammar was directly manipulated. The major manipulation involved training which required either exact encoding and recall of instances or looking for common patterns across sets of instances. Although this manipulation is similar to earlier studies that have compared looking for rules with memorization of instances (Mathews et al., 1989), the manipulation used in this study is much stronger. Participants in the exact recall groups were repeatedly tested to learn to discriminate their study list from both additional valid and invalid letter strings. Thus, their training involved only developing a mental database of the exact learning set of instances and to avoid generalizing to new instances during training. Only at retrieval during the unexpected grammar test did these participants attempt to generalize to new valid strings. The exact recall condition should demonstrate better instance recall and the pattern finding group should demonstrate better grammar (semantic) knowledge. The main issue of interest is what this manipulation does to the non-emphasized type of knowledge.

The exemplar view suggests that exact encoding of exemplars should enhance semantic knowledge of the grammar by creating a better (more precise) database to compare similarity to new exemplars presented at test. Since according to this view grammar knowledge is derived at retrieval anyway, not looking for patterns during training should not harm grammaticality judgments.

The single-system abstraction view suggests that looking for patterns will decrease episodic knowledge but enhance semantic knowledge. The dual-system abstraction view predicts that both types of knowledge are relatively independent, so that both conditions should enhance the emphasized type of knowledge without strongly affecting the other type of knowledge.

The data from experiments will be analyzed through the framework of signal detection theory. The reason for this approach is to allow a precise examination of which kind of knowledge (episodic or grammatical) is used and how much (level of sensitivity for detecting differences between item types: old vs. new; valid vs. invalid). The details of this approach are discussed in the methods section.

EXPERIMENT 1

The aim of this work was to examine the relation between episodic knowledge of particular grammar strings and knowledge about grammaticality of strings. The exemplar views predict a strong positive relation between the two types of learning. If grammar learning is truly based on memory of exact strings, then it follows that those who study letter strings for exact memory will also have a strong grammar learning; likewise, those who study with the goal of grammar learning will also remember the exact stimuli to which they were exposed.

The single-system abstraction model (Mathews, 1991) predicts a negative relation between these two types of knowledge. That is, an increase in grammar learning will be accompanied by the forgetting of specific instances studied during training. Likewise, a strong memory of the details of memorized items will be associated with poor learning of the grammar. The present experiment manipulated emphasis on item vs. grammar learning through training.

The primary manipulation of this experiment caused participants to learn in one of two ways: for a strongly detailed episodic memory, or a very relationship-oriented (grammar oriented) learning of items. All participants were trained by being quizzed repetitively and tested toward the end of the session. The training consisted of membership in either an episodic-emphasis (EE) group, or learning-emphasis group (LE). Those in the EE group were presented with letter strings and told to acquire an exact memory of them and they were repeatedly quizzed on exact recognition of these items during training. Members of the LE group were told that the stimuli have a secret pattern, and that the task is to pay attention to the items to gain a “feel” for the family resemblance patterns across items. These participants were repeatedly quizzed during training on their ability to recognize valid strings (family members) from invalid strings (non-family members).

After training, participants were tested on both their grammatical knowledge and their episodic memory for the strings studied during training. Responses to the test questions, “did you

study that word today” and the grammar learning question, “was that word a family member” were used as measures of episodic memory and grammar learning, respectively.

METHOD

Participants

114 undergraduate students from Louisiana State University participated in order to receive course credit. The age of the participants ranged from 18 to 22 years. Participants are assumed to have been highly motivated as they were competing for monetary prizes ranging from \$10 to \$100 for highest performance.

Design

The experiment consisted of a study phase and test phase. A single factor with two levels of study type (EE vs. LE) was used.

Materials

The entire corpus of 177 valid letter strings generated by the Domangue et al (2004) finite state grammar (see Figure 1) were divided into 11 sets of 16 strings that are representative of the entire grammar. Different sets were used as study and test sets. Each set of 16 letter strings were highly representative of the whole grammar. The representativeness was achieved first treating the whole grammar as a population with a probability distribution of letter string characteristics. The characteristic of primary interest were the chunks (beginnings, middles, and endings of each letter string). There are five possible beginning-chunks (CVC, CXP, CXT, SCP, SCT) and 3 possible end-chunks (VV, VPS, XS), producing 15 possible beginning-ending combinations. These combinations were treated as “types” of strings, and were distributed evenly between the sets to make each set equally representative of the grammar. An extra string, the 16th string of each set was included based on probability of occurrence (e.g. “CVC” is the most likely beginning and appeared slightly more often in sample sets. It has a higher frequency because it reaches three letters at an earlier node

<u>SET A</u>	<u>SET AX</u>	<u>SET B</u>	<u>SET BX</u>
1 CVCPTTTTTVV	1 CVCTTPTTTTV	1 CVCPTTTTTVV	1 CVTTCITPVV
2 CVCPVV	2 CVPCVV	2 CVCTSSSSSX	2 CVSSSSCTSXS
3 CVCTSSSSXS	3 CVTSSSCSX	3 CVCTSSSXVV	3 CVCSTXSXVV
4 CVCTSXXTVPS	4 CVCSTVXXPS	4 CVCTSSXXVPS	4 CVCVXSXSTPS
5 CXPTTTTTV	5 CXTTTTPTVV	5 CXPTTTTTV	5 CXTTTTPTVV
6 CXPTVPS	6 CXVPTPS	6 CXPTVPXTVPS	6 CXXPTTPWPS
7 CXPVPXTTVV	7 CXPPTTVTVV	7 CXPVPXTTVV	7 CXPXTPTVV
8 CXTSSSSXS	8 CXSSTSSXS	8 CXTSSSXVV	8 CXSSXXSTVV
9 CXTXTTTTVPS	9 CXVTTTXXPS	9 CXTSXVPS	9 CXXSTVXPS
10 CXTXTPXVV	10 CXVXPXTTVV	10 CXTXTTVV	10 CXTXTTVV
11 SCPTVPXTV	11 SCXPTVTPVV	11 SCPTTVV	11 SCTTPTVV
12 SCPTVPXVPS	12 SCTPVXVPTPS	12 SCPTTVPS	12 SCTVPTPS
13 SCPTVV	13 SCTPVV	13 SCTSSSXVV	13 SCSXSXTSVV
14 SCTSSXTVV	14 SCTXTSVV	14 SCTSSXS	14 SCSSTXS
15 SCTSXXTVV	15 SCTXSTXVV	15 SCTSXXTVV	15 SCTXSTXVV
16 SCTSXVPS	16 SCXTXSVPS	16 SCTSXTVPS	16 SCSTXTXVPS

Figure 2. Illustration of Letter String Selection: In a single study segment, 4 letter strings are randomly selected from the study list (Set A). In the quiz, 16 letter strings are selected from 4 total lists: the study list (Set A), an invalid version of the study list (Set AX), a new valid list (Set B), and an invalid version of the new valid list (Set BX). Note that the 4 items selected from each list correspond to the 4 randomly selected items from the study segment.

Procedure

The basic structure of the experiment was essentially the same for all participants. They were responsible for learning (either episodically or grammatically) some “set” of letter strings. They studied four strings, and then were quizzed on them. This study-quiz phase occurred in an iterative fashion (explained below) for approximately 35-45 minutes. This variation in time came from response times; however, exposure-time to strings had no variation. The study-quiz phases comprised the “training session”, as this is where the major learning was expected to take place. After this, participants were tested (both episodically and grammatically) on the old valid (studied) sets, new valid sets, and new invalid sets. Each experimental session consisted of a training session followed by a test of both episodic and grammar knowledge.

Training Phase: In the training phase, participants studied letter strings and then responded to a quiz. This procedure was repeated four times until all 16 strings had been studied exactly once. Four letter strings were studied one-at-a-time for 15 seconds each in duration. Next, the instruction for the quiz was given. Participants in the EE group were told that the question to answer about each of the following 16 strings was “did you STUDY that word today?” Participants in the LE group

were asked “was that word a FAMILY member?” The stimuli were called “words” rather than “letter strings” as the prior terminology is easier to understand. Also, the all caps were used to provide fast visual information on what question is being asked. This was not necessary in the training phase, but it is helpful in the testing phase where both question types are being asked of each stimulus.

Participants were informed that they should respond on a four-point scale: “no certain”, “no guess”, “yes guess”, and “yes certain”. Response keys were marked as NC, NG, YG, YC, on yellow stickers placed on keyboard keys F, G, H, and J respectively. The participants were told that their responses would be judged on this scale for accuracy. Correct responses add points, and incorrect responses take away points. Additionally, “guesses” are worth one point, while “certain” responses are worth two points.

Stimuli in the quizzes were pulled from a pool of four sets of 16 strings (see Figure 2 for an illustration). Note that 75% of this pool is “new” (not on the study list) while 25% is “old” (on the study list). This means that the EE group must affirm the 25% old stimuli as studied, and negate the other 75% as not studied. Also note that 50% of this pool is valid while 50% is invalid. Consequently, the LE group must affirm the 50% valid items as “family” members and the other half as not.

In this quiz phase, each letter string was presented for 4 seconds, followed by the 16 quiz questions. The stimuli and the questions were not presented together. This was done in order to give equal exposure-time to all stimuli presentations. The letter string and the question were never shown simultaneously. The participants were given feedback after answering each question. The feedback screen informed the participant about the correctness (or incorrectness) of their response, and simultaneously showed the letter string again for 7 seconds.

At the end of the quiz, the participant was shown his/her score for that training cycle. The next study phase had the same format and content as the previous study phase; it began with four

new randomly selected letter strings, and was followed by another quiz of 16 strings. This process continued four times until the entire study list was presented. As a result, the complete training list was presented twice by the end of training.

Test Phase: The experimental session ended with a test phase. The test phase contained three lists of items: the study list, a new valid list, and a new invalid list. The study list is the only list with items seen by the participant during training. All other items are new. The overall format for the test was the same as the quiz format, with two differences: letter strings were presented for 7 seconds. This was 3 seconds longer than the quiz presentation time. This was done because in the test phase, accuracy scores were being measured. To ensure that participants had ample time to view the stimuli, 7 seconds were given for each letter string. Also there was no feedback on the test until a final score. The participant was presented with 2 questions for each item. The two questions were the same two used in the quiz phases; only this time, all participants got both questions instead of just the question they had prepared for. Before the test, an additional set of instructions was given in order to explain the “other” question which was not seen during the study phase. The EE group was told that the letter strings that they had been studying actually followed some secret pattern, and that they would be required to report which ones were “family members”. Essentially, they received the same instructions that the LE group had followed during training. Likewise, the LE group was prepared for the episodic question by being informed that they were going to be asked about which exact items were on their study lists. Which of the two questions was shown first was a variable that was held constant within subjects and counterbalanced between subjects.

RESULTS

The data was analyzed in terms of responses to three types of test items: items that were studied (old valid), items that are new and grammatical (new valid), and ungrammatical items (new invalid). The participant’s goal was to endorse (say yes to) only the old valid items for the episodic question, and any valid items (old and new) for the grammar question.

Although the goal of each type of test question was to evaluate only its respective type of knowledge (episodic or grammatical), the other type of knowledge could also be used on each test. Depending on how it was used, using the other type of knowledge on a test could either enhance or reduce one's performance. For example, if a participant recognized an item as old (episodic knowledge) then they could correctly infer that it is grammatical. Similarly, if that item is recognized as ungrammatical, it could be correctly inferred that it was not on the study list. However, if one inferred that an item was old on the episodic test because it was valid, this would lead to increased false alarms to new valid items.

In order to best interpret the data it is necessary to look at both simple endorsement rates for the three types of items (old-valid, new-valid, and invalid) and to calculate sensitivity measures for correct responding d' measures. Two different signal detection analyses were calculated for the three pairs of test item types (see Figure 4). Each analysis treated one item type as targets and one as lures. In these analyses, the three item types were treated as mutually exclusive distributions (see figure 4). It is assumed here that each participant had varying levels of yes response "strength" for each item type. If a participant has successfully memorized items on a study list, the old items (rather than new) should have an increased episodic strength. Likewise, strength toward valid items (rather than invalid) should increase if grammar learning has indeed taken place. Thus, on a dimension of strength, these three distributions of item types are apart from each other. The distance between them is known as 'sensitivity' or d' .

The distances between these distributions are calculated by treating affirmative responses toward one distribution as hits, and another as false alarms: (a) old valid items as hits and new valid items as false alarms, (b) new valid items as hits and new invalid items as false alarms. For each of the two question types (episodic and grammar), a pure index of knowledge may be obtained (i.e., one that reflects only the relevant type of knowledge). Grammar knowledge could not have assisted participants in making a distinction between new valid items and old valid items. This is because the

only distinction between these items is whether they were on the study list. Similarly, episodic knowledge can not help participants make a distinction between new valid items and new invalid items. Since they are both new, the only distinction is whether the item follows the rules of the artificial grammar. These measures will be referred to as $d_{(\text{pure e})}'$ and $d_{(\text{pure g})}'$, respectively.

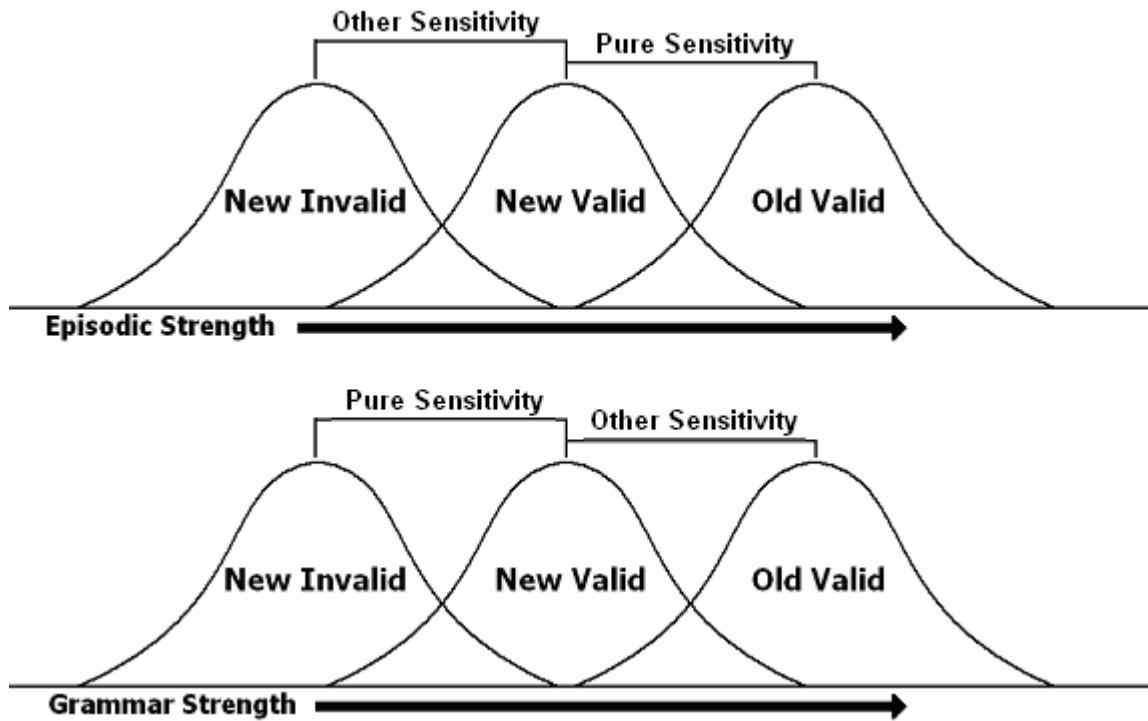


Figure 3: Scheme for Sensitivity Measures

Two additional d' measures reflect use of the other type of knowledge on a given test. That is using grammatical knowledge on the episodic test $d_{(\text{g on ET})}'$, and using episodic knowledge on the grammar test $d_{(\text{e on GT})}'$.

The above mentioned sensitivity measures will be discussed as $d_{(\text{pure})}'$ and $d_{(\text{other})}'$, for pure sensitivity and other type of knowledge sensitivity respectively. The primary questions to be answered regarding the hypotheses deal with the effect of the training manipulation on the two $d_{(\text{pure})}'$ measures. Also of interest is how those $d_{(\text{pure})}'$ (for episodic and grammaticality) are correlated. Finally, information can also be gained from the two $d_{(\text{other})}'$ measures. Those measures can show

when, how, and the extent to which the other type of knowledge is being used (e.g. episodic knowledge is used on a grammar question, and vice versa). Use of grammar knowledge on an episodic test could facilitate or hinder the participants score. If the participant knows that an item is invalid, then they also know that it could not have been on the study list. Conversely however, if they know that the item is valid, they may wrongly select it as a studied item, even though it may not be. On the grammar test, using episodic knowledge can only facilitate the score. If a participant knows that an item is old, then they also know that it must be a valid item. Examining what kinds of knowledge are being used on the tests may potentially give insight into both strategic (useful) and inappropriate use of episodic and semantic cognition in relation to each other. Endorsement rates as a function of training type for the three test item types is shown in Table 1.

Table 1a. Endorsement Rates on Episodic Test

Group	Old Valid	New Valid	New Invalid
EE	0.67 (0.02)	0.35 (0.03)	0.11 (0.02)
LE	0.71 (0.03)	0.63 (0.03)	0.31 (0.02)

Table 1b. Endorsement Rates on Grammar Test

Group	Old Valid	New Valid	New Invalid
EE	0.73 (0.02)	0.57 (0.03)	0.32 (0.03)
LE	0.68 (0.02)	0.59 (0.03)	0.29 (0.02)

It is clear from Table 1a that although the both groups responded “yes” equally to the old valid items, the EE group correctly disconfirmed (responded no to) new valid items and new invalid items at a higher rate than the LE group. None of the endorsement rates on the grammar test differed as a function of item type. However old valid items were endorsed more by the EE group than the LE group.

The issue of accuracy of the two types of knowledge is addressed using signal detection data. Table 2 illustrates the effect that learning emphasis (episodic vs. grammar) has on its own test-

question type and the other test-question type. The exemplar hypothesis predicts that no matter what kind of training undergone by participants, they will show an equal level of knowledge on each of the two test-question types. The single-system abstraction model predicts that learning of one type will produce a detriment of learning of the other type. The dual-system abstraction model predicts a small positive correlation between the two types of learning; also that the two types of knowledge may move relatively independent of each other.

Four independent samples t-tests were run on the d' measures. Training type was the only factor used in these analyses. The means are displayed in Table 2. Only two of the four comparisons were found to be statistically significant at the $\alpha = 0.05$ level.

Table 2a. Sensitivity Scores on Episodic Test

	$d_{(\text{pure e})}'$	$d_{(\text{g on ET})}'$
EE Group	0.93 (0.07)	1.10 (0.09)
LE Group	0.28 (0.08)	0.98 (0.10)

Table 2b. Sensitivity Scores on Grammar Test

	$d_{(\text{pure g})}'$	$d_{(\text{e on GT})}'$
EE Group	0.80 (0.09)	0.51 (0.08)
LE Group	0.95 (0.10)	0.24 (0.07)

Episodic Test $d_{(\text{pure e})}'$: This measure represents the signal detection sensitivity between old valid items and new valid items. It is an indicator of the true episodic score, as it partials out the influence of grammar knowledge on episodic questions. The EE group had a significantly better memory of the study items than the LE group ($t_{(112)} = 6.06, p < .05$).

Episodic Test $d_{(\text{g on ET})}'$: This is a measure of the extent to which participants used grammar knowledge on the episodic test. There was no difference between the EE group and the LE group on this measure ($t_{(112)} = 0.91, p = 0.37$). Despite this lack of difference, the means of both groups in table 2 show that each group used a substantial amount of grammar knowledge on the episodic test.

Grammar Test $d_{(\text{pure } e)'}'$: This is the direct measure of grammar learning. It only considers the difference between new items (valid vs. invalid). It was found that both groups (EE and LE) had equal grammar knowledge ($t_{(112)} = -1.01, p = 0.31$).

Grammar Test $d_{(e \text{ on } GT)'}'$: This measure indicates the application of episodic knowledge to the answering of grammar questions. The EE group was significantly more likely to use such knowledge on the grammar test ($t_{(112)} = 2.52, p < .05$).

Table 3a. Correlations on Sensitivity Scores for EE Group

	$d_{(\text{pure } e)'}'$ Episodic Test	$d_{(\text{pure } g)'}'$ Grammar Test	$d_{(g \text{ on } ET)'}'$ Episodic Test	$d_{(e \text{ on } GT)'}'$ Grammar Test
$d_{(\text{pure } e)'}'$ Episodic Test				
$d_{(\text{pure } g)'}'$ Grammar Test	0.05			
$d_{(g \text{ on } ET)'}'$ Episodic Test	-0.10	0.46*		
$d_{(e \text{ on } GT)'}'$ Grammar Test	0.30*	-0.12	0.09	

* $p < 0.05$

Table 3b. Correlations on Sensitivity Scores for LE Group

	$d_{(\text{pure } e)'}'$ Episodic Test	$d_{(\text{pure } g)'}'$ Grammar Test	$d_{(g \text{ on } ET)'}'$ Episodic Test	$d_{(e \text{ on } GT)'}'$ Grammar Test
$d_{(\text{pure } e)'}'$ Episodic Test				
$d_{(\text{pure } g)'}'$ Grammar Test	0.07			
$d_{(g \text{ on } ET)'}'$ Episodic Test	-0.29*	0.58*		
$d_{(g \text{ on } GT)'}'$ Grammar Test	0.50*	-0.42*	-0.25	

* $p < 0.05$

The various hypotheses also have different predictions regarding correlations. The exemplar hypothesis predicts that episodic knowledge and grammar knowledge will have strong positive correlations. The single-system abstraction model predicts that the two knowledge types will have strong negative correlations. The dual-system abstraction model predicts that grammar knowledge and episodic knowledge will have a small positive correlation.

Correlations: The data were divided according to the factor: training type (EE or LE). Pearson product-moment correlations were run on all four of the d' measures. Across both the EE and LE groups there are some similarities, which will be discussed first. Where the two groups show the same statistically significant trends, an overall correlation (pooling both groups) is reported. In neither case was there a significant correlation between the $d_{(\text{pure } e)}$ ' measures, indicating that strong knowledge on one test tends not to extend to strong knowledge on another test. In both the EE and LE groups, there were correlations between the $d_{(\text{pure } e)}$ ' and $d_{(\text{e on GT})}$ ' measure ($r_{(112)} = 0.46, p < 0.01$). This relationship between the two types of knowledge was also inversely true; $d_{(\text{pure } g)}$ ' and the $d_{(\text{g on ET})}$ ' were correlated ($r_{(112)} = 0.52, p < 0.01$). The phenomenon illustrated here is when strong pure knowledge of any type is demonstrated on a test, that same type of knowledge is also used to in the answering of the 'other' test. There were no significant differences found between wrong knowledge-use on one test versus another.

There was one area where the EE and LE groups were different. In the EE group, there was no relationship between $d_{(\text{pure } e)}$ ' on a test, and $d_{(\text{other})}$ ' on the same test; however, in the LE group there was such a relationship. In the LE group the $d_{(\text{pure } e)}$ ' and $d_{(\text{g on ET})}$ ' were negatively correlated ($r_{(55)} = -0.29, p < 0.05$). The $d_{(\text{pure } g)}$ ' and $d_{(\text{e on GT})}$ ' were also negatively correlated ($r_{(55)} = -0.42, p < 0.01$). This indicates that for the LE group, when participants were over-reliant on using wrong knowledge on a test, it would decrease the score of that test. Likewise, when they performed well (e.g. when test score was not hurt), they did not require as much assistance from the inappropriate knowledge.

DISCUSSION

The results vary slightly with regard to their theoretical implications. The data speak most strongly about the exemplar view of grammar learning, and also the single-system abstraction view. First to be discussed is the evidence that either supports the exemplar view while disconfirming the single-system abstraction view, and then the opposite. Finally, the rationale for the second experiment will be given.

Participants in the EE group, who gained (to a substantial extent) exact memory of the specific letter strings also managed to learn the grammar. This supports the exemplar view that learning examples is sufficient for some grammar learning. The rest of the evidence seems to go strongly against the exemplar hypothesis. The correlational data revealed no relation between acquisition of the two types of knowledge. If the exemplar view is true one would expect a strong correlation between the $d_{(\text{pure})}$ measures of both tests, since the two types of knowledge are supposedly the same. Also there was no correlation between the uses of other knowledge on one test versus another. What also seems to go against the exemplar theory is that participants in the LE group were extremely poor at remembering what letter strings they had studied, and yet, they did as well as the EE group on the grammar test.

The second experiment was designed to offer a stronger test of the hypotheses and to provide further insight on the relation between the two types of knowledge. Therefore there were a few changes made from experiment one. First, the training manipulation was made more robust by extending the length of the experiment to three days (in-a-row) of training. The LE group in the first experiment failed largely to gain episodic knowledge; perhaps this would be different if they had more exposure to the same studied exemplars over three sessions.

The second change was the introduction of an episodic interference variable. When present, episodic interference is the studying of a different study list each day. Furthermore the study lists of days 2 and 3, were used as the lure lists of days 1 and 2 respectively. This was done to generate

interference in episodic learning. Recall that the single-system abstraction model predicts that interference to episodic learning should lead to an increase in grammar learning. Groups without episodic interference simply studied the same list every day. According to this hypothesis, episodic interference should impair episodic memory while fostering grammar learning. The absence of this factor should do the opposite. This factor was introduced in order to provide a strong test of the single-system abstraction model.

EXPERIMENT 2

A major change made to the second experiment was the introduction of more sessions. In all of the sessions, the participants went through a training phase identical to that used in the first experiment: a cycle of studying and being quizzed on the study set. The test phase was different. Instead of receiving two questions for each item, they only received one. The single question was the one that matched their training condition (e.g. the EE group only had to answer episodic questions; the LE group only had to answer grammar questions). In essence, the tests for days 1 and 2 were supplementary training in preparation for the third day. Only on the third day (final session) were participants required to answer both questions. The test format for the final session was identical to test format used in Experiment 1.

Another change to the design was the addition of a new factor: episodic interference. This was added in order to examine the compounding effect of receiving the same list every day, versus having to study with a new list each day. Participants in the no-episodic-interference group studied the same list for all three sessions. These participants were “quizzed” during training with Sets B through D on sessions 1 through 3 respectively. Participants in the episodic-interference group studied a different list every day (Sets A-C) while being quizzed on Sets B through D. The episodic-interference came from lure-lists becoming study lists on the next day. Interference also came from the changing of study lists on a daily basis.

METHOD

Participants

121 undergraduate students from Louisiana State University participated in order to receive course credit. The age of the participants ranged from 18 to 22 years. Participants are assumed to have been highly motivated as they were competing for monetary prizes ranging from \$10 to \$100 for highest performance.

Design

The experiment consisted of a study phase and test phase. The three factors utilized in this 2x2 between subjects design were study type (EE or LE), and episodic interference: (interference or none).

Materials

The materials were identical to those used in Experiment 1.

Procedure

The procedure was identical to that used in Experiment 1, except for the test phase. During days one and two only the emphasized question was presented at the test, because that was the question type that the participants trained for. On the final test, all received both questions.

RESULTS

First a comparison of endorsement rates is discussed, followed by signal detection data. The same signal detection analysis used in Experiment 1 was also used in Experiment 2. According to the exemplar view, both types of knowledge (episodic and grammar) should be highly correlated. Each type of training should increase both types of knowledge. The interference manipulation should have the same effect on both knowledge types; if the interference works, it should also interfere with grammar learning. The single-system abstraction view predicts that episodic training will reduce grammar learning; and that grammar training will reduce episodic memory. It also predicts that episodic interference will hinder episodic memory and assist with grammar learning. The dual-system abstraction view predicts small correlations between the two types of knowledge. Of primary interest were the means of the d' measures and how they vary according to condition.

The endorsement rates are presented as a preliminary illustration of the participants' choosing patterns. Table 4a show the surprising pattern of the EE groups endorsing old valid items at a lower rate than the LE group, on the episodic test. However, they were also much less likely to endorse new valid items than the LE group. This indicates that the high endorsement of old valid

items by the LE group was likely a result of a liberal bias – a bias that will be controlled for in the d' analysis. This observation is further supported by the high endorsements of the invalid items by the LE group. In Table 4b, the grammar test reveals similar pattern to the episodic test. The old valid endorsement rates between the EE and LE groups do not appear to have large differences. However, the new valid rates show the LE group to be approximately 20% higher than the EE group. In the endorsements of invalids, the LE interference group is noticeably higher than all other groups. The d' analysis is discussed next to offer a clearer illustration of the data. Four 2-Way ANOVA's were used in this analysis.

Table 4a. Endorsement Rates on Episodic Test

	Old Valid	New Valid	New Invalid
EE: No interference	0.76	0.20	0.04
EE: Interference	0.70	0.23	0.05
LE: No interference	0.82	0.51	0.20
LE: Interference	0.79	0.54	0.22

Table 4b. Endorsement Rates on Grammar Test

	Old Valid	New Valid	New Invalid
EE: No interference	0.80	0.47	0.18
EE: Interference	0.80	0.49	0.15
LE: No interference	0.87	0.66	0.15
LE: Interference	0.83	0.70	0.25

Episodic Test $d_{(pure\ e)}$: This is the direct measure of episodic learning. It is the participants' sensitivity for the distinction between two types of valid items: old vs. new. The analysis revealed a main effect for training emphasis ($F_{(1, 117)} = 21.17$, $MSE = 0.10$, $\eta_p^2 = 0.15$), a main effect for episodic interference ($F_{(1, 117)} = 5.43$, $MSE = 0.10$, $\eta_p^2 = 0.04$), yet no interaction between those variables ($F_{(1, 227)} = 4.82$, $MSE = 0.11$, $\eta_p^2 = 0.02$). For the training emphasis effect, the EE group

($M = 1.60$) had superior episodic memory to the LE group ($M = 0.97$). For the episodic interference effect, the participants with no episodic interference ($M = 1.13$) were better at remembering study items than those who had a different study list everyday ($M = 1.44$).

Table 5a. Sensitivity Scores on Episodic Test

	EE Group		LE Group	
	d(pure e)'	d(g on ET)'	d(pure e)'	d(g on ET)'
No Interference	1.81 (0.13)	0.94 (0.13)	1.08 (0.14)	1.24 (0.14)
Interference	1.39 (0.14)	1.06 (0.13)	0.86 (0.14)	1.10 (0.14)

Table 5b. Sensitivity Scores on Grammar Test

	EE Group		LE Group	
	d(pure g)'	d(e on GT)'	d(pure g)'	d(g on ET)'
No Interference	1.01 (0.16)	1.14 (0.13)	1.77 (0.17)	0.93 (0.14)
Interference	1.25 (0.16)	1.08 (0.13)	1.48 (0.17)	0.52 (0.13)

Episodic Test $d_{(e \text{ on } ET)'$: This measure represents the misapplication of pure grammar knowledge to episodic questions. There were no main effects or interactions for this measure.

Grammar Test $d_{(pure \text{ } g)'$: This is the most direct measure of grammar learning. It is the participants' sensitivity for the distinction between two types of new items: valid vs. invalid. There was a main effect of emphasis training ($F_{(1, 117)} = 8.81$, $MSE = 1.12$, $\eta_p^2 = 0.07$) showing that the LE group ($M = 1.63$) learned the grammar more effectively than the EE group ($M = 1.13$). There was no effect for interference, and no interactions.

Grammar Test $d_{(e \text{ on } GT)'$: This measure represents the misuse of episodic knowledge for making grammaticality judgments. There was a main effect of emphasis training ($F_{(1, 117)} = 8.61$, $MSE = 0.09$, $\eta_p^2 = 0.07$). Participants were more likely to use episodic knowledge for grammar questions if they were trained episodically ($M = 1.11$) vs. rather than being trained grammatically ($M = 0.73$).

Table 6a. Correlations on Sensitivity Scores for EE Groups

	$d_{(\text{pure } e)'}'$ Episodic Test	$d_{(\text{pure } g)'}'$ Grammar Test	$d_{(g \text{ on } ET)'}'$ Episodic Test	$d_{(e \text{ on } GT)'}'$ Grammar Test
$d_{(\text{pure } e)'}'$ Episodic Test				
$d_{(\text{pure } g)'}'$ Grammar Test	0.23			
$d_{(g \text{ on } ET)'}'$ Episodic Test	-0.25*	0.39*		
$d_{(e \text{ on } GT)'}'$ Grammar Test	0.39*	-0.06	0.06	

* $p < 0.05$

Table 6b. Correlations on Sensitivity Scores for LE Groups

	$d_{(\text{pure } e)'}'$ Episodic Test	$d_{(\text{pure } g)'}'$ Grammar Test	$d_{(g \text{ on } ET)'}'$ Episodic Test	$d_{(e \text{ on } GT)'}'$ Grammar Test
$d_{(\text{pure } e)'}'$ Episodic Test				
$d_{(\text{pure } g)'}'$ Grammar Test	0.34*			
$d_{(g \text{ on } ET)'}'$ Episodic Test	0.21	0.69*		
$d_{(e \text{ on } GT)'}'$ Grammar Test	0.54*	0.05	0.18	

* $p < 0.05$

Table 6c. Correlations on Sensitivity Scores for Episodic Interference Groups

	$d_{(\text{pure } e)'}'$ Episodic Test	$d_{(\text{pure } g)'}'$ Grammar Test	$d_{(g \text{ on } ET)'}'$ Episodic Test	$d_{(e \text{ on } GT)'}'$ Grammar Test
$d_{(\text{pure } e)'}'$ Episodic Test				
$d_{(\text{pure } g)'}'$ Grammar Test	0.03			
$d_{(g \text{ on } ET)'}'$ Episodic Test	-0.17	0.53*		
$d_{(e \text{ on } GT)'}'$ Grammar Test	0.47*	0.02	0.09	

* $p < 0.05$

Table 6d. Correlations on Sensitivity Scores for No Interference Groups

	$d_{(\text{pure } e)'}'$ Episodic Test	$d_{(\text{pure } g)'}'$ Grammar Test	$d_{(g \text{ on } ET)'}'$ Episodic Test	$d_{(e \text{ on } GT)'}'$ Grammar Test
$d_{(\text{pure } e)'}'$ Episodic Test				
$d_{(\text{pure } g)'}'$ Grammar Test	0.28*			
$d_{(g \text{ on } ET)'}'$ Episodic Test	0.10	0.63*		
$d_{(e \text{ on } GT)'}'$ Grammar Test	0.53*	-0.15	0.09	

* $p < 0.05$

Correlations: The d' data were divided according to the factors: training type (EE or LE) and also episodic interference (present or not). Pearson product-moment correlations were run on all four of the d' measures for all participants. First to be reviewed are the findings where were true for all conditions. In such cases, the overall correlation for all groups is reported. Next the differing factor effects are examined.

When strong knowledge of any types (episodic or grammar) is demonstrated, it is also very much applied to the other test, to assist with the other question. This is shown by the $d_{(\text{pure e})}'$ being very correlated with $d_{(\text{e on GT})}'$ ($r_{(119)} = 0.51, p < 0.01$). Likewise, the $d_{(\text{pure g})}'$ was highly correlated with $d_{(\text{g on ET})}'$ ($r_{(119)} = 0.51, p < 0.01$). In some cases, the correlation data varied according to the factors. The two $d_{(\text{pure})}'$ measures (for each test) correlated only in the LE training manipulations ($r_{(61)} = 0.34, p < 0.01$) and the interference manipulations ($r_{(59)} = 0.28, p < 0.05$). This correlation was not found for the EE training condition or the no-interference manipulation. Another point of difference in the data, was a finding in the EE manipulation; a strong display of episodic knowledge is associated with the less use of inappropriate knowledge on episodic questions.

DISCUSSION

These data illustrated clearer theoretical implications than did the data from the first experiment. Some of the data followed the same trends and some did not. Like in Experiment 1, when participants demonstrated strong knowledge of any type, this knowledge was also used very much to assist with the other test. This implies an overall phenomenon of participants capitalizing on one type of knowledge, whether used correctly or incorrectly. This is bolstered by the finding that inappropriate knowledge use on one test did not correlate with such use on another. Experiment 2 demonstrated that when participants have sufficient opportunity to learn (three sessions) the two types of knowledge are sometimes positively correlated; but only when the training type was LE and/or when interference was present. Both the training manipulation and the interference manipulation produced the effects that they were intended to give; participants performed better at

whatever question-type that they were trained to answer. Also, the episodic interference variable produced a statistically significant hindrance to episodic learning.

In Experiment 2, the exemplar hypothesis is almost never supported. Only in the LE training and interference conditions, were the type knowledge types correlated positively. This relationship is eliminated by any condition that supports episodic learning (EE training and no-interference). The single-system abstraction model also failed to gain support, as the two knowledge types were not negatively correlated. Also, training in one type of knowledge did not hinder learning in the other type.

GENERAL DISCUSSION

The two present experiments attempted to test two hypotheses, the exemplar hypothesis and the single-system abstraction model. They were tested on their predictions with regard to the relation between episodic memory and grammar learning. The exemplar view predicted a strong positive correlation while the single-system abstraction view predicts a strong negative correlation. The data supported neither, rather instead supported a milder view perhaps in line with the dual-system abstraction model.

Although participants trained episodically in Experiment 1, learned the grammar just as well as those trained grammatically, this finding was compromised by the stronger learning manipulation in Experiment 2. The effect of the training variable revealed that participants performed better on what ever test they trained for, and worse (than the ‘other’ group) on the test they did not train to take. According to the exemplar view, this double-dissociation should be highly unlikely as episodic memory and grammar learning are considered identical. Also, neither of the two experiments showed a strong positive correlation between the two types of knowledge (episodic and grammar); moreover, there was often no correlation.

The findings also go against the predictions of the single-system abstraction model. There was no negative correlation between episodic and knowledge. Also, training for one type of test did not hinder the score for the other test; at least not to the extent of generating a negative correlation. The episodic interference variable hindered episodic memory, yet it did not buttress grammar learning as was predicted by the single-system abstraction model.

Previous research has not provided substantial evidence addressing this issue. A few differences may have had influence on the present study. First, the research was concerned largely with episodic knowledge, which is unusual in the artificial grammar learning paradigm. Typically only grammar tests are given. Second, the strength of the manipulations in the present study was perhaps extreme. Recall that participants in the episodic group were given 15 seconds to study each

stimulus, and told to either gain an exact memory. No known studies to date have exercised this level of effort toward getting participants to remember episodically. Another difference between this study and previous ones in the field was the method used to produce implicit learning. Instead of asking participants to memorize letter strings, they were given a more passive exercise than usual: to get a “feel” for the pattern. As each stimulus was presented, participants simply watched the screen. This produced a level of learning that surpassed the episodic-learning group in terms of grammar knowledge. Some of these methodological differences between the present study and previous studies may have assisted the researchers in finding these results.

The data support the notion that episodic memory and semantic memory are different as they can be differentially influenced by the same manipulation; here, the training emphasis factor. The data also reveal a phenomenon of wrong knowledge use. Often episodic knowledge is used on grammar tests. This is especially true where episodic knowledge is strong. Similarly, grammar knowledge is used sometimes on episodic tests. It is unclear whether this can be controlled or managed by those who are using this knowledge. More research is needed in order to explain whether such phenomenon can be consciously controlled. Overall, these findings may potentially have theoretical implications to the study of the episodic memory and semantic learning dissociation.

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VITA

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