An examination of the effects of adult age on explicit and implicit learning of figural sequences

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Memory for previously learned figural sequences and item-to-item covariations within figural sequences was examined under explicit and implicit instructional conditions in three age groups: young adults (17–23 years); middle-aged adults (35–45 years); and older adults (55–65 years). In Phase 1 of the experiment, the acquisition phase, half the subjects in each age group learned sequences of three to eight items in which the item-to-item changes conformed to an artificial grammar, and the other half of the subjects in each age group learned strings in which the item-to-item changes were nongrammatical. In Phase 2, the implicit/explicit test phase, subjects made forced-choice judgments about parts of the strings that they learned in Phase 1, under either explicit or implicit instructions. Analyses of Phase 2 data revealed that subjects in both instructional conditions used item-to-item covariations in making decisions about grammatical strings. However, use of previously learned covariations as well as the number of correct judgments about previously learned strings was greater in the explicit condition than in the implicit condition. An age-related deficit was found for explicit recognition of grammar-following sequences.

In everyday life, people sometimes learn how to perform complex tasks by acquiring and using explicit knowledge of the rules that constitute the task. For example, people solve algebra problems by deliberately or explicitly applying knowledge of mathematical rules. However, it has also been suggested that learning to perform complex tasks might also occur implicitly, without any cognitive effort or conscious awareness of the rules and relations that govern task performance.

The ability to implicitly acquire knowledge of the regularities or of the high-level rules embodied in complex knowledge domains has received considerable attention in recent years. In contrast to explicit learning, *implicit learning* refers to the nondeliberate acquisition of knowledge about the structural relations between objects or events (see, e.g., Frensch, 1998). A number of investigators have pointed out that methodological and procedural flaws limit our understanding of the possible differences between learning under implicit and explicit conditions (e.g., Dulany, 1997; Frensch, 1998; Perruchet, 1994; Redington & Chater, 1996).

A key issue that bears on the usefulness of the distinction between explicit and implicit learning has to do with the nature of the information that is learned. In typical studies of implicit learning using artificial grammar

tasks (e.g., Dienes, Broadbent, & Berry, 1991; Knowlton & Squire, 1996; Perruchet & Pacteau, 1990; Reber, 1989; Reber, Walkenfeld, & Hernstadt, 1991), subjects are given strings of letters to memorize. Unbeknownst to the subjects, the order of the letters is governed by rules of a finite grammar, like that illustrated in the top panel of Figure 1. After studying some number of letter strings conforming to the grammar, subjects are told that the strings share an underlying grammar, and they are asked to make categorical judgments about grammatical and nongrammatical strings. Implicit learning of the abstract structure of the grammar is said to occur if subjects perform at better than chance accuracy in classifying strings as either grammatical or nongrammatical.

In contrast to such abstractionist accounts of implicit learning, some researchers (e.g., Dulany, Carlson, & Dewey, 1984; Perruchet, 1994; Perruchet & Pacteau, 1990) have argued that subjects are learning probabilities of covariation of simple two-letter or three-letter sequences that happen to conform to the grammar, and not a formal representation of the grammar. In the present study, we examined the effects of adult age and implicit and explicit instructional conditions on measures of recognition of learned sequences and item-to-item covariations within sequences.

As Redington and Chater (1996) and others have pointed out, many studies of implicit and explicit learning have not included the necessary control groups. Typically, subjects are given a set of rule-following (RF) strings to learn and are then asked to judge RF strings and non-rule-following (NR) strings in a subsequent test phase. Absent from most designs is a comparison group of subjects given NR strings in the learning phase. In the present experiment, half of the subjects in each age group

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Figure 1. Grammar A was used by Reber, Walkenfeld, and Hernstadt (1991) to generate grammar-following strings of letter sequences. Strings were generated by traversing the diagram from the IN arrow to the OUT arrow, adding a letter at each transition from one state to the next. For example, the letter string TSXXVV is consistent with Grammar A. Grammar B was used in the present experiment. For Grammar B, rule-following strings were formed by traversing the diagram from the IN arrow to the OUT arrow, adding the type of featural change indicated on the arrows.

received RF strings and half of the subjects in each age group received NR strings in the learning phase.

Another relatively unique aspect of the present study has to do with the instructional manipulation that was used. In contrast to instructions typically used (e.g., Dienes et al., 1991; Reber et al., 1991), subjects were given no clues that there were regularities across strings. The subjects who were given explicit instructions were told that the strings would be the same as the ones they had seen in the learning phase, but they were not told that there was a grammar that applied across the strings. The explicit instructions were intended to direct the subjects to make item selection decisions on the basis of their explicit memory for previously learned strings. The implicit instructions were intended to tap implicit learning by asking subjects to complete the test strings without suggesting any connection between previous strings or with any overarching rules.

There were several reasons for selecting figural relations as the domain for this investigation. First, sequences of shape transformations seem to portray a somewhat less artificial progression than do sequences of letter strings. That is, rather than learning sequence of letters, such as TSXXVV, the subjects in the present experiment learned sequences of visual-spatial transformations of a complex figure. The figure changed in size or orientation, or in hav-

ing a piece darkened or removed as the observer looked from left to right. However, just like an artificial grammar that produces sequences of letters, a comparable grammar was used to specify the particular item-to-item changes in the figural sequence.

Another reason for selecting figural relations performance as the task domain is that there are large adult age differences in the ability to extract rules and relations across sequences of figural patterns (see, e.g., Baltes, Sowarka, & Kliegl, 1989; Cattell, 1971; Willis, Blieszner, & Baltes, 1981). In addition to examining age differences in the learning of figural sequences, we examined the relationship between the ability to learn figural relations and psychometrically assessed figural relations ability.

The effects of aging on implicit learning have been investigated in several studies with the use of Nissen and Bullemer's (1987) serial reaction time task (e.g., Cherry & Stadler, 1995; D. V. Howard & J. H. Howard, 1989, 1992; D. V. Howard & Wiggs, 1993). Generally, the results of these experiments suggest that there is an age-related decline in explicit sequence learning, but that implicit forms of learning may be spared. However, in a recent study, using alternating serial patterns and random patterns as stimuli, J. H. Howard and D. V. Howard (1997) reported that there were age-related deficits in the magnitude of implicit serial pattern learning and in the con-

ditions under which learning is revealed. The aim of the present study was to provide a careful examination of the effects of adult age on memory for previously learned figural sequences and item-to-item covariations within these sequences under implicit and explicit instructional conditions.

METHOD

Subjects

A total of 120 subjects participated. The subjects were from three age groups, as follows: 40 were young adults (20 males, 20 females) between 17 and 23 years ($M = 19.1$, $SD = 1.4$); 40 were middle-aged adults (20 males, 20 females) between 35 and 45 years ($M = 39.7$, $SD = 3.2$); and 40 were older adults (20 males, 20 females) between 55 and 65 years ($M = 59.4$, $SD = 2.9$). The young adult subjects were Syracuse University undergraduate volunteers who received course credit for participation. The middle-aged and older subjects were community residents who volunteered in response to newspaper advertisements and were paid for participation. Mean years of formal education for the young adults, middle-aged adults, and old adults were 12.8 ($SD = 1.3$), 15.6 ($SD = 2.7$), and 14.5 ($SD = 2.2$), respectively.

All subjects had normal or corrected-to-normal visual acuity of 20/30 or better as measured by the Titmus II Vision Tester. The subjects were asked to estimate their own health on a 5-point scale ranging from *excellent* (1) to *poor* (5). Mean self-ratings were 1.8 ($SD = 0.8$) for the young adult subjects, 1.8 ($SD = 0.8$) for the middle-aged subjects, and 2.1 ($SD = 0.8$) for the older adults.

Subjects were administered the Digit Span (forward and backward) subtest from the *Wechsler Adult Intelligence Scale-Revised* (Wechsler, 1981). The Digit Span scores for the young adults, middle-aged adults, and older adults were 16.2 ($SD = 3.6$), 16.5 ($SD = 4.1$), and 14.8 ($SD = 4.2$), respectively; the scores for the three age groups were not reliably different [$F(2,117) = 2.06$, $MS_e = 32.9$, $p < .13$]. The subjects were also given four tests known to be strong markers of figural relations abilities (Cattell, 1971; Willis et al., 1981) from the *Culture Fair Test* (Scale 2; Cattell & Cattell, 1960). For the young adults, middle-aged adults, and older adults, the combined scores for the four figural relations tests were 34.8 ($SD = 4.4$), 33.9 ($SD = 3.9$), and 28.9 ($SD = 5.6$), respectively. As expected, the age differences for the figural relations scores were reliable [$F(2,116) = 17.77$, $MS_e = 398.25$, $p < .0001$]. The scores from one middle-aged subject who did not follow the instructions while taking the figural relations test and who scored zero on all subtests were dropped from the analysis. The Pearson correlations between the combined figural relations scores and the four figural relations subtest scores were high, ranging from .56 to .78.

Stimuli and Procedure

The subjects were tested individually in one session that lasted 2.0–3.2 h. Because the session was lengthy, they were given the opportunity to take brief rest breaks. The subjects first completed a biographical information sheet and an informed consent questionnaire, followed by the digit span tests and figural relations tests. Next, the acquisition phase and the implicit/explicit test phase of the string learning task were administered. In Phase 1 of string learning, the acquisition phase, the subjects were presented with 20 strings or sequences of three to eight arrow-shaped items. The items were professionally drawn in black ink on heavy white paper, and the strings of items were arranged in a booklet with pages 11 in. $\times$ 17 in. The items were placed 1.25 in. apart. The largest version of the arrow-shaped item was .75 in. $\times$ 1.25 in., and the smallest version of the item was .5 in. $\times$.88 in. Four types of item transforma-

tions were depicted in the strings as follows: the arrow shape enlarged; the arrow shape rotated clockwise 90°; one of the six ovals contained within the arrow shape removed; or one of the ovals contained within the arrow shape filled in. Only one change occurred from one item to the next item in the string.

The strings were presented one at a time. The subject's task was to learn and recall the sequence of item-to-item changes displayed in each string. The subject was given a template card depicting an arrow-shaped item and was instructed to verbalize the item-to-item changes depicted in each string using the template to illustrate the sequence of left-to-right changes. The subject was given as much time as he or she wanted to study each string. When the subject was ready, the page on which the string appeared was turned to a blank page, and the subject attempted to simultaneously verbalize the sequence of item-to-item changes shown in the string and illustrate the sequence of transformations using the template. The subject was given as many trials as were necessary in order to learn each string to a criterion of two consecutive correct recalls. After the subject correctly described the sequence of changes depicted in a string on two consecutive trials, the next string was presented.

Two sets of 20 strings were constructed. For the RF set, the item-to-item changes shown in the 20 strings conformed to an artificial grammar (see panel B of Figure 1). This grammar was adapted from the one shown in panel A of Figure 1 used previously by Reber (1989) and others and was modified for the purpose of presenting figural sequences rather than letter sequences. For the NR set, the item-to-item changes in the strings were random.

In Phase 2, the implicit/explicit test phase, subjects were given the same 20 strings presented in Phase 1, except that a pair of two items was removed from each string and was replaced by an empty box and two pairs of items below the box. Both of the pairs of items completed the sequence of items, but one of the choices (50% A and 50% B) made the string identical to one of the strings shown in Phase 1. For the RF strings, the incorrect choice violated one or more of the rules of the grammar. The positions of test items within the strings was varied in a way that would permit an analysis of the degree of learning of covariations in the RF sequences. In other words, the locations of the missing pairs varied across the strings, and the locations and features of the missing items were identical for RF and NR strings. Depending on the location of the missing pair, the choices of pairs in Phase 2 represented either two or three sequential operations; that is, pairs of items at the end of a string involved two operations, and pairs of items positioned elsewhere in the strings involved three operations.

In Phase 2, the subjects were given either explicit instructions or implicit instructions. The subjects receiving explicit instructions were told to pick the pair of items that completed the string so that it would be identical to one of the strings presented in Phase 1:

You will now be presented the same twenty strings you have just memorized. The only difference will be that two shapes are missing from each string. In their place is an empty box with two choices below it, A or B. Your task is to complete the string with the pair of items that makes the string identical to one of the strings you have previously seen.

Subjects receiving implicit instructions were told to select the pair of shapes that best completed the string, without any reference to the previously presented strings:

Your next task will be to help us generate more strings for other subjects in this study. Please choose the pair of shapes that you feel best completes the string in a reasonable manner.

Each of the 20 strings was presented one at a time. After completing Phase 2, the subject was thoroughly debriefed and questioned regarding the extent to which he or she was aware of a rule. Each subject in the implicit instructions condition was also ques-

Table 1
Percentages of Occurrence of Each Type of
Item Change by Position for Rule-Following (RF)
and Non-Rule-Following (NR) Strings

Item Change	Position							
	1	2	3	4	5	6	7	8
RF Strings								
Lose	.50	0	.15	.11	.13	.17	.38	0
Rotate	0	.55	.45	.39	.33	.67	.38	.75
Fill	.50	.30	.20	.17	.20	.08	.25	.25
Enlarge	0	.15	.20	.33	.33	.08	0	0
NR Strings								
Lose	.25	.20	.15	.28	.27	.08	.50	.25
Rotate	.25	.25	.30	.33	.53	.58	.13	.50
Fill	.30	.45	.20	.11	.07	.17	.38	.25
Enlarge	.20	.10	.35	.28	.13	.17	0	0

tioned about whether he or she noticed any similarities between the strings in Phase 1 and Phase 2. No subjects in the RF condition reported any awareness that the RF items followed a grammar.

RESULTS

The duration of Phase 1 was much shorter for younger adults than for middle-aged and older adults, and younger adults generally required fewer trials to reach the acquisition criterion of two correct recalls for each sequence than did the older groups. However, because there were large individual differences in the amount of experimenter–subject interaction in Phase 1, and because there seemed to be large within-group differences in the number of trials that the subjects required in order to reach the acquisition criteria, it was inappropriate to submit the Phase 1 data for statistical analysis. One feature of the design of this experiment was to ensure that all subjects attained an equivalent level of learning for each and all of the 20 strings in Phase 1. Thus, for the primary analysis, a 3 (age) $\times$ 2 (gender) $\times$ 2 (condition) $\times$ 2 (instructions) analysis of variance (ANOVA) was computed for the number of correct responses in Phase 2. All four factors were between subjects. For all of the effects examined, the significance level was set at $p < .05$, and reliable interactions were analyzed using planned comparisons with the significance level set to $p < .025$. Because no main effect of gender or interactions involving gender were obtained, the data were reanalyzed, collapsing over this variable.

The ANOVA revealed main effects of condition and instructions. The main effect of age did not reach significance [$F(2,100) = 2.53$, $MS_e = 13.2$, $p < .08$]. The subjects given RF strings were more accurate than the subjects given NR strings [$F(1,100) = 14.03$, $MS_e = 73.2$, $p < .001$]. The subjects given explicit instructions were more accurate than the subjects given implicit instructions [$F(1,100) = 61.31$, $MS_e = 319.76$, $p < .001$].

These main effects were qualified by the two-way interactions of instructions $\times$ age [$F(2,100) = 5.1$, $MS_e = 26.62$, $p < .008$] and condition $\times$ instruction [$F(1,100) =$

6.02, $MS_e = 31.41$, $p < .02$]. Analysis of simple effects within the instructions $\times$ age interaction indicated that there were age differences for the subjects who received explicit instructions [$F(2,54) = 4.71$, $MS_e = 31.97$, $p < .01$], but no age differences for subjects who received implicit instructions [$F(2,52) = 0.94$]. The means for the young, middle-aged, and older adults who received the explicit instructions were 14.9 ($SD = 2.2$), 13.6 ($SD = 2.9$), and 12.0 ($SD = 2.6$), respectively.

Breakdown of the condition $\times$ instructions interaction suggested that the difference between learning RF strings and NR strings was significant when subjects were given the explicit instructions [$F(1,55) = 15.55$, $MS_e = 94.83$, $p < .001$]; there was no difference in performance for subjects given the implicit instructions [$F(1,53) = 0.64$, $p < .42$]. The performance of subjects who were given implicit instructions was at chance level for both RF strings ($M = 10.5$, $SD = 2.5$) and NR strings ($M = 10.0$, $SD = 2.1$), and the benefits of exposure to a consistent grammar across strings emerged only with explicit instructions. For the subjects given explicit instructions, the means for the RF and NR strings were 14.7 ($SD = 2.9$) and 12.2 ($SD = 2.2$), respectively.

The Phase 2 data were further analyzed by examining the extent to which subjects relied on item-to-item covariations within the RF and NR strings as a function of implicit and explicit instructions. Each of the two response pairs in Phase 2 consisted of two items, each representing either two or three item-to-item, rule-based operations. Following Perruchet (1994), covariation probabilities were determined for each item-by-item transformation based on the frequencies of particular types of transformations occurring at particular positions in the sequence. The probabilities of each of the types of item-to-item changes by positions are presented in Table 1.

The percentages of occurrence associated with each operation at each location were multiplied together to determine the overall probability of occurrence of each choice of pairs (A or B). To account for the relative difficulty of the choice between A and B, the probability for the incorrect choice was subtracted from the probability for the correct choice, thereby to determine the derived covariations across positions for each string in Phase 2. By taking the subjects' correct responses and dividing by the total number of responses, a percent correct score was calculated for each string. These percentages were then correlated with the derived covariations presented in Table 1 for each of the 20 RF and 20 NR strings. Plots of these results by groups are shown in Figure 2. There was a relationship between performance and the derived covariations for the RF strings ($r_s = .5$ and $.36$), but not for the NR strings ($r_s = .14$ and $-.05$). These results indicate that subjects in both instructional conditions used covariations within sequences in making decisions about RF strings. Note that the values of the fits for the regression lines are small, even for the fit of the correlations for the subjects receiving explicit instructions and RF strings ($R^2 = .27$), because the strings differed

Figure 2. The four panels show the patterns of relationship between performance and derived covariations for each of the 20 rule-following (RF) and non-rule-following (NR) strings for subjects in the explicit and implicit instructional conditions. The correlations are reliable for subjects receiving the RF strings with explicit instructions ($r = .50$) and implicit instructions ($r = .36$), but not for subjects receiving the 20 NR strings ($r_s = -.05$ and $.14$).

from each other in terms of the difficulty of the choice between A and B. To illustrate, for the subjects who received the RF strings (the left panels of Figure 2), one of the strings involved a relatively easy choice between A and B, as is indicated by a derived covariation of .21; 85% of the subjects who received explicit instructions, and 68% of the subjects who received implicit instructions, selected the correct choice on this string. In contrast, for another string, the incorrect choice actually appeared more consistent with the grammar than did the correct choice, as is indicated by the derived covariation of $-.08$. Less than half of the subjects responded correctly to this string; 50% of the subjects in the explicit instruction condition and 36% of the subjects in the implicit instruction con-

dition responded correctly on this string. Even though there was a small (and unintended) amount of consistency in the covariations in the NR strings, there was no evidence of acquisition of item-by-item covariations for the subjects who received the NR strings ($r_s = .14$ and $-.05$). Correlations between percent correct and derived covariations were not computed separately for each of the age groups by type of strings and instruction conditions because the small numbers of data in these cells would have prohibited meaningful interpretation.

Finally, the relationship between grammar learning and figural relations ability was examined by calculating the simple correlation between the sum of the scores on the four figural relations subtests and the number correct re-

sponses for subjects receiving RF strings with explicit instructions ($N = 30$). A Pearson coefficient of $r = .51$ was obtained; thus, there was a significant relationship between rule extraction and psychometrically assessed figural relations ability when subjects were specifically instructed to use their prior knowledge of the strings. For the two groups of subjects given NR strings and for the group of subjects given RF strings with implicit instructions, the correlations between figural relations performance and performance in Phase 2 were unreliable.

DISCUSSION

In the present experiment, we examined adult age differences in the recognition of previously learned figural sequences under implicit and explicit instructional conditions. As predicted, there was an age-related deficit in the explicit recognition of previously learned strings, even though all subjects learned each of the strings to the same criterion. No evidence for implicit learning of the strings was obtained for any of the age groups. The subjects not told to explicitly remember previously learned sequences performed at chance in Phase 2, regardless of whether or not the strings were grammatical or non-grammatical. However, analyses of item-by-item covariations revealed that subjects in both instructional conditions used some of the simple relationships between items in the grammar in making decisions about grammar-following strings.

Consistent with recent interpretations offered by Perruchet and others (see, e.g., Dulany, 1997; Frensch, 1998; Perruchet, Vinter, & Gallego, 1997), the findings of the present study suggest that the activation of learned knowledge structures following memorization depends on explicit instructions. Group differences in recognizing previously learned RF and NR strings were evident only for subjects who were explicitly told that they would be making judgments about the strings that they had learned in Phase 1. Second, use of previously learned covariations was greater for subjects receiving explicit instructions than for subjects receiving implicit instructions. Thus, it seems that merely informing the subjects that they would be seeing the same strings as before was sufficient for them to retrieve a greater number of RF strings and to rely more on item-to-item covariations inherent within strings. The results of this study also suggest that individual differences in educating or extracting figural relations is associated with the ability to explicitly use knowledge of item-by-item covariations.

REFERENCES

- BALTES, P. B., SOWARKA, D., & KIEGL, R. (1989). Cognitive training research on fluid intelligence in old age: What can older adults achieve by themselves? *Psychology & Aging*, 4, 217-221.
- CATTELL, R. B. (1971). *Abilities, their structure, growth, and action*. Boston: Houghton-Mifflin.
- CATTELL, R. B., & CATTELL, A. K. S. (1960). *Handbook for the individual or group culture fair intelligence tests: Scales 2 and 3*. Champaign, IL: Institute for Personality and Ability Testing.
- CHERRY, K. E., & STADLER, M. A. (1995). Implicit learning of a non-verbal sequence in younger and older adults. *Psychology & Aging*, 10, 379-394.
- DIENES, Z., BROADBENT, D., & BERRY, D. (1991). Implicit and explicit bases in artificial grammar learning. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 17, 875-887.
- DULANY, D. E. (1997). Consciousness in the explicit (deliberative) and implicit (evocative). In J. D. Cohen & J. W. Schooler (Eds.), *Scientific approaches to the question of consciousness* (pp. 179-212). Mahwah, NJ: Erlbaum.
- DULANY, D. E., CARLSON, A., & DEWEY, G. I. (1984). A case of syntactical learning and judgment: How conscious and how abstract. *Journal of Experimental Psychology: General*, 113, 541-555.
- FRENSCH, P. A. (1998). One concept, multiple meanings: On how to define the concept of implicit learning (pp. 47-104). In M. A. Stadler & P. A. Frensch (Eds.), *Handbook of implicit learning*. Thousand Oaks, CA: Sage.
- HOWARD, D. V., & HOWARD, J. H., JR. (1989). Age differences in learning serial patterns: Direct versus indirect measures. *Psychology & Aging*, 4, 357-364.
- HOWARD, D. V., & HOWARD, J. H., JR. (1992). Adult age differences in the rate of learning serial patterns: Evidence from direct and indirect tests. *Psychology & Aging*, 7, 232-241.
- HOWARD, D. V., & WIGGS, C. L. (1993). Aging and learning: Insights from implicit and explicit tests. In J. Cerella, J. M. Rybash, W. J. Hoyer, & M. L. Commons (Eds.), *Adult information processing: Limits on loss* (pp. 511-527). San Diego: Academic Press.
- HOWARD, J. H., JR., & HOWARD, D. V. (1997). Age differences in implicit learning of higher order dependencies in serial patterns. *Psychology & Aging*, 12, 634-656.
- KNOWLTON, B. J., & SQUIRE, L. R. (1996). Artificial grammar learning depends on implicit acquisition of both abstract and exemplar-specific information. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 22, 169-181.
- NISSEN, M. J., & BULLEMER, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology*, 19, 1-32.
- PERRUCHET, P. (1994). Learning from complex rule-governed environments: On the proper functions of nonconscious and conscious processes. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance XV: Conscious and nonconscious information processing* (pp. 811-836). Cambridge, MA: MIT Press.
- PERRUCHET, P., & PACTEAU, C. (1990). Synthetic grammar learning: Implicit rule abstraction or explicit fragmentary knowledge. *Journal of Experimental Psychology: General*, 119, 264-275.
- PERRUCHET, P., VINTER, A., & GALLEGO, J. (1997). Implicit learning shapes new conscious percepts and representations. *Psychonomic Bulletin & Review*, 4, 43-48.
- REBER, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General*, 118, 219-235.
- REBER, A. S., WALKENFELD, F. F., & HERNSTADT, R. (1991). Implicit and explicit learning: Individual differences and IQ. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 17, 888-896.
- REDINGTON, M., & CHATER, N. (1996). Transfer in artificial grammar learning: A reevaluation. *Journal of Experimental Psychology: General*, 125, 123-138.
- WECHSLER, D. (1981). *Wechsler Adult Intelligence Scale-Revised*. New York: Psychological Corporation.
- WILLIS, S. L., BLIESZNER, R., & BALTES, P. B. (1981). Intellectual training research in aging: Modification of performance on the fluid ability of figural relations. *Journal of Educational Psychology*, 73, 41-50.

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