OBSERVATIONS

Automatic Mediation or Absence of Mediation? Commentary on Crutcher and Ericsson (2000)

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R. J. Crutcher and K. A. Ericsson (2000) showed that subjects stopped reporting mnemonic mediation in a recall task after sufficient practice. They concluded that subjects continued to use the mediator indefinitely but that its execution eventually became automatic and no longer required access to working memory. Their article thus supports the more general hypothesis that multistep cognition can take place without awareness. In this article the authors evaluate that conclusion on both conceptual and empirical grounds and report results of a new experiment that indicate that a qualitative shift to direct, unmediated recall can occur for at least some tasks.

An active question in the area of memory and automaticity is whether mnemonic mediators, which are often used spontaneously in recall tasks (e.g., Bower, 1972; Richardson, 1998), can be bypassed after retrieval practice in favor of independent, unmediated associations that directly link the cue and the response. Subjects sometimes report that mnemonic mediators drop out of awareness after practice. When a cue is presented, the answer comes to mind directly, without any intermediate thoughts (e.g., Crutcher & Ericsson, 2000). However, as Adams and McIntyre (1967) pointed out (see also Bellezza & Poplawsky, 1974; Bellezza, Poplawsky, & Aronovsky, 1977; Crutcher & Ericsson, 2000), such reports do not necessarily imply a transition to direct, unmediated retrieval. Instead, it is possible that the original mnemonic pathway continues to be used, albeit at an automatic level outside of awareness. We refer to this hypothesis as *automatic mediation*.[1] According to this account, the mediating representations are no longer available in working memory and thus are not reportable. Rather, they are activated only in long-term memory.

Resolution of this issue should be helpful in gaining an understanding of the role of awareness in mental processing more generally. If in memory tasks people can execute multistep mnemonics outside of awareness (i.e., in a manner that is not reportable), then the door is open to any number of other relatively high-level cognitive processes operating outside of awareness. Alternatively, if there is a transition to unmediated retrieval after practice, with no intermediate stage of performance involving automatic mediation, then awareness and working memory activity

might best be seen as a necessary condition, or at least as a necessary consequence, of any cognitive operation that involves access to a long-term memory representation for purposes of performing a goal-directed task.

This issue may also be important in a more practical sense. If a mnemonic that is once used must always be used, then performance at high practice levels may be forever slower and more error prone in comparison with items for which direct, unmediated retrieval is available from the start. This scenario would be unfortunate if true because there is little doubt that initial memorization is enhanced by bootstrapping through mnemonics (for reviews, see Montague, 1972; Richardson, 1998). On the other hand, if subjects can generally make a transition to optimal, unmediated retrieval after moderate practice, then there is little justification for discouraging use of mnemonics during initial learning, as has sometimes been the case in educational settings.

In an important contribution to this issue, Crutcher and Ericsson (2000) explored the effects of practice on mnemonic mediation using the keyword foreign-vocabulary-learning task (Atkinson, 1975; Atkinson & Raugh, 1975; Raugh & Atkinson, 1975). In that task, subjects first extract a native language (e.g., English) keyword that sounds similar to the foreign word and then use that keyword as a cue to retrieve an interactive image involving the translation. For example, the Spanish word for dog is *perro*. In the keyword method, subjects might be instructed to extract the keyword *pear* out of *perro* and then to form an interactive image, such as an image of a dog eating a pear. Upon future presentation of the foreign word, subjects can usually extract the keyword and recall the interactive image with relative ease, making the method an effective learning tool.

In their last experiment, Crutcher and Ericsson (2000) used a novel interference manipulation to test for the presence of auto-

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[1] Crutcher and Ericsson (2000) referred to this process as *covert mediation*. Because the word *covert* may seem to imply strategic deception by the subjects, which is not a part of the hypothesis, we refer instead to *automatic mediation*.

matic mediation. Subjects first received extensive practice on the foreign-vocabulary task. Next, for half of the Spanish words, subjects were trained to associate the keyword with a new English word that had not been seen prior to that point. For example, the keyword *pear* for the Spanish word *perro* would be associated with a new English word (e.g., *tree*). That phase of the experiment constituted the interference manipulation. Afterward, subjects were again tested on the main vocabulary task for all items. The authors reasoned that if subjects had made a transition to unmediated retrieval during the preinterference vocabulary practice phase, their vocabulary task response times (RTs) during the postinterference practice phase would not depend on whether the item's keyword had been associated with a new English word during the interference manipulation. On the other hand, in light of well-established memory-interference principles, if subjects had merely automated the keyword and imagery steps of the mnemonic, then their performance on main-task trials would be worse for items for which the keywords had been associated with new English words. As predicted by the automatic mediation account, postinterference vocabulary task RTs were slower for items that had been subject to the interference manipulation.

A Critique of the Automatic Mediation Account

A close examination of Crutcher and Ericsson's (2000) results, however, casts doubt on their account. First, their interference manipulation yielded an association from the keyword directly to the interfering English word. Hence, on the subsequent vocabulary trials, that manipulation must have had its effect immediately prior to the interactive-image stage of processing. Figure 1 depicts this fact. Their finding of RT slowing for the interference items thus appears to have no bearing on whether subjects continued to use the interactive image at an automatic level after practice (i.e., the solid arrows in Figure 1 up to the interactive image, dog eating a pear, and the dashed arrow from the interactive image to the response, dog) or instead bypassed that stage entirely (as represented by the dotted arrow from *pear* to *dog* in Figure 1). The latter case is an example of a partial transition to unmediated performance. In either case, RT slowing would be expected in their interference manipulation, provided only that subjects continued to
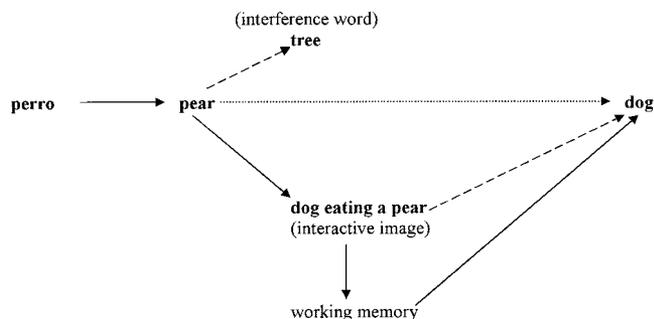

Figure 1. Hypothetical retrieval pathways for a sample item in the keyword foreign-vocabulary-learning task. The solid arrows represent the initial, mediated retrieval route, assumed in both models; the dotted arrow represents a direct link between pear and dog; the dashed arrows represent other long-term memory associations.

extract the keyword as the first processing step for at least some items.

Although continued keyword access could in itself be construed as a type of automatic mediation, it can also be understood in other ways. The keyword, by definition, is phonemically related to the foreign word. Indeed, for more than half of the items in Crutcher and Ericsson's (2000) experiments, the phonemes of the keyword were a proper subset of those of the foreign-word stimulus (see their Appendix D). Under such conditions, Haider and Frensch's (1996) information-reduction model appears to be applicable. They found that if part of a stimulus was irrelevant to a task (even if unbeknownst to the subjects), subjects would learn to ignore it and instead only attend to the relevant part. In the case of the keyword task, their model appears to predict that subjects would learn to extract the keyword automatically as a first step in processing the stimulus. The principle of information reduction suggests that this process might occur without awareness and thus may not be reportable.

Also, extraction of a phonologically related subset of a stimulus is neither a global nor even typical property of mnemonics. Thus, regardless of whether one prefers to classify continued use of the keyword in the Crutcher and Ericsson (2000) experiments as automatic mediation or information reduction, their results should not lead one to the conclusion that, as a general rule across different tasks, the original mediation pathway continues to govern retrieval performance in an automatic fashion.

Second, Crutcher and Ericsson (2000) took their findings that practice on the full vocabulary task facilitated subsequent performance on the English subtask (i.e., the keyword to English word translation), and vice versa, as evidence against a shift to unmediated retrieval with practice. We would argue, however, that those findings are consistent with such a shift. Prior to the shift for most items, subjects in effect practice the English subtask—in the context of practicing the mnemonic mediator for the vocabulary task—on multiple trials. It is not surprising that such practice can facilitate English subtask performance on a subsequent test. Crutcher and Ericsson dismissed this account on grounds of parsimony, but we see no violation of that principle. The same memory system could strengthen both the subtask and direct associative connections during, and/or after, each trial on which the mnemonic mediator is used. In fact, this is exactly the assumption in Rickard's (1997) model of strategy shifts in related skill learning tasks. A similar account applies to their finding that subtask practice facilitated subsequent performance on the full vocabulary task. Provided that their subjects had not typically made a transition to unmediated retrieval by the end of the initial vocabulary test (which the evidence showed), then it is not surprising that subsequent subtask practice facilitated use of full mediation on the final vocabulary task.

Third, in their Experiments 3 and 4, Crutcher and Ericsson (2000) found that postpractice vocabulary task RTs had become significantly faster than English subtask RTs. As they noted, these results would seem to constitute evidence in favor of a transition to unmediated retrieval. However, in a position presumably motivated by their interference findings, Crutcher and Ericsson argued otherwise. They suggested that automatic mediation, which does not require that intermediate results of the mnemonic be loaded into working memory, can be executed faster than can the English subtask, even though the vocabulary task involves two subtasks,

one of which is the English subtask. It is unclear, however, whether or how such an account could be implemented in a more specific process model.

Experiment

In this experiment we sought to buttress the arguments above by demonstrating that a shift to direct, unmediated retrieval with practice does occur for at least one task. Subjects learned a set of eight color-word to letter (henceforth denoted as color-word → letter) associations, followed by a set of letter to digit (henceforth denoted as letter → digit) associations, where the set of stimulus letters was the same as the set of response letters in the preceding phase. In the subsequent main task, subjects received extensive practice retrieving the appropriate digit when presented with the color-word cue. Next, an interference phase analogous to that of Crutcher and Ericsson (2000, Experiment 4) was administered to determine whether subjects had made a transition to automatic mediation or unmediated retrieval as a result of the main task practice.

Method

Subjects. Twenty-seven University of California, San Diego undergraduate students participated for course credit or financial reward.

Materials, design, and procedure. The test stimuli consisted of eight color words (e.g., *RED*) and eight individual letters (e.g., *H*), for which the subject provided vocal responses. All letters and words were presented in uppercase with a standard letter width and height of 3 mm × 5 mm. Responses consisted of eight letters (corresponding to the same letters that were used as stimuli) and the digits 1 through 9, excluding the number 8.[2]

Subjects were tested individually on IBM-compatible PCs. All experiments were programmed using the Micro Experimental Laboratory (Schneider, 1988) software (Version 2.01) and accompanying voice-key apparatus (Model 200A). Each subject was seated about 50 cm from a 35.5-cm color monitor and approximately 5 cm from a microphone. Subjects were instructed to place their elbows near the edge of the table, with each hand resting on the opposite arm, keeping the subject at a roughly constant distance from the microphone and monitor. The program was then initiated, and the experimenter read aloud the instructions presented on the screen while the subject read along silently. Instructions were presented in this manner at the start of each phase of the experiment. An overview of the experimental phases is given in Table 1.

Phase 1 involved training of the color-word → letter associations. On each trial of the first few blocks of this phase, subjects were simultaneously presented with a color-word stimulus (e.g., *GREEN*), the answer (e.g., *F*), and instructions to memorize the answer. After 5 s, these instructions were replaced by instructions to vocally make the correct letter response when ready. After the subject responded, the computer presented the next item. After completing three blocks of these study trials, subjects were asked whether they felt sufficiently comfortable with the task to proceed to the trials in which they would be required to generate the answers from memory. If they responded "no," they were allowed one additional study block.

Next, subjects performed several blocks of production trials for the color-word → letter associations, in which they were required to produce the response letter when presented with the color-word. Each trial proceeded as follows: (a) the screen went blank for 200 ms, (b) an asterisk fixation point appeared in the center of the screen for 500 ms, (c) the screen went blank as before, and (d) the color-word stimulus was presented, centered on the location of the preceding asterisk. On presentation of the stimulus, subjects were required to speak into the microphone the answer they had earlier memorized as quickly and as accurately as possible. After

Table 1

An Outline of the Experiment With Two Example Items

Phase	Stimulus	Description	Response	No. of blocks
		Study blocks		
1	GREEN = F		"F"	3–4
	RED = Q		"Q"	
		Production blocks		
1	GREEN	⟶	"F"	Varies
	RED	⟶	"Q"	
		Study blocks		
2	F = 5		"5"	3–4
	Q = 9		"9"	
		Production blocks		
2	F	⟶	"5"	Varies
	Q	⟶	"9"	
		Main task phase		
3	GREEN	→ (F) →	"5"	60
	RED	→ (Q) →	"9"	
		Production blocks		
4	F	⟶	"5"	2
	Q	⟶	"9"	
		Study + production blocks		
5	F = 1		"1"	3–4
	GREEN	⟶	"5"	
	RED	⟶	"9"	
		Interference phase		
6	F	- - - →	"1"	30
	GREEN	⟶	"5"	
	RED	⟶	"9"	
		Manipulation check phase		
7	F	⟶	"5"	10
	Q	⟶	"9"	

Note. Arrows indicate memory retrieval. The dotted arrow indicates retrieval of a response that differs from that learned in Phase 2.

the subject responded and the voice key tripped, the experimenter used the computer keyboard to enter the subject's response, then pressed the EN-TER key. If the voice key failed to trip as the subject vocalized his or her response, or if it tripped too soon (e.g., if the subject vocalized an "uh" before answering), the experimenter entered the subject's response, but then pressed the hyphen key, providing a record of trials in which voice key failures occurred. The computer then provided accuracy feedback and, if the subject was in error, presented the correct response. Each block concluded by listing the percentage of accurate responses and the mean RT of correct responses. The subject continued to receive these blocks until he or she completed three consecutive blocks with 100% accuracy, a mean RT

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[2] The numeral 8 was excluded simply because pilot data indicated that subjects were unusually likely to find mnemonics that rhymed with it, making performance on this item different than on the others.

of 1,000 ms or less on the last block, and mean RTs of 1,200 ms or less on the two preceding blocks.

In Phase 2, the letter → digit phase, subjects were taught to give a unique spoken digit response for each of the eight letter stimuli. This phase exactly matched the preceding color word → letter phase, save for the fact that the cues consisted of letters, and the responses consisted of digits. Thus, by the end of the second phase, each color-word had been associated with a particular letter and each letter had been associated with a particular digit such that each of eight unique stimulus–response triplets could be diagrammed as follows: color-word → letter → digit.

In the instructions that preceded Phase 3 (the main task phase), subjects were told that in the following blocks, they would again be presented with the color-words that they had seen in Phase 1 but that rather than directly speaking the letter associated with a particular color word, they should say only the digit that was associated with that letter. In terms of basic structure, trials in this phase matched those of production blocks from the preceding phases. There were a total of 60 blocks in this phase, and subjects were permitted to take brief breaks after Blocks 20, 39, and 57.

Phase 4 was identical to the production blocks of Phase 2, except that each subject received only two blocks. These data allowed us to determine whether main task RTs had fallen below the letter → digit component task RTs by the end of the main task phase.

Phase 5 was a preliminary phase prior to the primary interference phase, in which subjects studied the interference associations while also continuing to perform the main task. It involved interleaved blocks of (a) study of four new letter → digit interference associations and (b) production trials for the main task, just as in Phase 3. The four letter stimuli and digit responses that were remapped to create the interference items were selected randomly, as were the four new letter–digit pairings. Each interference block consisted of four study trials, one for each new interference item. In this phase, each subject received three mandatory pairs of interference and main task blocks, as well as an optional fourth pair of such blocks.

Phase 6, the interference phase, was identical to the preceding phase, with the exception that the remapped letter → digit interference blocks were production blocks instead of study blocks. Each subject received 30 blocks of the interference task and 30 blocks of the main task, interleaved, with brief breaks permitted after Blocks 9 and 23.[3]

Prior to Phase 7 (the manipulation check phase), subjects were instructed that they would once again be presented with letter stimuli and that in all cases they should give the original responses that they had learned in Phase 2. These trials were identical to production trials of Phase 2. Subjects received 10 blocks, after which the experiment concluded.

Results

The data from Phases 1 and 2 were not analyzed. From the main task phase (Phase 3) onward, the voice key failed to trip correctly on a total of 2.1% of trials. These trials were removed from all subsequent analyses. Overall accuracy in the main task phase was 0.973, ranging from 0.963 on the first block to 1.000 on the 60th block. As expected, accuracy did not differ for the interference and control items in the main task phase (0.974 and 0.972, respectively). Overall proportion correct for main task items during the interference phase (Phase 6) was 0.987 for both the control and interference items, and there was no interaction with practice block. If interference was occurring for the main task items during the interference phase, it certainly did not manifest in terms of accuracy. For the four new letter → digit items in the interference phase (the interference manipulation), overall accuracy was 0.961, ranging from 0.860 on the first block to 0.988 on the 30th block.

Mean correct RTs during the main task phase (Phase 3) are shown on the left side of Figure 2, separately for interference and
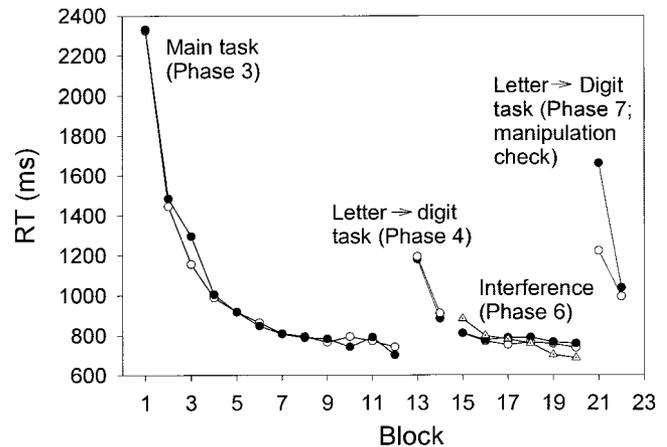

Figure 2. Mean response time (RT) performance as a function of practice block for selected phases of the experiment. Solid circles represent means for the interference items, and open circles represent means for the control items. Triangles represent the letter → digit interference blocks. For the main task and interference phases, each point represents the average of five consecutive practice blocks. For the letter → digit phases, each point represents one practice block.

control items, and averaged over consecutive five-block sequences, yielding 12 superblocks from the original 60. Data were averaged first within-block for each subject, then across all blocks within each superblock for each subject, and then over subjects. As expected, there were no significant visual or statistical differences between the interference and control items at any point during this phase. The large decrease in main task RTs with practice is consistent with a qualitative process shift, either to automatic mediation or unmediated retrieval. At the end of that phase, mean RTs were around 750 ms, a speed well within the range that has been observed in other studies when subjects report using a direct retrieval strategy.

The letter → digit subtask RTs on the two blocks immediately following the main task (Phase 4) were much slower than the RTs on the last main task superblock (see Figure 2). Two matched *t* tests, comparing the mean main task RT on the last superblock to the mean RT on the first and second Phase 4 letter → digit blocks (averaging over the interference and control conditions because there was no effect at this point), were both highly significant, $t(26) = 6.26$, $p < .001$, and, $t(26) = 4.21$, $p < .001$, for the comparison to the first and second letter → digit blocks, respectively. These results, which replicate those of Crutcher and Ericsson (2000, Experiments 3 and 4), appear

[3] Crutcher and Ericsson (2000) did not interleave the interference and vocabulary task blocks. Our interleaving approach has the advantage that no main task forgetting should occur during the interference phase. It should also yield a potent interference effect if subjects continue to use the letter as a mediator for the main task automatically or not. Postman and Parker (1970) showed that, even if subjects continued to retrieve the first response during the A–Br transfer phase of an A–B, A–Br paradigm, recall accuracy of the first response was significantly reduced during transfer, relative to a control condition (for the case in which accuracy was measured by whether the response was correct given the stimulus).

to be most consistent with a shift to unmediated retrieval. As we noted in the model critique section, it is not clear how one would reconcile this finding with automatic mediation in a detailed process model.

The main task RT results during the interference phase (Phase 6) are shown on the right side of Figure 2, along with RTs for the remapped letter → digit interference blocks (the triangular symbols in Figure 2) that were interleaved with the main task blocks. Here again, the 30 blocks for each task were grouped into 6 superblocks. Throughout that phase, there was again no visual evidence of any significant difference between interference and control main task RTs. The remapped letter → digit RTs decreased markedly with practice, falling below the main task RTs toward the end. The latter effect probably reflects the fact that there were only four letter → digit items in those blocks, as opposed to eight items in the main task blocks. A 2 (type: control vs. interference) × 6 (superblocks) within-subjects analysis of variance (ANOVA) was performed on the subject means for the main task items. There was a main effect of superblock, $F(5, 130) = 4.36$, $p < .01$, but there was no effect of type, $F(1, 26) = 2.49$, $p > .10$, nor was there a Type × Superblock interaction, $F(5, 130) = 0.63$. In contrast to the Crutcher and Ericsson (2000) results, the interference manipulation evidently did not influence main task performance.

The manipulation check results (Phase 7), in which subjects were asked to retrieve all of the original letter → digit items, are shown at the far right of Figure 2. A 2 (type: control vs. interference) × 2 (practice phase) within-subjects ANOVA was performed to determine whether there was a significant interference effect. For the practice phase factor, the main task mean RTs on the last superblock of the interference phase were compared with the mean RTs on the first block of Phase 7. The effects of practice phase, $F(1, 26) = 38.42$, $p < .001$; type, $F(1, 26) = 6.72$, $p < .05$; and their interaction, $F(1, 26) = 5.07$, $p < .05$, were all significant. There were no significant effects of either type or the Type × Practice Phase interaction in an identical analysis comparing the last superblock on the main task to the second block of Phase 7, although the effect of practice phase was still significant, $F(1, 26) = 22.3$, $p < .001$. The same results held when the same analysis was performed on subsequent blocks of Phase 7 (not shown in Figure 2). These latter findings indicate a fast recovery of the original letter → digit associations. Fast recovery from associative interference is not uncommon in the literature. It should also be kept in mind that there were only four items in each condition of these analyses, reducing statistical power relative to other analyses.

These results show that subjects did not continue to mediate through the letter after practice, and they strongly suggest a transition to direct, purely unmediated retrieval. It remains possible, however, that subjects discovered secondary mediators after some practice. By *secondary mediation,* we refer to a mnemonic that provides a pathway to the answer that does not use the instructed letter mediator. The RT interference manipulation in Experiment 1 was only sensitive to the possibility of automatic mediation through the letter. Verbal protocols that were collected from a second set of subjects, however, appear to eliminate this as a sufficient account.[4]

Discussion

We have shown that Crutcher and Ericsson's (2000) conclusion in favor of automatic mediation after practice is unwarranted. Our alternative framework, which postulates a transition to unmediated retrieval, combined with an information-reduction process when applicable, is sufficient to account for their findings and appears to be necessary to account for the current findings. There are of course several differences between our task and theirs that could also be pivotal, including our use of a different mediator and a smaller set of items and our interleaving of main task and interference items during the interference phase. However, our main experimental goal here was simply to demonstrate that a transition to direct retrieval does occur in at least some task domains.

The lack of evidence for automatic mediation suggests to us the following working principle: Awareness, as indexed by reportable working memory activity, always accompanies activation of any intermediate long-term memory representation that can in turn be used successfully as a cue for another retrieval (i.e., another step of a mnemonic) in the service of a goal-directed task. Note that implicit priming is not inconsistent with this hypothesis, because it simply reflects partial activation of memory nodes one link, or perhaps two, away from the presented cue (McNamara, 1992). It does not in itself reliably trigger response execution in a goal-directed task. We suspect, in fact, that processing outside of awareness in higher cognition involves little more than priming of associates, schemata, and emotions.

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[4] Retrospective reports were collected after each trial for a second set of 12 subjects, using a technique very similar to that used by Crutcher and Ericsson (2000; see also Ericsson & Simon, 1993). This experiment was otherwise identical to the one that is described in the main text, with the exception that it ended after subjects completed the main task phase (Phase 3). These subjects reported using direct, unmediated retrieval on 98% of the trials between Blocks 50 and 60 of the main task, a result which converges nicely with the finding of the main RT experiment. Reports that were consistent with secondary mediation reached a peak of 20% on the 37th main task block and quickly decreased thereafter. These reports occurred at least once for 29% of items. It stands to reason that subjects would sometimes be able to discover new mnemonics (secondary mediators) that can be executed more quickly than the mediator that we instructed them to use. For example, for the item *RED* → *Q* → *9,* one subject reported seeing *R* as a "kind of flipped 9." Secondary mediators of this type in principle can be discovered for any instructed mnemonic. For 71% of items, however, secondary mediation was never reported on any trial. Statistically, this proportion should be very close to that for the subjects in the main experiment, who were selected randomly from the same population. These results therefore corroborate our conclusion that a transition to direct, unmediated retrieval did occur after practice for most items.

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