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Investigating the Role of Instructional Focus in Incidental Pattern Learning

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ABSTRACT. The authors used a novel dual-component training procedure that combined a serial reaction time task and an artificial grammar learning task to investigate the role of instructional focus in incidental pattern learning. In Experiment 1, participants either memorized letter strings as a primary task and reacted to the stimuli locations as a secondary task or vice versa. In Experiment 2, participants were given the same dual-component stimuli but performed only one of the two training tasks. Instructional focus affected the amount of learning and the likelihood of acquiring explicit knowledge of the underlying pattern. However, the effect of instructional focus varied for the different types of stimuli. These results are discussed in terms of the role of focused attention in incidental learning.

Keywords: attention, cognition, learning, instruction, transfer

UNDERSTANDING AND MODELING THE PROCESSES of human learning is the focus of much research in cognitive psychology. A large portion of this work has examined task performance after the effortful and intentional study of material. Participants in these scenarios devote attention to learning the material and are aware of the knowledge they have acquired. When an

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individual's performance on the test task is improved after performing the study task, it is usually due to the application of new knowledge to that task. Such learning is referred to as *explicit* learning (Seger, 1994).

However, it appears that knowledge can also be acquired *incidentally*—without the intention to do so, and *implicitly*—without "awareness" of the acquired knowledge (Frensch & Runger, 2003; Reber, 1989; Roediger, 1990; Schacter, 1987; Seger, 1994). The classic example of an incidental learning paradigm is Arthur Reber's (1967) artificial grammar study. In Reber's study, participants were asked to memorize strings of letters that were constructed using a finite-state grammar. After memorizing a number of letter strings, the participants were given an unexpected test in which they were presented letter strings constructed using the grammar and random strings, and they were asked to indicate whether or not each string was grammatical. Participants were able to identify the grammatical strings at better-than-chance levels, even though they were unable to verbalize their decision criteria or accurately state the grammar rules. This initial experiment has led to much research in the study of incidental learning (Berry, 1997; Reber, 1989; Seger, 1994; Stadler & Frensch, 1998).

Another classic example of an incidental learning paradigm is Nissen and Bullemer's (1987) serial reaction time (SRT) study. In this study, participants were asked to tap a series of four keys in response to the spatial position of an asterisk on a visual display. The order of the positions followed either a random or a complex repeating sequence. It was found that participants who practiced tapping in the sequenced condition had faster reaction times than those tapping in the random condition. The faster reaction times were interpreted as evidence that the participants had learned the sequence. When interviewed after the task, participants stated they noticed a pattern but were unable to fully describe the nature of that pattern. These results show that even though participants were unaware of the pattern structure they were still able to "learn" the sequence as measured by their reaction time performance.

Although there is now considerable evidence that incidental learning occurs, there is still much controversy in determining the underlying cognitive processes and in defining the nature of what is learned. For example, one issue involves determining whether there are two learning mechanisms (one for incidental and one for explicit) or just one general system that can account for both types of learning phenomena (Frensch & Runger, 2003; Goschke, 1997; Roediger, 1990; Knowlton & Squire, 1993). A second issue involves the nature of awareness of the acquired knowledge (Dulany, Carlson, & Dewey, 1985; Shanks & St. John, 1994; Frensch & Runger, 2003). This issue has resulted in the development of multiple tests to assess awareness of learning. Often, psychologists define the type of knowledge acquired by the test used to assess awareness (e.g., verbal reports, forced-choice tasks, generation tasks), but because the field has yet to find a consensus as to what a definitive test of conscious versus unconscious knowledge is, the term *implicit* varies in operational meaning from study to study. In the present study, we are primarily concerned with investigating the capacity and processing characteristics involved in incidental learning. We only refer to the implicit versus explicit distinction when trying to characterize the nature of the acquired knowledge based on evidence from the test tasks.

A fruitful approach used to address these issues has been to examine how other aspects of cognitive processing affect incidental learning. One area of recent interest concerns the role of attention in incidental learning (Cleeremans, 1997; Chun & Jiang, 1998; Cohen, Ivry, & Keele, 1990; Dienes, Broadbent, & Berry, 1991; Jimenez, 2003; Jimenez & Mendez, 1999; Shanks, Rowland, & Ranger, 2005). This research can be divided into two types of experimental paradigms: dual-task and dual-stimulus studies. Dual-task studies have examined how the amount of *attentional resources* affects learning (e.g., Cohen et al. 1990; Dienes, Broadbent, & Berry, 1991) whereas dual-stimuli studies have examined how the participants' *focus of attention* (also referred to as *selective attention*) affects learning (e.g., Cleeremans, 1997; Jimenez & Mendez, 1999). The rationale common to both paradigms is that manipulating participants' attentional processes allows researchers to test hypotheses about the underlying learning mechanisms and the nature of the acquired knowledge and to compare the similarities and differences between incidental and explicit learning scenarios.

Although much progress has been made, this research has also produced some conflicting results regarding the role of selective attention in incidental learning (reviewed in the next section). In an effort to better understand these findings and the role of attention more generally, we employ a novel paradigm for investigating these issues. Specifically, we use a *transfer appropriate processing* manipulation (c.f. Morris, Bransford, & Franks, 1977) to investigate how participants' focus of attention, vis-à-vis the task instructions, affects what is learned from dual-component stimuli. Previous work on transfer appropriate processing (TAP) has shown that the way in which information is processed affects what is learned and has implications for how that knowledge is later accessed and used. For example, in Morris et al.'s seminal study, participants were instructed to process words in two different ways, either for meaning or for rhyming, and showed differential learning depending on the match between the learning condition and the test type. (Words processed for meaning were recalled better on a standard recognition test, whereas words processed for rhyming were recalled better on a recognition rhyming test.) In the current work, we use a TAP paradigm to investigate the incidental learning of multiple patterns and its relation to implicit versus explicit knowledge acquisition. This extends the previous approaches by examining how the task goals impact the processing of both the target stimuli as well as a secondary nonfocused aspect of the task stimuli. We also examine how the amount of processing can modulate what is learned. However, before we describe our approach in detail, we first review the relevant previous work on attention and incidental learning.

Attention and Incidental Learning

Dual-Task Studies

One approach to examine the role of attention in incidental learning has been to have participants perform an additional task while performing one of the two classic incidental learning tasks. For example, Dienes, Broadbent, and Berry (1991) had subjects produce random digits while memorizing artificial grammar strings. It was shown that this "divided attention task" interfered with subjects' ability to make grammatical judgments between random and structured strings. They postulated that both the memorization of the strings and random digit production involved the phonological loop and therefore, not enough attentional resources could be devoted to the strings to extract the pattern.

Divided attention procedures have also been conducted in the SRT tasks. Nissen and Bullemer (1987, Experiments 2 & 3) added a tone counting task to the original SRT task. They found that this eliminated reaction time advantages on the sequenced trials when compared to the random trials. This study also showed that an attention-demanding task interferes with incidental learning. Cohen et al. (1990) subsequently extended this finding, demonstrating that the tone-counting task only interferes with learning particular kinds of location sequences. They showed that the tone-counting task interfered with incidental learning of complex "ambiguous" sequences in which a given position does not predict the next location in the sequence, but not for simpler "unique" sequences in which each position uniquely predicts the next location.

For each of the dual-task experiments the researchers added an explicit distracter task (i.e., tone counting or random number generation) that presumably induced a cognitive load on participants and reduced the amount of attention given to the relevant aspects of the stimuli and therefore disrupted learning. Consistent with this interpretation, participants in the Cohen et al. (1990) study could still learn under dual-task training conditions as long as the sequence stimuli were simplified. This suggests that less complex stimuli require fewer attentional resources to learn the relevant aspects of the pattern. Taken together, these studies suggest that although awareness may not be necessary for incidental learning, at least some minimal amount of attention is required.

Dual-Stimuli Studies

A second approach to examine the role of attention in incidental learning paradigms has been to use dual-stimuli paradigms, in which two sources of information are present in the stimuli (e.g., Cleeremans, 1997; Jimenez & Mendez, 1999; 2001; Mayr, 1996). For example, in the Cleeremans' (1997) study, participants performed a probabilistic SRT task but were also given an additional explicit cue on every trial that predicted with some degree of validity where the next stimuli location would appear. Participants could therefore perform the task well by either learning the probabilistic grammar, the cues, or both. Results showed that participants became sensitive to both types of information (i.e., the probabilistic grammar sequence as well as the explicit cues) showing that explicit and incidental learning can occur in parallel.

Using a similar paradigm, Jimenez and Mendez (1999) extended this work by examining how participants given single or dual-task procedures learned from multiple sources of information. In these experiments, the location of the stimuli was also generated by a probabilistic finite-state grammar similar to the one used in Cleereman's study. However, it was the SRT stimuli themselves (not a separate explicit cue) that predicted with some degree of validity the next position of the sequence regardless of the grammaticality of the sequence. Participants were asked to either perform the SRT task alone (the single-task learning condition) or in conjunction with a counting task in which they were asked to keep track of the number of various shapes presented in the stimuli (dual-task learning condition). Across three experiments, the authors showed that the participants in both the single- and dual-task learning conditions acquired knowledge of the probabilistic grammar as evidenced by participants' faster reaction times on the grammatical sequences than on the ungrammatical ones. In addition, they showed that participants who were instructed to focus on the relevant aspects of the stimuli (vis-à-vis the secondary counting task) also learned about the shape–location contingencies.

In sum, the Jimenez and Mendez (1999) results suggested that only minimal amounts of attentional resources were required to learn the grammar (i.e., no difference between the single and dual-task conditions learning conditions), but "selective attention" was required to learn about the shape–location contingencies (i.e., only those participants who had performed the counting task and attended to the relevant aspects of the stimuli showed shape learning). However, the authors did not report any measures of awareness in their studies, so it is not clear to what degree learning of the secondary pattern was explicit or could be verbalized.

Mayr (1996) conducted a similar study examining whether participants could incidentally learn multiple patterns from the environment. In this study, participants tapped keys in response to different types of objects that were presented in various locations on the computer screen. Both the objects and the locations followed two uncorrelated repeating patterns. Participants showed learning for both sequences as evidenced by a slow down in their reaction times when either sequence (objects or locations) switched from a patterned to a random block.

In a second experiment, Mayr had participants perform the object SRT task in conjunction with a tone-counting distracter task under three pattern-learning conditions. One training group was given structured object and location sequences (similar to Experiment 1), a second group was given a structured object sequence with random locations, and a third group was given structured locations with random objects. Participants in the group who received the two structured sequences showed reaction time evidence for learning both patterns and similar learning gains to those who were given only one of the structured sequences.

This study shows that participants were capable of learning multiple sequences simultaneously. The fact that participants' reaction times increased when either the locations or objects switched from sequenced to random block provided clear evidence that participants were sensitive to the structure of each sequence. In addition, the results from Experiment 2 show that participants were able to show learning for both sequences even under dual-task conditions. This result is consistent with the Cohen et al.'s (1990) and Jimenez and Mendez's (1999) findings and suggests that there are particular situations in which participants can show incidental learning under cognitive load (i.e., fewer attentional resources). However, in contrast with the Jimenez and Mendez (1999) study, participants in Mayr's study showed learning of the location sequences even though they were instructed to only react to the type of object. That is, participants were not given instructions to pay attention to the location aspect of the stimuli. These conflicting results do not paint a clear picture for the role of attention and instructional focus on the incidental learning of multiple patterns.

In sum, previous work on attention and incidental learning suggests that (1) only a minimal amount of attention allocation may be necessary for incidental learning to occur (depending on the complexity of the learning stimulus), (2) explicit and incidental learning can take place in parallel, and (3) people are able incidentally to learn multiple patterns from the environment. However, what is unclear from previous studies is the role of instructional focus in incidental learning. If incidental learning requires selective attention, then directing participants' attention to particular aspects of the stimuli through task instructions should affect the learning of the underlying patterns. Furthermore, if the amount of processing affects what is learned, we should see improvements in learning as the amount of processing increases. To investigate these questions, we introduce a novel incidental learning procedure that allows for the systematic investigation of the role of focused attention on incidental learning of multiple patterns.

Current Experiments

Our methodology combines the artificial grammar procedure with the SRT task. In this design, strings of letters are presented in a visual display in one of four spatial locations. In Experiment 1, participants were assigned to one of two dual-stimuli learning conditions. Participants in the memory-focused learning condition were instructed to memorize the letter strings as the primary task and to react to the screen locations as a secondary task. It was presumed that the participants in this condition would devote more attention to the grammar stimuli and would engage in memorization processes (e.g., rehearsal strategies). Participants in the motor-focused learning condition were instructed to react to the screen locations as the primary task and to read the letter strings as a secondary task. This instruction would presumably cause these participants to devote more attention to the stimuli location and would encourage a focus on motor processes (e.g., optimizing location identification and executing the appropriate motor response).

The rationale for using this manipulation is derived from the notion that performing the task under different priority instructions should lead participants to focus attention on different aspects of the stimuli as well as spend more time processing it. Furthermore, it allows us to manipulate the way in which participants process the training stimuli without directly manipulating their awareness of the underlying pattern or the way in which the stimuli are presented. After training, participants were given an unexpected test of their ability to make judgments of the grammaticality of new strings made using the same grammar rules. They were also tested on an SRT task with a block of patterned trials that followed the same sequence as training and a block of random trials. The training groups were compared to a no-training control group that only completed the test phase.

In Experiment 2, we used the same learning and test materials from Experiment 1 but had participants perform only one of the two training tasks. Using this design, we implemented an even stronger manipulation of instructional focus. Because participants performed only one of the two training tasks, it was presumed that they would focus their attention on the aspects of the stimuli that were relevant for performing that task and would be less likely to focus on other aspects of the stimuli that were not task-relevant. They were also expected to spend more time actively processing the task-relevant aspects of the stimuli as compared to Experiment 1. The memory-only group was told that they were performing a memory task and that the stimuli would be presented in various locations on the screen. They were not informed as to the pattern of locations and did not react to those locations. The motor-only group was told that they were performing a motor skills task and that the stimuli they were responding to were letter strings that would appear in various locations on the screen. Participants were not informed as to the nature of the letter strings and were not instructed to memorize or read the letter strings. One important issue that arises from moving from a dual-task to a single task-learning scenario is whether participants would now be more likely to acquire explicit knowledge about the task-relevant pattern. To examine this possibility, we gave a posttest questionnaire to assess whether participants gained explicit (verbalizable) knowledge of the grammar rules or location sequence.

In these experiments, we implement a TAP approach (Morris, et al., 1977) to influence how participants process the different aspects of the stimuli. By systematically manipulating the participants' task goals, we expected participants to focus more attention and cognitive processing to the task-relevant dimension of the stimuli but at the same time incidentally process the other task-irrelevant aspects of the stimuli. The three questions of interest were: (1) Do people learn multiple patterns simultaneously? (2) Does instructional focus modulate this learning? (3) Does the amount of processing affect amount of and type learning (implicit vs. explicit)? If instructional focus matters for incidental learning, the training groups would be expected to perform better on the tests that assess their primary training. If the amount of processing affects learning, we expect to see larger learning effects in Experiment 2.

EXPERIMENT 1

The purpose of this experiment was to investigate the affect of instructional focus on incidental learning of multiple patterns. Instructional focus was manipulated by having participants perform a dual-component training procedure under different priority conditions.

Method

Participants

Eighty-five participants (memory-focused $n = 30$, motor-focused $n = 31$, no-training $n = 24$) from the subject pool at the University of Illinois at Chicago participated in the study as part of a course requirement in their introductory psychology class.

Materials and Apparatus

All material was designed using PsyScope software (International School of Advanced Studies, Trieste, Italy) and presented on a microcomputer with a monitor (Cohen, MacWhinney, Flatt, & Provost, 1993).

Training Materials

The grammar strings were constructed using a finite-state grammar used by Redington and Chater (1996; originally used by Reber & Allen, 1978). Figure 1 presents an illustration of the grammar rules. This particular grammar generates 41 permissible letter sequences of three-to-six letters in length, which were used as the structured material. Twenty-two of the 41 grammatical strings were selected for the learning phase of the experiment.

The letter strings were presented as the stimuli in the SRT task. The SRT task was similar to the task used by Curran and Keele (1993). The stimulus appeared in one of four quadrants of the screen. Each stimulus remained on the screen for three seconds, regardless of how quickly the subject reacted, to equate exposure time. The locations on the screen corresponded with four matching keys. Participants were assigned to one of four different sequences to control for any effect of sequence order. The sequences consisted of six elements. Two of the four possible locations were repeated, while the other two locations appeared only once. This kind of location pattern is referred to by Curran and Keele (1993) as a “hybrid sequence” because it combines both unique and ambiguous locations. Ambiguous sequence locations can be followed by more than one possible location and therefore cannot be learned via simple pair-wise associations. The four spatial locations from left to right, top to bottom were labeled 1, 2, 3, and 4. The four sequences were: 1–2–3–2–4–3, 1–4–3–1–3–2, 1–3–2–4–1–2, and 4–2–3–2–1–3.

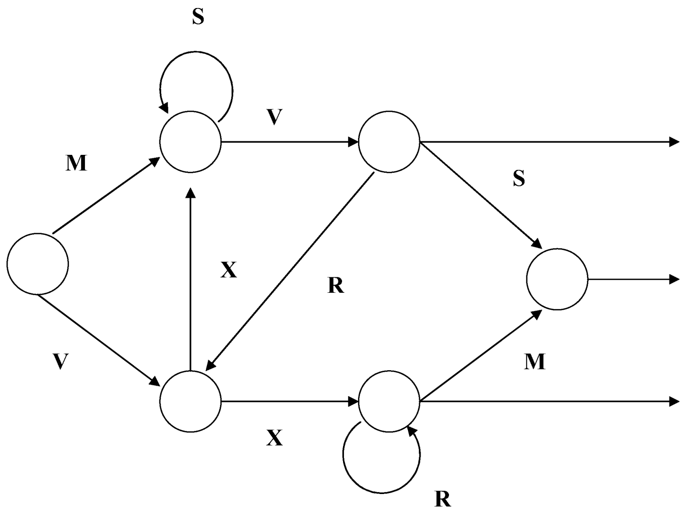

FIGURE 1. Finite state grammar used to generate the letter strings used in the training and test phase.
Source: **Adapted from Redington, M. & Chater, N. (1996). Transfer in artificial grammar learning: A reevaluation.** ***Journal of Experimental Psychology: General, 125,*** **123–138.**

The training session consisted of 60 repetitions of the six-location sequence for a total of 360 learning trials.

Participants for each training group were given different initial instruction materials. Participants in the memory-focused group were told that their primary task was to memorize the letter strings and that their secondary task was to respond to the location of the stimuli by pressing the corresponding key. In contrast, participants in the motor-focused group were told that their primary task was a motor skills task in which they were to respond to the location of the stimuli by pressing the corresponding keys and that their secondary task was to read through each letter string.

Test Materials

There were 50 test letter strings; half were grammatical and half were ungrammatical. The 25 grammatical letter strings included 6 old letter strings, those seen during training, and 19 novel letter strings that were constructed via the same grammar as training. The 25 ungrammatical letter strings were also generated from the training grammar but these strings violated one or more of the grammar rules. The rule violations were distributed across the letter string positions to control for any effect of violation position (5 first position, 6 second position, 2 middle position, 5 second-to-last position, 4 final position, and 3 strings that violated all letter positions).

The SRT test presented strings of asterisks in place of the grammar strings used in the training materials. The test consisted of two blocks. The sequenced block presented the asterisks in serial locations that followed the same pattern of the training materials. The random block presented the asterisks in serial locations that were randomly determined. The locations were presented one at a time and remained on the screen for 3 seconds, after which the next location was presented. Reaction times were collected for each stimulus presentation and serve as the dependent variable.

Procedure

We randomly assigned participants to the memory-focused group, the motor-focused group, or no-training control group. The no-training group provides an important comparison condition to control for any learning that occurs through performing the test. By using appropriate controls (a no-training test group instead of estimates of chance performance), we can effectively address questions regarding learning due to training versus test performance (Redington & Chater, 1996). If the training groups show improved performance above the no-training control group on the test task, this improvement must be due to knowledge acquired from the training task.

The experiment involved two phases. The memory and motor-focused groups first completed a learning phase. All groups then completed a testing phase. Test order was counterbalanced across all participants. Before beginning the experiment training, participants were given instructions for their learning condition. All other aspects of the experiment were the same for both training groups.

Learning Phase

For each trial, one of the 22 training grammar strings was presented in one of the four screen locations. The order of screen locations followed one of the four sequenced patterns. Participants responded to the location by pressing the key that corresponded to the location. Participants were first given a 15-trial warm-up to familiarize them with the task. Then the participants completed the learning phase. The learning phase consisted of 15 blocks. Each block consisted of four repetitions of the six-location pattern. Participants were presented with 360 trials in total (60 repetitions of the location pattern). Each letter string was presented for 3 s to equate exposure to the stimuli. The total learning phase took approximately 12 min. The reaction times to the spatial locations were recorded during the learning phase to assess the effects of the instructional manipulation.

Test Phase

The grammar-classification task was similar to the methods used by Reber (1976). Participants were informed that the letter strings presented in the learning phase had been constructed using a set of complex rules. They were then instructed to perform a classification task of 50 letter strings, of which half of the letter strings were generated by the same grammar (i.e., rules) as training, and half of the strings violated those rules. The letter strings were presented one at a time in the center of the screen. Two scores of classification performance were calculated. The first score was based on all 50 grammatical and ungrammatical test strings. The second score was based on the 19 novel grammatical items and 25 ungrammatical items for a total of 44 test strings. In the results section, we report the scores from this second performance measure because it provides the strongest test of the claim that what participants learn from training is abstract and rule-based and not simply based on recognition memory for old items.

The SRT test consisted of a sequenced block and a random block. The sequenced block followed the same serial location pattern as the training phase. Participants received 10 repetitions of the same six-location sequence that they were trained on. For the random block, participants received 60 trials for which the screen location was randomly determined. Participants responded by pressing the key that corresponded to the screen location. The dependent measure was the average reaction time on sequenced and random blocks.

Results

In this section, we address three questions regarding participants' learning performance. First, we examine whether the two instructional groups show evidence for a differential focus of attention—that is, was the instructional manipulation successful? Second, we examine whether there is evidence for pattern learning and if the training groups show improved performance in comparison with the no-training control group on the test tasks. Third, we examine whether learning is affected by participants' instructional focus and if the two training groups showed differential performance on the two test tasks.

For participants to be included in these analyses, they had to reach a criterion of 80% accuracy on the SRT test. By using this criterion, we can make sure that the three test groups had approximately the same high-level accuracy performance when comparing the mean RTs between the groups. Two motor-focused training participants fell below this criterion, showing only 57% and 29% accuracy respectively, and were excluded from the following analyses.

Alpha was set to .05 for all main effects and interactions. We calculated eta-squared (η^2) effect sizes for all main effects, interactions, and main comparisons. Cohen (1988; see also Olejnik & Algina, 2000) suggests that effects be regarded as small when $\eta^2 < .06$, medium when $.06 < \eta^2 < .14$, and large when $\eta^2 > .14$. In addition, we also report Cohen's *d* effect sizes to quantify the amount of learning and make across-experiment comparisons.

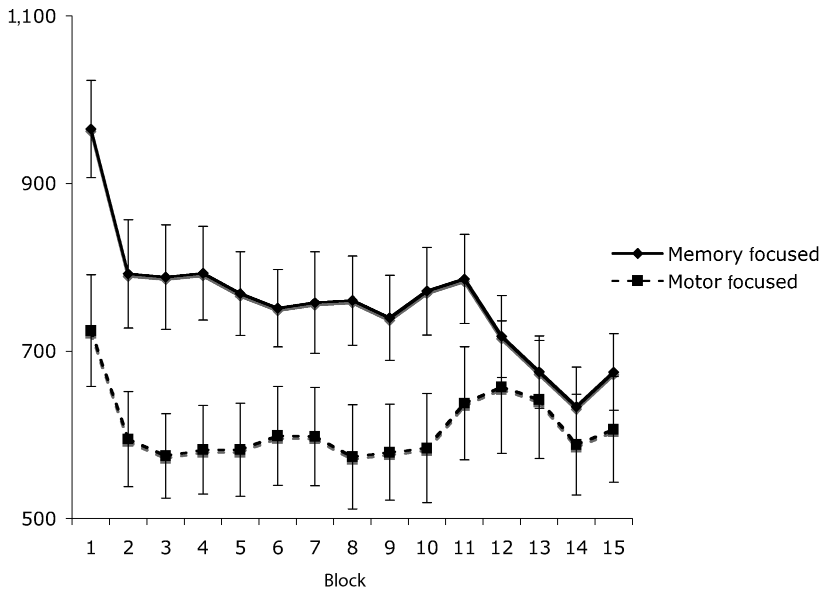

FIGURE 2. *M* RTs and *SE* across training blocks for both memory-focused and motor-focused groups.

Learning Performance

Learning Trial Reaction Times

To investigate the effect of instructional focus on the serial position learning rate, we conducted a 2-training (motor-focused vs. memory-focused) by 15-learning block mixed analysis of variance (ANOVA) on average location reaction times. Analysis revealed a medium-sized main effect of training, $F\ (1, 57) = 4.61$, $MSE = 1{,}780{,}666$, $p < .05$, $\eta^2 = .08$. There was also a medium-sized main effect of learning block, $F\ (14, 798) = 5.39$, $MSE = 27{,}863$, $p < .05$, $\eta^2 = .09$. These results were best explained by the interaction of training by learning block, $F\ (14, 798) = 2.34$, $MSE = 27{,}863$, $p < .05$, $\eta^2 = .04$ (see Figure 2).

To follow-up the interaction of training by learning block, a simple effects analysis was conducted for both memory-focused and motor-focused groups. Analysis for the memory-focused group revealed a simple effect of learning block, $F\ (14, 406) = 4.88$, $MSE = 34{,}482$, $p < .05$, $\eta^2 = .14$. A linear trend analysis revealed a large linear decrease in reaction times across learning blocks, $F\ (1, 29) = 12.53$, $MSE = 121{,}745$, $p < .05$, $\eta^2 = .30$. Analysis for the motor-focused group revealed a simple effect of learning block, $F\ (14, 392) = 2.34$, $MSE = 21{,}008$, $p < .05$, $\eta^2 = .08$. However, in contrast to the memory-focused group, the motor-focused group did not exhibit a significant linear decrease in reaction times,

$F < 1$. These results suggest that the manipulation had an effect on the learning task performance.

Test Performance

Grammar-Classification Task

To investigate the effects of training (motor-focused, memory-focused, and no-training) on grammar learning, a one-way ANOVA was conducted on the percentage of correctly classified strings. We report the grammar test scores using the 19 novel grammatical letter strings and 25 ungrammatical letter strings.[1] Results revealed a large main effect of training, F (2, 82) = 18.06, MSE = 43.21, $p < .05$, $\eta^2 = .31$ (see Figure 3). Follow-up analyses revealed no difference in classification performance between the motor-focused and memory-focused groups, $F < 1$. However, both of the training groups performed significantly better than the no-training control group on the classification task (motor-focused vs. no-training, F (1, 82) = 29.47, MSE = 43.21, $p < .05$, $\eta^2 = .27$; memory-focused vs. no-training, F (1, 82) = 26.49, MSE = 43.21, $p < .05$, $\eta^2 = .25$).

In addition, we calculated Cohen's d effect sizes to assess the amount of improvement for each of the training groups over the no-training control group. Effect size analysis showed large effects for both memory-focused and motor-focused groups over the no-training group, $d = 1.98$ and $d = 1.95$ respectively. Each training group performed an average of 2 *SD*s better than the no-training group on the grammar classification task.

SRT Task

First, we examined each subject's RT data to remove any trial outliers that were either 3 *SD* above or below their mean RT performance for both the patterned and random blocks. To investigate the effect of training on serial location learning, we conducted a 3-training (motor-focused vs. memory-focused vs. no-training) by 2-test (sequenced vs. random) mixed design ANOVA on mean reaction times. Analysis revealed a large main effect of test, F (1, 80) = 117.57, MSE = 5,522, $p < .05$, $\eta^2 = .60$, and a medium-sized main effect of training, F (1, 80) = 3.35, MSE = 24,946, $p < .05$, $\eta^2 = .08$. These results are best explained by the large training by test interaction, F (2, 80) = 7.85, MSE = 5,522, $p < .05$, $\eta^2 = .16$ (see Figure 4).

To follow-up the interaction of training by test, a simple effects analysis was conducted for both the patterned and random blocks. Analysis of the patterned block revealed a simple effect of training group, F (2, 80) = 9.20, MSE = 12,037, $p < .05$, $\eta^2 = .19$. Follow-up analyses revealed no difference between the memory-focused and motor-focused groups for mean reaction times on the patterned block, $F < 1$. However, both groups had faster average reaction times than the no-training group (memory-focused vs. no-training, F (1, 80) = 15.57, MSE = 12,037, $p < .05$, $\eta^2 = .16$; motor-focused vs. no-training, F (1, 80) = 12.83, MSE

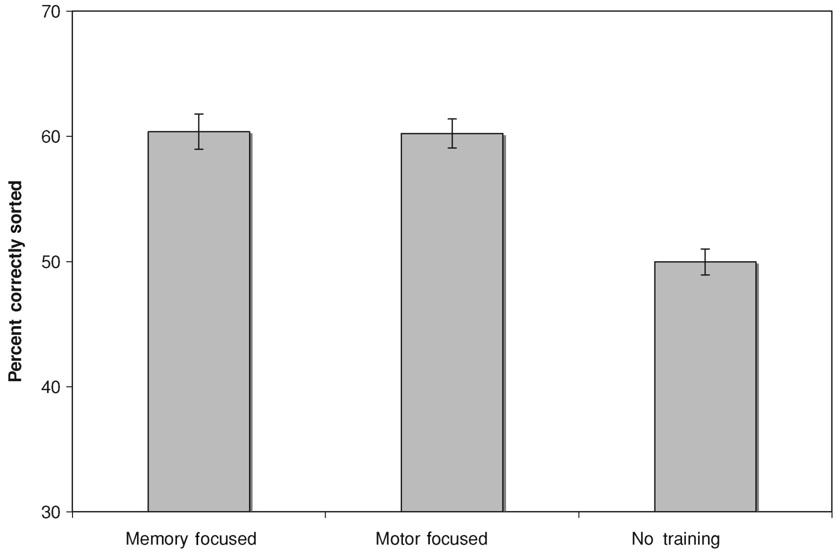

FIGURE 3. ***M*** **grammar-sorting scores and** ***SE*** **for the memory-focused, motor-focused, and no-training groups in Experiment 1.**

$= 12{,}037$, $p < .05$, $\eta^2 = .14$). Follow-up analyses for the random block revealed no simple effect for training, $F < 1$.

We also calculated Cohen's d effect sizes to assess the amount of improvement in reaction times as measured by participant's *difference scores* (i.e., average RT on random trials minus average RT on patterned trials) for each training group over the no-training group.[2] This analysis revealed moderate to large learning effects for the motor-focused and memory-focused groups over the no-training group, $d = .66$ and $d = 1.14$ respectively.

Discussion

We examined three types of evidence for incidental learning in this experiment: learning trial reaction times, grammar classification performance, and SRT test performance. The learning trial reaction times provide evidence that instructional focus affected location response behavior during the learning phase. Recall that both training groups received the exact same dual-component stimuli (i.e., grammar strings and sequenced locations). The difference between the training groups was the instructional focus (i.e., task priority). The memory-focused instructions were designed to focus participants' attention on memorizing the

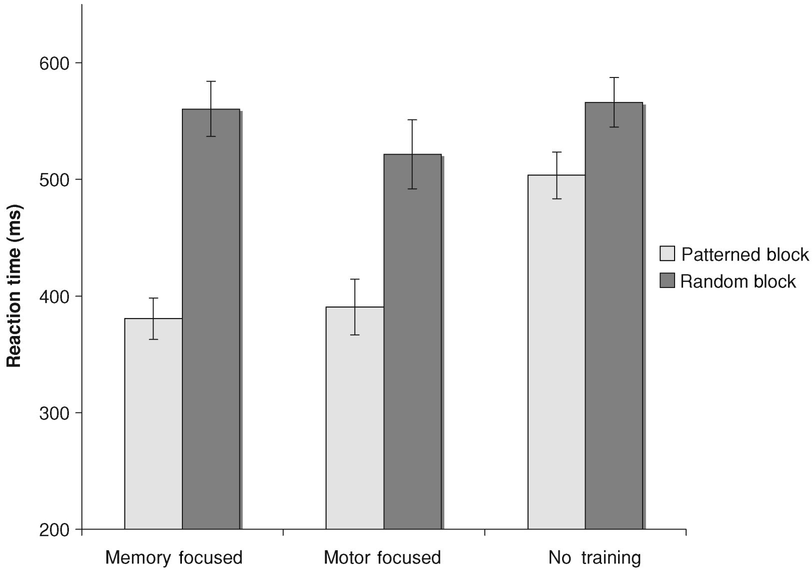

FIGURE 4. ***M*** **reaction times and** ***SE*** **for the memory-focused, motor-focused, and no-training groups on the patterned and random blocks of the SRT test in Experiment 1.**

grammar strings, and reacting to screen locations was the secondary task. The motor-focused instructions were designed to focus participants' attention on reacting as quickly as possible to the screen locations, and reading the grammar strings was the secondary task. Those in the memory-focused group showed a linear decrease in reaction times to screen locations throughout the training task. In contrast, the motor-focused group showed a sudden decrease in reaction times that remained constant through the rest of the training task (see Figure 2). These results suggest the two groups processed the stimuli differently. The sudden drop in reaction times for the motor-focused participants suggests that they paid close attention to the serial position aspect of the stimuli because they responded quickly and accurately across the majority of the learning trials. Unfortunately, the nature of the artificial grammar-learning paradigm does not enable a complementary measure of on-line learning performance. Therefore, we have no similar manipulation check of the effects of instructional focus on grammar acquisition during the learning phase.

The behavioral differences observed during the learning phase did not translate into differential performance during the testing phase. On the grammar classification task, both training groups showed evidence of grammar acquisition above the no-training control group (see Figure 3). However, instructional focus did not lead to differences in grammar classification performance between the training groups. This result is somewhat surprising when compared to what we know about the effects of instructional focus on explicit learning. For example, research on TAP has shown that instructing participants to focus on the aspects of the learning stimuli that are important for a later test clearly improves performance on the assessment tasks (e.g., Adams, Kasserman, Yearwood, Perfetto, Bransford, & Franks, 1988; deWinstanley, Bjork, & Bjork, 1996; Morris et al., 1977). Although our instructions were designed to focus participants' attention on the relevant aspects of the learning stimuli (letter strings or spatial location), this manipulation did not have any clear effect on participants' subsequent test performance.

The behavioral differences of the learning phase also did not translate into differences in SRT test performance (see Figure 4). Once again both training groups showed evidence of location pattern learning above the no-training control group. However, no differences were detected between instructional focus groups. One possible explanation for the lack of difference between the two groups is that they both reached the same final performance level during learning. That is, although the two groups may have processed the material in different ways (as evidenced by the different learning rates), both groups achieved the same final performance and therefore showed equal learning on the test. This interpretation suggests that it is not how the stimuli are processed that matters but instead the total amount of processing.

These results provide evidence that the participants were able to learn multiple patterns from the dual-component stimuli. This finding is consistent with the prior work on the incidental learning of multiple patterns (Cleeremans, 1997; Jimenez & Mendez, 1999, 2001; Mayr, 1996; Willingham, Salidis, & Gabrieli, 2002) and shows that participants in the current study could learn two qualitatively distinct patterns concurrently. However, because we did not employ post-hoc probes of awareness, it is not clear to what degree the acquired knowledge was implicit, explicit, or a combination of both. This issue is further examined in Experiment 2, where we use posttest questionnaires to assess the possibility of participants' acquisition of explicit (verbalizable) pattern knowledge.

In contrast to previous work showing that dual-task training procedures interfere with incidental learning (e.g., Dienes, et al., 1991; Nissen & Bullemer, 1987), the current results show significant learning gains for both learning conditions. There are two important differences between the current approach and the previous dual-task studies that can account for this result. First, instead of using an ambiguous location sequence, we used hybrid sequences, the properties of which have been shown to facilitate incidental learning even under conditions of distraction (Cohen et al., 1990). Second, the distracter tasks used in previous studies were typically explicit memory tasks that created a cognitive load for participants. In contrast, our secondary tasks, reacting to screen locations or reading through letter strings, were not memory tasks and probably did not create such a memory load, and therefore they did not substantially reduce attentional processing to the relevant aspects of the stimuli.

Finally, our manipulation of instructional focus did not significantly affect the amount of learning. This result is consistent with some other results in the literature that suggest that only minimal amounts of attention are necessary to lead to incidental pattern learning (Chun & Jiang, 1998; Jiang & Chun, 2001; Jimenez & Mendez, 1999, 2001; Mayr, 1996). Although this explains why participants show pattern learning for the secondary task, it does not explain why we failed to see larger effects of learning for more attentional processing of the stimuli in the primary task. One possible explanation for this null result is that the manipulation of focus of attention was not strong enough. Although the instructional manipulation affected participants' reaction times during learning, it is possible that it did not cause enough of a difference in processing between the primary and secondary tasks to cause differences in the amount of pattern learning. To investigate this possibility, we explore a stronger manipulation of instructional focus in Experiment 2 and ask whether participants are able to acquire knowledge of multiple patterns when only performing one of the two training tasks.

EXPERIMENT 2

The purpose of Experiment 2 is to further investigate the effect of instructional focus on incidental learning of multiple patterns. Participants in this experiment were presented the same dual-component stimuli as that used in Experiment 1 but were instructed to perform only one of the two training tasks. Participants in the memory-only group memorized letter strings without reacting to stimuli locations, whereas participants in the motor-only group responded to sequence locations without memorizing or reading the letter strings.

Because participants performed only one of the training tasks, we presumed they would focus most of their attention on the task-relevant dimension of the dual-component stimuli. Therefore, if selective attention to the relevant aspects of the stimuli affects incidental learning, we would expect to see differential learning between the training groups. In addition, we were interested in the degree to which participants acquired different kinds of knowledge of the patterns as a function of instructional focus. To assess whether participants acquired any explicit knowledge of the patterns, we administered a posttest questionnaire. Finally, we were interested in the degree to which performing a single- versus a dual-training task affects the amount of learning. To investigate this question, we compared the training group performance across experiments. If splitting attention between two tasks in Experiment 1 reduced the total amount of learning, then we should see larger learning effects for the single task training groups in Experiment 2.

Methods

Participants

Sixty-four participants (memory-only $n = 32$, motor-only $n = 32$) from the subject pool at the University of Illinois at Chicago participated in the study as part of a course requirement in their introductory psychology class. We used the same no-training group ($n = 24$) from Experiment 1 to serve as a comparison on test performance.

Materials and Apparatus

The materials and apparatus were exactly the same as those used in Experiment 1. The primary difference was the instructions given at the beginning of the experiment. Participants in the memory-only group were told that their task was a memorization task in which they were to memorize letter strings. Participants in the motor-only group were told that their task was a motor skills task in which they were to respond to the location of the stimuli by pressing the corresponding keys.

In addition, we administered a posttest questionnaire to assess participants' explicit (verbalizable) knowledge of the training patterns. There were two questions. The first asked participants to describe how they decided what letter strings were grammatical versus ungrammatical. The second asked whether they noticed a pattern in the spatial locations of the stimuli and to describe it if they did.

Procedure

Participants were randomly assigned to either memory-only or motor-only training. In addition, the same no-training control group from Experiment 1 was used as a measure of baseline test performance. The experiment consisted of a learning phase followed by a testing phase. The primary difference between the groups was that the memory-only group was instructed to memorize the letter strings, whereas the motor-only group was instructed to respond to the sequence locations. All other aspects of the experiment were the same for both training groups. After performing the test tasks, participants were given the posttest questionnaire to fill out.

Results

The three questions addressed in this section were: (1) Did the participants learn multiple patterns? (2) Did the instructional focus modulate this learning? (3) Was the acquired knowledge explicit? We do not have an online performance measure to compare the two training groups in this experiment because participants performed different training tasks. So, to assess learning we turn directly to performance on the two test tasks. All training participants were included in the following analyses and had SRT accuracy scores of 80% or above.

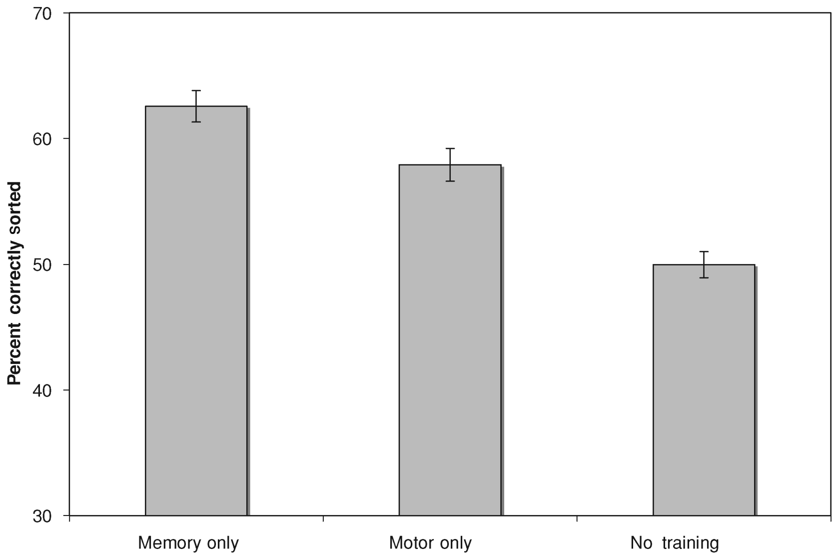

FIGURE 5. ***M*** **grammar-sorting scores and** ***SE*** **for the memory-only, motor-only, and no-training groups in Experiment 2.**

Test Performance

Grammar-Classification Task

To investigate the effects of training (motor-only, memory-only, and no-training) on grammar learning, a one-way ANOVA was conducted on the percentage of correctly classified strings. Results revealed a large main effect of training, F (2, 85) = 20.50, MSE = 47.95, $p < .05$, $\eta^2 = .33$ (see Figure 5). Follow-up analyses revealed that the memory-only group performed better than the motor-only group, F (1, 85) = 6.26, MSE = 47.95, $p < .05$, $\eta^2 = .07$, and the motor-only group performed significantly better than the no-training group, F (1, 85) = 16.53, MSE = 47.95, $p < .05$, $\eta^2 = .16$.

We also calculated Cohen's d effect sizes to assess the amount of improvement for each of the training groups over the no-training group. Effect size analysis showed large learning effects for both memory-only and motor-only groups over the no-training group, $d = 2.40$ and $d = 1.91$ respectively.

SRT Task

As in Experiment 1, we first removed any RT trial outliers that were 3 *SD* above or below that participant's mean RT for that block (patterned or random). To investigate the effects of training (motor-only, memory-only, no-training) on

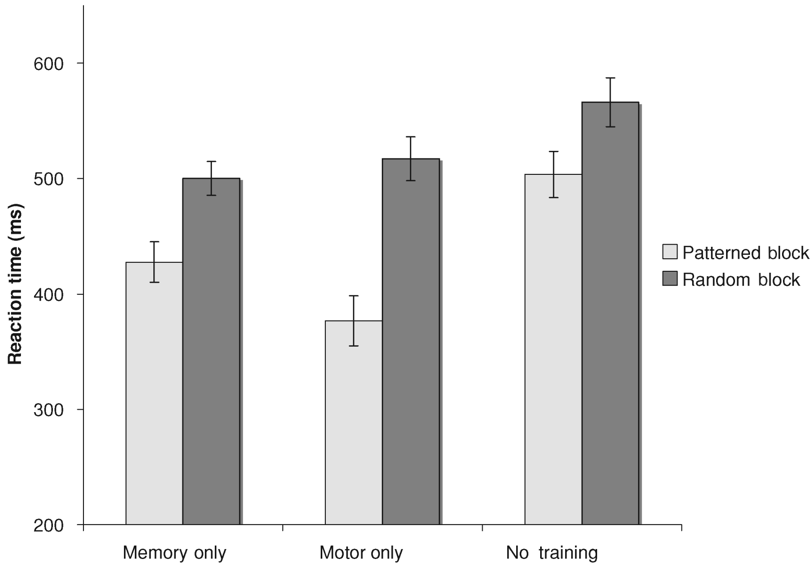

FIGURE 6. *M* RTs and *SE* for the memory-only, motor-only, and no-training groups on the patterned and random blocks of the SRT test in Experiment 2.

serial position learning, a 3-training by 2-test (sequenced vs. random) mixed design ANOVA was conducted on mean reaction times. Analysis revealed a large main effect of test, $F\ (1, 85) = 118.76$, $MSE = 3{,}147$, $p < .05$, $\eta^2 = .58$. Overall reaction times were faster on the sequenced block ($M = 428.64$; $SD = 117.81$) than on the random block ($M = 524.11$; $SD = 101.78$). Analysis also revealed a training by test interaction, $F\ (2, 85) = 8.16$, $MSE = 3{,}147$, $p < .05$, $\eta^2 = .16$ (see Figure 6).

To follow-up on the interaction, two interaction contrasts were conducted comparing each training group to the no-training group as a function of test type (patterned vs. random). There was no interaction for the memory-only and no-training groups as a function of test (F < 1). Inspection of the means indicate that both groups had similar gains from sequenced to random trials. However, there was a significant interaction for the motor-only and no-training groups as a function of test ($F\ (1, 54) = 10.75$, $MSE = 3{,}547$, $p < .05$, $\eta^2 = .17$). Inspection of the means shows that the motor-only group had a significantly larger learning gain than the no-training group.

We also calculated Cohen's *d* effects sizes to assess the amount of learning as measured by participant's difference scores for each training group over control. Consistent with the ANOVA results, there was medium-sized learning effect for the motor-only group ($d = .76$) and a small effect for the memory-only group ($d = .10$).

Posttest Questionnaire

Grammar Question

The grammar question asked participants to describe how they decided which letter strings on the classification test were grammatical versus ungrammatical. These descriptions were then classified as to whether they exhibited one or more of the following four strategies: (1) did not know or guessed; (2) used incorrect grammar rules; (3) used general familiarity or similarity to the strings they remembered from training, or (4) used correct grammar rules. Table 1 shows examples of participants' responses for each category. Most of the participants' descriptions were given a single classification. However, four descriptions in the memory-only group exhibited two strategies; these participants described both incorrect as well as correct rules. The descriptions were classified under a single category (strategy 4) for having mentioned some correct rules.

A frequency count of participants' strategy use across both groups revealed that more participants in the memory-only group were aware of the grammar rules than in the motor-only group (see Table 2). A chi-square analysis revealed an effect for training group across strategy type (χ^2 (3, N = 64) = 10.58, $p <$ .05). Follow-up comparisons revealed that significantly more participants acquired explicit knowledge of the grammar rules in the memory-only group than in the motor-only group (χ^2 (1, N = 64) = 5.38, $p <$ .05). One issue of interest is whether these "explicit knowledge" participants account for the classification advantage of the memory-only group over the motor-only group.

To answer this question, we excluded the participants who reported explicit rules and compared the classification performance for the remaining participants from the two training groups. The results showed that the effect of instructional focus remains even when the "explicit knowledge" participants are excluded from the analysis (memory-only: M = 61.7, SE = 1.63; motor-only: M = 57.43, SE = 1.43, [F (1, 85) = 5.10, MSE = 47.95, $p <$ .05]). This indicates that the remaining 24 memory-only participants had knowledge of the grammar that could not be expressed verbally, but positively influenced classification performance nonetheless. That this group performed better than the motor-only group suggests that the manipulation of instructional focus significantly influenced grammar learning even for those who were not able to verbally report what they learned.

Sequence Location Question

The sequence location question asked participants whether they noticed a pattern in the locations in which the stimuli were presented and what they did to describe it as best they could. These descriptions were classified according to whether they exhibited one or more of the following knowledge types: (1) no knowledge (i.e., did not notice a pattern); (2) incorrect description of the location sequence; (3) generally aware that a pattern existed but did not describe it in

TABLE 1. Examples of Participants' Answers to the Two Post-Hoc Test Questions

Test question	Example descriptions
Grammar strategy description	
Guessing/no knowledge	*"I had no clue, I guessed."*
Incorrect rules	*"I looked at the length of the string. If they were too long I pressed the no key and if they were too short I pressed the no key. If the letter string was 5 letters long I would press the yes key."*
General familiarity	*"To decide I just went by memory to see if the new letter strings looked like the old ones."*
Correct rules	*"If it began with the letters M or V, if they did, whether if it was followed by the letter S or V if it began with an M, and the letter X if it began with a V."*
Location pattern description	
No knowledge	*"I was trying to focus on the letters & didn't really notice the boxes they were in."*
Incorrect rules	*"They went in the 4, 3, 2, 1, pattern earlier. Top Left, Top Right, Bott(om) Left, Bott(om) Right."*
General awareness	*"My eyes began to move where the boxes soon would appear. I became faster with my reaction time as I saw some type of pattern. The pattern was not completely clear, however, some form of pattern was present."*
Correct rules	*"The Pattern was 1, 3, 4, 2, 3, 2. It would follow this patter(n) throughout the experiment. At first, I wasn't able to see the pattern, but after a couple of minutes it became clear that a pattern was being formed and made it easier for me to react quicker, knowing were the box will appear next."*

detail, or (4) correct description of the location pattern. Table 1 shows examples of participants' responses for each knowledge type. Each description was classified under a single category.

TABLE 2. Number of Participants Classified as Having Each Knowledge Type as a Function of Test

	Category			
Test/group	No knowledge	Incorrect rules	General familiarity	Correct rules
Grammar Test				
Memory Only	2	2	19	9
Motor Only	6	4	20	2
Sequence Test				
Memory Only	20	3	5	4
Motor Only	7	0	4	21

Participants' descriptions of the location pattern revealed strong evidence for the development of explicit knowledge as a result of instructional focus. Table 2 shows the number participants from each training group to have pattern descriptions implicating each knowledge type. As can be clearly seen by inspection of the frequencies, more people became aware of the specific pattern in the motor-only group than in the memory-only group. A chi-square analysis revealed a significant difference of knowledge type between the two groups (χ^2 (3, N = 64) = 20.93, $p < .05$). Follow-up analyses revealed that significantly more participants in the motor-only group acquired specific declarative knowledge of the pattern (χ^2 (1, $N = 64$) = 18.97, $p < .05$). This result shows a large proportion of the motor-only group acquired explicit knowledge of the location pattern, whereas only a few participants from the memory-only group acquired such knowledge.

The next question is whether these "explicit knowledge" participants were driving the learning advantage of the motor-only group on the SRT task. Table 3 shows the effect size scores for each training group as a function of knowledge type. The motor-only group showed large learning effects regardless of knowledge type, although the effect was larger for the explicit knowledge participants than for the implicit knowledge participants. In contrast, the memory-only group showed learning effects only for the explicit knowledge participants. These results suggest that the motor training led to both explicit and implicit knowledge of the location pattern. However, the primary effect of instructional focus was to increase the number of participants in the task-relevant condition to acquire explicit knowledge of the pattern.

TABLE 3. Learning Effects as a Function of Knowledge Type

	Group	
Knowledge type	Memory only	Motor only
Explicit	$d = 1.65$ $n = 4$	$d = 1.46$ $n = 21$
Implicit	$d = -.07$ $n = 28$	$d = 1.15$ $n = 11$

Discussion

We used three types of evidence to assess learning in this experiment: (1) performance on the grammar classification test, (2) performance on the SRT test, and (3) participants' answers to the posttest questionnaire. We do not have an online learning measure in this experiment because participants performed different training tasks. Recall that the memory-only group just memorized the letter strings during training and did not react to the sequence locations, whereas the motor-only group just reacted to the sequence locations and were not instructed to read or memorize the letter strings. This manipulation provides a strong test of focus of attention because participants presumably focused all conscious attention on a single task-relevant dimension of the training stimuli.

The grammar classification results provide evidence that participants' instructional focus did affect the nature and magnitude of incidental learning. The memory-only group showed significantly better grammar classification than the motor-only group (see Figure 5). Examination of the posttest questionnaires revealed that more participants from the memory-only group acquired explicit knowledge of the grammar as compared to the motor-only group. However, the memory-only participants who did not acquire verbalizable grammar rules still showed a classification advantage over the motor-only group. This result suggests that focusing participants' attention on memorizing the letter strings led to improved implicit learning of the underlying artificial grammar.

Although the motor-only group did not perform as well as the memory-only group, they still showed evidence of grammar learning because they performed significantly better than the no-training control group on grammar classification. This suggests that even though these participants were not instructed to read or memorize the letter strings they were still able to learn the grammar. This result is consistent with other studies using simple exposure paradigms that show incidental learning (Chun & Jiang, 1998; Jiang & Chun, 2001; Mayr, 1996). However, it is possible that participants could have covertly engaged in more elaborate processing by reading or rehearsing the letter strings. We have no evidence by which to evaluate the latter hypothesis.

TABLE 4. Summary of Learning Effects and Comparisons across Experiments

Training condition	Learning effects	
Experiment 1: Dual task	Grammar sorting	SRT
Memory focused	1.98	1.14
Motor focused	1.95	.66
Experiment 2: Single task		
Memory only	2.40	.10
Motor only	1.91	.76
Comparison across experiments	Grammar sorting	SRT
Primary Task Advantage Single vs. Dual Performance	.42	.10
Secondary Task Advantage Dual vs. No performance	.04	1.04

Performance on the SRT test showed a similar pattern of results with a significant learning advantage for the motor-only group who was focused on the relevant aspects of the location stimuli (see Figure 6). However, contrary to the grammar learning results, analysis of participants' descriptions of the sequence patterns revealed that the majority of motor-learning participants acquired explicit and detailed knowledge of the sequential structure. The results from the remaining motor-only participants who did not express explicit sequential knowledge still showed a learning advantage over the no-training group, suggesting that these participants also acquired implicit knowledge of the location sequence from training. In contrast, the memory-only group did not show evidence of incidental learning because their learning gains were similar to those of the no-training group (Figure 6; Table 4). One possible explanation for these findings is that the linguistic stimuli did not require explicit instructions to direct participants' attention to process it, whereas the location information did.

In contrast to Experiment 1, the results from this experiment showed that participants' instructional focus had a significant impact on both the amount of learning as well as on the type of knowledge acquired. Participants who focused on the aspects of the stimuli relevant for their task showed greater learning for the pattern embedded within those stimuli. This result is consistent with the Jimenez & Mendez (1999) findings showing that selective attention modulates what is learned. In addition, it suggests that the *amount of processing* is critical to what is learned. To further evaluate this hypothesis, we compare effect sizes across experiments. These comparisons provide insight into how the amount of processing (single versus dual task) affects the amount of learning.

CROSS-EXPERIMENT COMPARISONS

In this section, we compare the size of the learning effects across experiments. Because we used the same no-training control group in both experiments, we have a standard baseline from which to compare learning gains. Comparing effect sizes provides information as to the relative impact of the particular training procedures. We can assess whether changing from a dual task to a single task affects the learning gains from the primary task. Of particular interest is whether splitting attention in the dual-task scenario reduces the total amount learning for each primary pattern or alternatively decreases learning of the secondary, nonfocused pattern. In Table 4, we present learning effects for each training group for both experiments.

Comparison of the effect sizes for grammar learning across experiments shows that switching from a dual-task to a single task boosts learning gains for the memory-only group by an additional .42 of a standard deviation over the no-training control group. This suggests more processing dedicated to the relevant features of the letter strings in the single task condition led to better learning of the underlying grammar. The motor groups showed similar grammar learning effects across experiments. This result is surprising because it suggests that decreasing the amount of processing to the grammar stimuli did not result in a similar reduction in grammar learning (only a .04 reduction in effect size).

Examination of the effect sizes for the SRT test shows a different pattern of results. Comparison of the effects sizes for sequence learning across experiments shows that switching from a dual-task to a single task resulted in only a minimal improvement in location learning for the motor-only group, with an additional .10 of a standard deviation improvement over the no-training group. In contrast to grammar learning, there was only a small benefit from increasing the amount of processing to the location stimuli. One possible explanation for only minimal improvement is that the performance was at ceiling. Unlike grammar learning, where participants could spend more time memorizing the letter strings, participants performing the SRT task could only make a single response. However, it is possible that participants could have engaged in more explicit processing (e.g., hypothesis testing). This outcome is plausible because of the effect of instructional focus on the number of participants to acquire “explicit” knowledge of the pattern. In addition, the participants in the memory-focused condition of the dual-task experiment performed better than the memory-only group from Experiment 2, who were not instructed to react to the strings (1.04 advantage over no-training). This increased benefit from reacting to the stimuli may be due to either increased attention to those stimuli, motor learning processes, or both.

In summary, this analysis shows that as the amount of processing dedicated to the relevant features of the primary task increases, so does the amount of learning of the underlying pattern. Specifically, there was an advantage for single-task versus dual-task learning of the primary pattern (with larger learning gains for grammar versus location learning). In addition, a similar pattern of results was obtained for the nonfocused pattern, but only for location learning (i.e., those who were instructed to react to the location stimuli had larger learning gains than those who were not). These results are consistent with the interpretation that the amount of attention given to the task-relevant aspects of the stimuli modulates the amount of learning.

GENERAL DISCUSSION

The present study introduced a novel incidental learning procedure that allowed for the systematic investigation of the role of instructional focus on learning outcomes. We used a transfer-appropriate processing approach where different instructions were designed to have participants process the stimuli in different ways and focus their attention on different aspects of the stimuli. This design combined the artificial grammar procedure with the SRT task. The goal was to provide a further test of the role of focus of attention and to see how the amount of processing impacts incidental learning.

In Experiment 1 participants performed this dual-component task under two priority conditions. Although the two training groups were focused on processing different aspects of the dual-component stimuli, they still showed significant learning of both patterns. In Experiment 2, this result was extended by investigating how the amount of processing affects incidental learning; participants performed only one of the two training tasks and were expected to focus their attention on a single dimension of the task stimuli. Participants showed better learning for the pattern underlying the task they performed.

These results reveal a complex relationship between instructional focus and incidental learning. They suggest that only a minimal amount of selective attention is necessary for incidental learning to occur, but as the amount of attention to the relevant aspects of the stimuli increases, so does the amount of learning as well as the likelihood to acquire explicit knowledge. That both implicit and explicit knowledge could be acquired concurrently from a single task is consistent with the notion that there are two learning mechanisms (one for explicit and one for implicit processing) that can operate simultaneously (Frensch & Runger, 2003; Goschke, 1997; Haider & Frensch, 2005; Knowlton & Squire, 1993).

As we find out more about the characteristics and properties of incidental learning, we can better articulate how this mode of learning is similar to and different from explicit learning. The results from the present experiments suggest that unlike explicit learning, incidental learning requires only a minimal amount of attention, and people can learn multiple patterns simultaneously without large interference effects. However, the results also show that the two modes of learning are similar, in that as the amount of processing increases, so does the amount of learning. Furthermore, these results suggest that attention allocation may be one key to linking incidental and explicit processing. One hypothesis to explore in future work is the notion that as the attention to patterned stimuli increases, so does the likelihood of triggering an explicit learning mechanism.

As we extend our understanding of the processing differences and parameters of attention required for each learning system, we should be able to determine for a given learning scenario what learning system is triggered—whether it is incidental, explicit, or both—and what type of knowledge is acquired, and then predict the behavioral outcomes for applying that knowledge to novel performance tasks. Future work should examine how incidental and explicit systems interact and determine whether the knowledge acquired from each system is informationally encapsulated (Fodor, 1983) or whether the knowledge acquired from one system affects learning in the other.

NOTES

1. The same effects were found when the six old grammatical items are included in the analysis. We report the effects for the novel items alone because it provides the strongest test of abstract grammar learning.
2. By using participant's difference scores to measure effect size, we can assess the effect of training on test performance while controlling for any learning that may have occurred at test. Learning that occurs during the test is measured by the control group difference scores—that is, their improvements on patterned versus random trials.

AUTHOR NOTES

Timothy J. Nokes is currently an assistant professor of psychology and a research scientist at the Learning Research and Development Center at the University of Pittsburgh. His research examines human learning and aims to understand the mechanisms of cognitive change and their implications for educational practice. **Ivan K. Ash** is currently an assistant professor of psychology in the College of Science at Old Dominion University. His research focuses on the role of automatic and controlled cognitive processes in decision making, judgment formation, and problem solving.

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