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Procedural Learning:

1. Locus of Practice Effects in Speeded Choice Tasks

Harold Pashler and Gordon Baylis
University of California, San Diego

When subjects perform 750 trials of a speeded choice task mapping different categories of symbols (e.g., letters, digits) onto different responses, excellent transfer is observed to new items in the trained categories (Experiment 1). However, when arbitrary sets of stimuli are mapped onto each response, introducing new stimuli substantially retards performance (Experiment 2), even when the size of the potential stimulus set remains constant (Experiment 3). Surprisingly, responses to already trained items are as slow as responses to new items in these transfer tests. When the mapping is categorical, shuffling the assignment of stimuli to responses drastically slows responses (Experiment 4). However, changing to a spatially homologous mapping with responses on the other hand produces excellent transfer (Experiment 5). Together, these results indicate that practice in speeded choice tasks affects primarily the response selection stage, rather than perceptual processing or motor responses. These data suggest that practice primarily strengthens links between category representations and spatially defined responses. Furthermore, when an arbitrary collection of symbols is mapped onto a given response, practice produces an ad hoc category representation and strengthens links between individual items and the category, as well as links between the category and the response.

With practice, people become dramatically faster and more accurate in sensorimotor skills. Characterizing these changes is of major importance, for both applied and theoretical purposes. In applied situations, it would be useful to know how conditions of skill acquisition can be structured so that learning is most efficient and to know when one form of training will produce useful transfer to other, related tasks. For theoretical purposes, understanding the functional character of skill learning should provide a basis for developing detailed models of the changes that underlie such learning (such as neural net models). The present article focuses on the changes in performance that occur with modest amounts of practice in very simple sensorimotor tasks, namely those requiring speeded choice responses. In speeded choice tasks, subjects are presented with a single stimulus and must rapidly select and execute a response depending on the identity of the stimulus. This is one of the simplest paradigms in which one can examine procedural skills and their development, and it provides a useful laboratory model for the numerous human skills that involve retrieving and producing arbitrary responses to stimuli.

Performance in speeded choice tasks is subject to various kinds of change as subjects perform repeated trials. Subjects' responses become faster (and often more accurate)—the *practice effect.* In addition, performance on individual trials depends on the nature of preceding trials. Specifically, performance is faster when the same stimulus is presented a second time in a row—the *intertrial repetition effect.* Previous research has not clarified what aspects of processing are affected by either practice or intertrial repetition and the conditions under which such effects transfer from one stimulus-response (S-R) event to another. Neither has the relationship between these two effects been previously explored. The present work represents an initial examination of all of these questions. This article focuses on the practice effect, whereas the accompanying article (Pashler & Baylis, 1991) examines the intertrial repetition effect and discusses how the repetition and practice effects are related to one another.

Practice Effects in Speeded Tasks

It is a truism that practice makes perfect, and speeded choice tasks are no exception. Woodworth (1938) summarized several early investigations of practice effects in reaction time (RT) tasks. Merkel (cited in Woodworth), for example, examined practice in tasks ranging from 2 to 10 alternatives, with a one-to-one mapping from stimuli to responses. Response times improved steadily over practice (see also Mowbray & Rhoades, 1959). Theories in this area have largely been driven by, and focused on, the quantitative character of the learning curve, and in particular the ubiquitous power function relating RTs to amount of practice (see Newell & Rosenbloom, 1981, for a review). Thus Crossman (1959) proposed a theory of the power function that postulated that different internal mechanisms for performing a task are sampled, and more effective ones are chosen over trials. Newell and Rosenbloom suggested a mechanism whereby rules for responding to larger and larger "chunks" of patterns are stored

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Correspondence concerning this article should be addressed to Harold Pashler. Department of Psychology C-009, University of California, San Diego, La Jolla, California 92093.

in memory; on certain assumptions this could yield a power function relating speed to practice. Logan (1988) proposed an *instance model* of automaticity that postulates that each trial creates a trace in memory that—the next time the task is performed—generates a lookup process that races against all previously accumulated processes to produce the desired output. This generates a speedup because the expected time of the fastest process becomes faster the more traces there are in memory, and this speedup follows a power function. Although these models provide an interesting array of possible mechanisms for practice effects, wherever such effects might occur, the models are stated so abstractly that they do not make concrete claims about the locus of improvement in various speeded choice tasks. The effects that they describe might potentially occur at many different loci or stages of processing. Without such specification, these models do not readily make predictions for transfer of training effects in speeded choice tasks.

In addition to these general accounts of practice, there have been many studies of the consequences of practice in simple tasks, especially for divided attention. It is an old observation that, with practice, tasks seem to be able to be performed more easily at the same time as other activities (e.g., Solomons & Stein, 1896). Schneider and Shiffrin (1977) confirmed that this was true of visual search tasks when combined with the task of holding on to a memory load, and they suggested that one could account for this by distinguishing between so-called *controlled mental processes* and *automatic mental processes,* the latter requiring consistent practice to be acquired. Unfortunately, the notion of consistency has not been specified clearly enough to make clear predictions outside the area of visual search tasks with symbolic stimuli (see Duncan, 1986, on this point). In the domain of speeded choice tasks, with a single stimulus determining the response, the concept of automaticity makes little in the way of predictions, except that it is important for training to be consistent, which does not take us very far.

Theoretical treatments of practice effects, then, have not provided a characterization of exactly what changes as performance improves in speeded tasks. In the present article, we focus on two simple and obvious functional questions concerning practice effects in speeded choice tasks. The first question is. What stages or processes are facilitated by practice (the question of the locus of the practice effect)? The second question concerns transfer: When a particular speeded choice task has been practiced, what other tasks potentially share in the benefit caused by this practice? Obviously, the answers to these questions are likely to be closely related. For example, one might naturally expect to find transfer to new tasks just in case these share the same target stage or process and that stage or process operates with the same inputs and outputs in both the training and the transfer tasks. For instance, if the locus of the practice effect was the execution of motor responses, then one would expect that positive transfer would be obtained to tasks using the same set of motor responses.

There are several empirical investigations that have dealt with these issues directly. One approach to determining the locus of practice effects depends on examining patterns of RT effects using the *additive factors* method. Brebner (1973) observed that the effect of S-R compatibility was substantially reduced over the course of practice. This suggests that practice in speeded choice tasks primarily affects the duration of response selection—given the general understanding of S-R compatibility effects—together with the logic of the additive factors method (Sternberg, 1969). Mowbray and Rhoades (1959) observed that the effect of the number of alternatives in a choice task was reduced with practice. This interaction suggests that practice affects either response selection or encoding, given the conclusions of Sternberg, who found evidence that number of alternatives affects both those stages. Consistent with both of these findings, then, is the suggestion made by Welford (1976), to the effect that practice speeds up the translation stage (response selection, in more modern parlance) and thus that after practice, "the connections between various identifications and their corresponding responses have become somehow 'built into' the operation of the translation mechanism" (p. 72).

The second question raised earlier was when and to what extent the practice effects observed in speeded choice tasks transfer to different tasks. In accord with the suggestion that response selection is the locus, one might expect transfer to new tasks just in case the same response selection operations can be used with the same inputs and outputs, that is, in case the same stimulus identifications lead to the same responses— to use Welford's terminology. However, transfer effects in choice tasks have barely been investigated at all (but see Gagne & Foster, 1949, for one such study). What has occupied many researchers, on the other hand, are transfer effects in visual search tasks, in which subjects respond to the presence or absence of target elements in displays composed of multiple items (see Rabbitt, 1978, for a review of many studies). A common finding is that early in practice, RTs depend heavily on the number of items in the display, whereas later in practice, effects of number of elements are much smaller (e.g., Neisser, Novick, & Lazar, 1963). The effect is not a general improvement in search ability, however, because if new targets and distractors are used, subjects' performance returns to its initial state (Schneider & Shiffrin, 1977). Nonetheless, substantial transfer can be obtained when either the targets or the distractors are kept constant and the other is changed (Kristofferson, 1972: Shiffrin, Dumais, & Schneider, 1981). It seems unlikely that what is being strengthened here is the mapping from stimuli to overt responses, however. For one thing, distractors are actually associated slightly more often with the negative response than with the positive response, and yet practice with these distractors produces beneficial transfer to positive trials with different targets. Schneider and Shiffrin suggested that what is learned is a so-called *automatic attention response,* whereby the practiced stimuli come to attract attention without conscious controlled search, and distractors come to "release" attention (see also Hoffman, Nelson, & Houck, 1983). Schneider (1985) suggested that the automatic attention response depended on both associative learning and learning of priority setting in different processing modules.

Studies of visual search suggest that transfer may occur even when stimuli are introduced that are physically different from those used in training. Schneider and Fisk (1984) studied practice effects in a visual search task in which subjects saw arrays of three words. They were required to respond to the location in the array of the unique word belonging to a particular semantic category. Schneider and Fisk reported excellent transfer to new (untrained) items that belonged to the trained categories compared with items in new categories. These results were interpreted as indicating that an automatic attention response can be attached to an abstract representation of a semantic category. Unfortunately, however, Schneider and Fisk used only a small number of categories in their experiment and did not use counterbalancing to ensure that particular semantic categories appeared equally often in training and transfer. Instead, they simply used one set of categories for training and another set of categories for the transfer test (e.g., the category *body parts* was used only in training, and the category *natural earth formations* was used only in the transfer test). For this reason, differences in the familiarity or cohesiveness of the categories could have been confounded with training versus transfer, and thus their results must be regarded as inconclusive. More clear-cut findings were obtained by Graboi (1971), who examined transfer in visual search for word targets. Subjects' speed was reduced very little when the target words they had practiced searching for were presented in a different case from that used in training, whereas a transfer test involving new words produced a dramatic slowing.

Nonetheless, studies of visual search and the theories that they have generated may or may not have much bearing on the nature of learning effects in speeded choice tasks. In visual search tasks, the process of finding a target form in a complex display is relatively difficult. On the other hand, in speeded choice tasks, there is but one stimulus presented, and intuitively it would seem that the subject's primary difficulty lies in the process of selecting an appropriate action based upon a stimulus identification that is already highly prepracticed. It is possible that the process that is most difficult might also be most susceptible to improvement with practice, and, therefore, that the two tasks could be affected by practice in different ways. In addition, concepts like automatic attention response do not have any natural application to tasks involving just a single stimulus. Therefore, the effects of practice in visual search and speeded choice tasks might be quite different.

In summary, then, the locus of practice effects in speeded choice tasks and the extent of transfer obtained from one task to another are not well understood. Some general theories of practice effects have been proposed, but they speak of mechanisms in such a general way that they do not immediately make predictions about locus or transfer of practice in speeded choice tasks. The same is true for general accounts of a distinction between so-called *automatic* and *controlled processes.* Previous empirical studies of transfer have been mostly restricted to visual search, and their generalizability to speeded choice tasks seems doubtful. The most directly pertinent investigations have used the additive factors method, and they have suggested that practice effects in speeded choice tasks have their primary locus in response selection, as argued by Welford (1976). Given the inconclusive state of the literature, we think that it may be most useful to start afresh, delineating a set of hypotheses that may be empirically distinguished by their predictions for transfer of training.

Preliminary Hypotheses

The experiments reported later look for different sorts of potential positive and negative transfer effects in speeded choice tasks. Before turning to the experiments, we will spell out a set of hypotheses that is certainly not exhaustive but would seem to include most of the common-sense possibilities.

In common with most authors, we conceive of the processing of stimuli that produces a response as including a number of successive stages that may or may not overlap to a modest degree (Miller, 1988; Sternberg, 1969). Our question, then, is how practice affects the sequence of processing stages. We begin by considering six hypotheses, all of which make an assumption that we will term the *pathway-specific speedup assumption.* According to this assumption, practice effects reflect increases in the ease with which a particular pathway is negotiated. By a pathway, we mean the execution of a particular stage of processing with a given input and a given output. According to the pathway-specific speedup assumption, practicing a task produces no benefit for any pathway not actually exercised during practice. (As Singley & Anderson, 1989, pointed out, this is really Thorndike's identical elements theory applied to internal representations.) We will now consider a set of hypotheses that share this assumption, and later we will examine a hypothesis that contradicts it.

First, practice effects in speeded choice tasks might be restricted to the process of identifying individual characters, which we call the perceptual speedup hypothesis. If this hypothesis were correct, we would expect that transfer would be obtained to new tasks that required subjects to identify the same physical stimuli, regardless of whether the mapping to particular responses remained the same. On this view, however, one might well expect that changing the case or font of characters would be disruptive.

Another possibility is that the speedup in this task would involve the categorization stage (e.g., the process of determining that A is a letter). This hypothesis—the categorization speedup hypothesis—predicts that transfer will occur to different instances of the same characters, but not to new characters in the same category.

Given the additive factors investigations mentioned earlier, it would seem plausible that the benefit of practice might be located primarily in the response selection stage, as proposed by Welford (1976). This hypothesis subsumes two quite different possibilities, however. One hypothesis would be that a principle of cognitive economy holds, and the effect of practice is to strengthen the link between the highest level node that is consistently mapped onto a particular response, on the one hand, and that corresponding response node, on the other hand. In the task shown, that is the link between the letter category and the response category. This hypothesis we call the highest link hypothesis. This would predict transfer to new exemplars of a category, so long as the mapping of categories to responses remained the same. If the stimuli do not belong to the same category (e.g.. if the letter *A* and the digit 7 were mapped onto the right response), then on this hypothesis, two links, one from A to the response and one from 7 to the response, would be created and strengthened because there is no superordinate category that includes both A and 7 while excluding alternative stimuli.

Another hypothesis at the response selection level would state that direct links always form from the lowest level of stimulus identity all the way to the response category. So, even if categorization of the stimuli on a given response is possible, the effects of practice are nonetheless to bypass the category and to create links all the way from the lowest level to the response. This view will be termed the shortcut hypothesis. On this view, transfer to other exemplars of a category will not occur in mappings in which individual categories of stimuli are mapped onto individual responses (henceforth termed *categorizable mappings).* Logan's (1988) model of automaticity represents one account of this type.

A third account involving the response selection stage is simply the union of the last two hypotheses mentioned; this would propose that practice builds links to a response from all of the nodes that are consistently associated with it. This will be termed the inclusive links hypothesis. On this account, like the highest link hypothesis, we should expect excellent transfer to new stimuli belonging to categories that have been trained in association with particular responses. It is interesting to note that the writings of some traditional learning theorists (e.g., Guthrie, 1935) would seem to endorse the inclusive links hypothesis, in their suggestion that all the various internal and external cues associated with a response come to be associated with that response.

A final possibility is that it is the execution of motor responses that is facilitated by practice. If this response execution speedup hypothesis were correct, we would naturally expect that transfer would be obtained whenever the new task involved the same motor responses.

Shuffled Mapping: Discriminating Between Pathway-Specific Hypotheses

Consider now what would happen if the mapping from stimuli to responses is shuffled in the transfer test (i.e., each category of stimulus is mapped onto a different response in transfer than it was in training). Here, all of the accounts postulating effects on response selection agree in at least one prediction: There should be severe disruption of performance. The accounts differ, however, in their predictions for performance when new versus old items from the already trained categories are tested in this sort of shuffled-mapping transfer test. According to the highest link hypothesis, the old and new items should behave the same because no strengthening of links will have occurred below the category level. According to either the shortcut hypothesis or the inclusive links hypothesis, on the other hand, the old items from the trained categories should suffer additional response competition that is not present for the new items in these categories, and thus a negative transfer effect should be observed for already trained category members in a newly shuffled mapping.

Overall Mapping Strength Hypothesis

There is another model to consider that is of a very different class from those just considered. Thus far, we have assumed that on any given trial just those pathways that are actually exercised on that trial are strengthened, or at least, that what practice produces are new links that connect nodes that were actually utilized on training trials. An alternative to this assumption is that when a given trial is performed, pathways are strengthened or created that connect nodes for stimuli that could have been but were not actually presented on practice trials. In its most straightforward form, this account would suggest that when the subject performs a given trial in a speeded classification task, all pathways within the entire mapping for the task are strengthened. (The results discussed earlier demonstrate that this is not true for visual search, but as noted there, that may or may not have relevance to speeded choice tasks.) This we call the overall mapping strengthening hypothesis. Unlike the other models previously described, this model predicts that when subjects practice an uncategorizable mapping, good transfer will occur to items that were included in the original task instructions but were not actually practiced. This model agrees with the other response selection models we have discussed, however, in predicting that shuffling the mapping will disrupt performance.

Experimental Approach

The experiments that will be described examine practice effects in speeded choice tasks with manual responses and visual stimuli. The amount of practice examined is modest—750 trials in each experiment. The obvious advantage to using this relatively modest level of practice is that it allows us to perform a larger variety of transfer tests. The possible disadvantage is that results obtained with these levels of practice might not generalize to more extensive practice. It is worth noting, however, that previous investigations (e.g., Logan, 1978) have suggested that the major effects of practice in simple tasks actually occur quite quickly. Extensive training may be useful for studying reduction of divided attention costs (automaticity), but even there the effects become quite apparent by 750 trials of practice (Logan, 1978), and some recent studies of automaticity use similarly modest degrees of practice (e.g., Logan, 1988). In any case, the issue of generalizability to more extreme degrees of practice will always be present after any finite amount of practice, whether modest or extended. Before turning to our experiments, the general method used in each of them is described to avoid redundancy as each experiment is presented.

General Method

Subjects

Subjects were students at the University of California, San Diego. Most students participated in partial fulfillment of a course requirement, although a few were paid for their participation.

Apparatus and Stimuli

The stimuli were presented on Princeton Graphics SR-12 monitors, controlled by IBM PC microcomputers (hereafter referred to as PC; equipped with Sigma Design Color-400 boards, providing display 640-pixel x 400-pixel display resolution). The stimulus was a single character appearing in the middle of the screen. Characters, in yellow on a black background, measured about 0.6 cm wide by 0.5 cm high. On the basis of a typical viewing distance of 60 cm, each character subtended a visual angle of 0.57° by 0.48°.

Design

The experiments were divided into 20 blocks of 50 trials (except as noted). The stimulus presented on a given trial was chosen randomly with replacement. The first 15 blocks constituted training, whereas the last 5 blocks of the experiments constituted a transfer test. Between the training and transfer blocks, some change in stimulus, mapping, or response was made; this differed from one experiment to the next.

Procedure

Subjects were given written instructions describing their task. The instructions stated that all responses should be made as rapidly and accurately as possible. The subject had available a card with the assignment of stimulus categories to responses printed out in large letters, to remind them of the mapping when needed. Most of the experiments used three adjacent response keys, which will be described as the *left, middle,* and *right* responses. These were made by depressing the [M], [,], and [•] keys on the PC keyboard; each subject used the first three fingers of his or her right hand for these responses, respectively (except for the final experiment). At the end of each block of the experiment, the subject rested until he or she felt ready to continue. At this time, feedback was provided for each of the preceding blocks, consisting of mean correct RT and number of errors. Prior to presentation of the first stimulus, a fixation point was presented for 500 ms, followed by a blank interval of 800 ms. Thereafter, each stimulus was presented at a chosen interval after the detection of the preceding response (this will be referred to as *response stimulus interval* [RSI]). Each stimulus remained on the screen until the subject had responded.

Data Analysis

Reaction times under 200 ms or over 2,000 ms were rejected as deviant.

Experiment 1: Training Transfer With a Categorizable Mapping

We begin by looking at transfer to new items in a mapping in which different categories of symbols are mapped onto different responses. In the first experiment, subjects performed a speeded choice task for 15 blocks of practice, in a task that mapped three different conceptual categories of symbols (letters, digits, and nonalphanumeric symbols) onto three different manual responses. Table 1 shows the mapping for training and transfer in this experiment and in the subsequent experiments. (Because assignment of stimuli was counterbalanced, the stimuli only pertain to one group of subjects, but they show the point of each experiment.) After the training, new stimuli belonging to these categories were introduced along with the old stimuli. If practice produces a speedup in the perceptual processing of the particular stimuli encountered in training, then no transfer to new stimuli should be obtained. The hypothesis that the training strengthens stimulus-specific links involved in selecting the responses (the shortcut hypothesis) would make the same prediction. On the other hand, if practice speeds up the selection of the responses by strengthening the link between the category and the response (the highest link hypothesis or the inclusive links hypothesis), then excellent transfer should occur. The same prediction should hold if the practice effect originated in a speedup of the motor responses themselves. The results are not diagnostic with respect to the overall mapping strength hypothesis.

Table 1
Stimuli Mapped Onto Each Response in Experiments 7-5

Experiment/ stimuli	Response		
	Left	Middle	Right
1 (categorizable)			
Trained	2, 7	P, V	&, #
Transfer	2, 7, 4, 9	P, V, K, W	&, #, %, =
2 (uncategorizable)			
Trained	P, 2	V, 8	K, 7
Transfer	P, 2, F, 9	V, 8, D, 3	K, 7, J, 4
3 (uncategorizable)			
Trained	L, P	Z, V	T, K
Transfer	P, F	V, D	K, J
4 (shuffled)			
Trained	2, 7, 4, 9	P, V, K, W	&, #, %, =
Transfer	P, V, K, W	&, #, %, =	2, 7, 4, 9
5 (hand switch)			
Trained	2, 7 (hand 1)	P, V	&, #
Transfer	2, 7, 4, 9 (hand 2)	P, V, K, W	&, #, %, =

Method

A total of 18 subjects participated. For all of the subjects, the mapping was the same. The digits [2], [7], [4], and [9] were mapped onto the left response key; the letters [P], [V], [K], and [W] were mapped onto the middle response key; and the symbols [&], [#], [%], and [=] were mapped onto the right response key. For all of the subjects, during the first 15 blocks of trials, only one half of the stimuli (2 characters per response) were presented, and for the final 5 blocks, all 12 characters were presented. The determination of which one half of the stimulus set was presented in the first 15 blocks was counterbalanced across stimuli: For one half of the subjects, the first two stimuli listed above for each response key were presented, whereas for the other half, the second two were presented. The RSI was 550 ms.

Results

Figure 1 presents the mean correct response times as a function of block and training condition. There is a marked decline in response times over the first 6 blocks, followed by

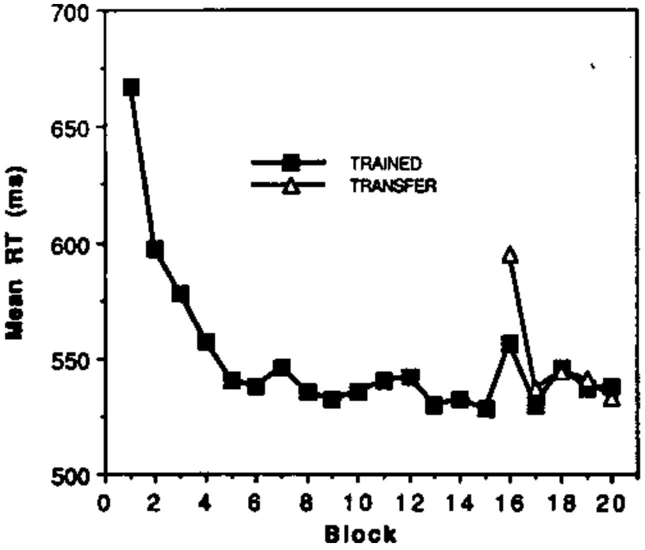


Figure 1. Mean reaction times (RT) in Experiment 1, as a function of block, for trained and transfer stimuli.

fairly constant performance through the 15th block. The introduction of the transfer stimuli in the 16th block seems to produce an increase in RTs for that block, followed by a return to the previous level for the final 4 blocks. Several particular questions were examined in the following analyses.

First, is there positive transfer to the new items in the trained categories? To assess this, we compared overall performance during the first 5 blocks of trials with the performance on the new (transfer) items over the first blocks after their introduction (i.e., Blocks 16-20). For this analysis, the factors were block and condition (initial vs. transfer). The average RT for the initial blocks was 588 ms, whereas the average was 550 ms for the transfer condition. This transfer effect was significant, $F(1, 17) = 8.8, p < .01, MS_e = 7{,}291$.

Second, is there complete transfer? Are subjects doing as well for the new (transfer) items as for the old (already trained) items during the last 5 blocks? An analysis of variance (ANOVA) was performed with two factors: block (16-20) and condition (new vs. old). The mean RT for new items was 550 ms, whereas the mean for the old items was 541 ms. The difference was not significant, $F(1, 17) = 2.6, p > .10, MS_e = 1{,}295$. However, the interaction between block and new versus old was significant, $F(4, 68) = 3.6, p < .02, MS_e = 773$. This plainly reflects the fact that for the 16th block, the transfer items are responded to somewhat slower than the trained items, but not for the other blocks. Naturally, the effect of block was significant in this analysis, $F(4, 68) = 7.7, p < .001$. The difference between old and new items for Block 16 alone was tested and was found to be significant, $F(1, 17) = 14.3, p < .001, MS_e = 951$. In short, the new items in the trained categories enjoyed virtually the entire benefit obtained by the old (previously trained) items in these categories, although in the 1st block of transfer there is some extra benefit for pretrained items.

The mean percentage of errors was computed for sets of five blocks. For the first three sets of five (training) blocks, these percentages were 5.82, 5.13, and 5.68, respectively. For the final five (transfer) blocks, the error rates were 5.64% for old items and 6.42% for new items. The latter difference was not significant, $F(1, 17) = 1.39, p > .25, MS_e = 0.0020$.

Discussion

The latency results show a high degree of transfer to new items in the old categories. This plainly rules out either the perceptual speedup hypothesis or the categorization speedup hypothesis. Either of these mechanisms should have produced very little transfer to new items in the old categories. The results are also inconsistent with one version of the response selection speedup account: the shortcut hypothesis.

The results are consistent with (a) a speedup of response selection based on the category identification (i.e., the highest link hypothesis or the inclusive links hypothesis) and also (b) the response execution speedup hypothesis. These results are reminiscent of the findings of Graboi (1971) and Schneider and Fisk (1984) with visual search. The small benefit for trained over transfer characters in the first block of transfer suggests some modest role for item-specific learning.

Experiment 2: Training Transfer (Uncategorizable) 1

If the practice effect in Experiment 1 is due to a speedup in pathway from the category to the response (the highest link hypothesis), then one would not expect any such positive transfer to extend to new items assigned to the same response when the items assigned to a given response did not belong to a common conceptual category. This should hold even when the initial instructions to the subject included those items. By contrast, if the speedup were at the level of the production of motor responses, then excellent transfer might be expected, comparable with that observed in the first experiment. Experiment 2 also tests the overall mapping strength hypothesis—which predicts good transfer to both new and old items—because according to that hypothesis, each trial strengthens the entire mapping, not just the pathway used to generate the response. In Experiment 2, then, subjects were presented with a mapping wherein the different stimuli mapped onto a given response did not belong to a common category.

Method

A total of 18 subjects participated. The stimuli were presented as in Experiment 1, except for the four characters mapped onto each of the response keys. The characters [P], [2], [F], and [9] were mapped onto the left response key; the characters [V], [8], [D], and [3] were mapped onto the middle response key; and finally, the characters [K], [7], [J], and [4] were mapped onto the right response key. These stimuli were selected so that there was no obvious relationship governing the mapping between stimuli and responses. For all of the subjects, during the first 15 blocks of trials, only one half of the stimuli were presented, and for the final 5 blocks, they were all presented, as in Experiment 1. The choice of which stimuli were withheld in the first 15 blocks was counterbalanced across subjects: For one half of the subjects, the first pair of stimuli listed earlier with each response key was withheld, whereas for the other half, the second pair of stimuli listed earlier was withheld. Subjects were not told that certain stimuli would be withheld until the latter portion of the experiment.

Results

Figure 2 presents the mean correct response times as a function of block and training condition. There was a fairly steady decline in response times over the first 13 blocks, followed by fairly constant performance through the 15th block. The introduction of the transfer stimuli in the 16th block produced a dramatic increase in RTs for that block, followed by a gradual decline, which did not, however, reach the earlier level of performance by the end of the experiment. Several questions were examined in the following analyses.

First, is there transfer to the new items? To assess this, we compared overall performance during the first 5 blocks of trials with the performance on the transfer items over the first 5 blocks after their introduction (i.e., Blocks 16-20). For this analysis, the factors were block and condition (initial vs. transfer). The average RT for the initial blocks was 740 ms, whereas the average was 799 ms for the transfer condition. This difference was significant, $F(1, 17) = 4.6$, $p < .001$, $MS_{\mathrm{e}} = 33{,}298$, indicating that new items are responded to more slowly in the transfer test than were old items during their initial learning.

Second, how does performance compare for the new (transfer) items as compared with the old (already trained) items during the last 5 blocks? An ANOVA was performed with two factors: block (16-20) and condition (new vs. old). The mean RT for new items was 798 ms, whereas the mean for the old items was 765 ms, $F(1, 17) = 7.3$, $p < .02$, $MS_{\mathrm{e}} = 6{,}908$. The interaction between block and new versus old was significant, $F(4, 68) = 2.8$, $p < .05$, $MS_{\mathrm{e}} = 3{,}226$. This seems to reflect primarily the fact that for the 16th block, more than in the remaining blocks, the trained items are responded to faster than the new items. Naturally, the effect of block was significant in this analysis, $F(4, 68) = 17.0$, $p < .001$, $MS_{\mathrm{e}} = 7{,}404$.

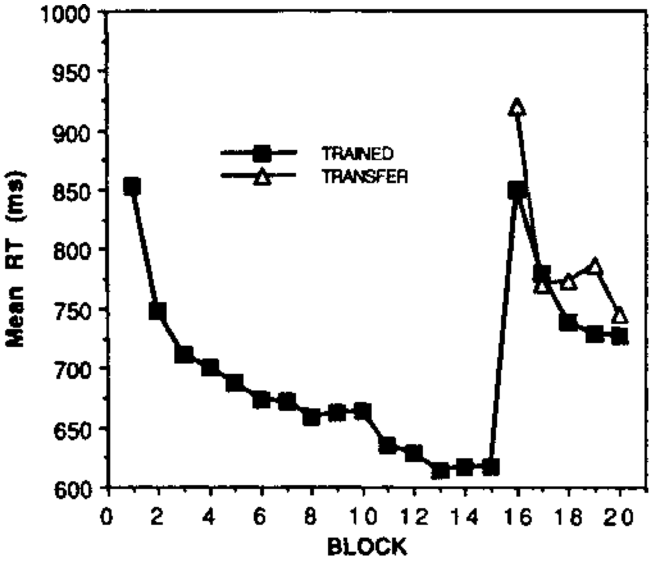


Figure 2. Mean reaction times (RT) in Experiment 2, as a function of block and condition (trained vs. transfer).

The mean percentage of errors was computed for sets of five blocks. For the first three sets of five (training) blocks, these percentages were 3.06, 4.46, and 4.40, respectively. For the final five (transfer) blocks, the error rates were 4.23% for old items and 4.19% for new items. The latter difference was not significant, $F < 1$.

As Figure 2 makes plain, the responses to the trained items were (unexpectedly) slowed in the transfer phase. This was confirmed with a comparison of Blocks 15 and 16 for trained items only, which showed a significant difference, $F(1, 17) = 164.1$, $p < .001$, $MS_{\mathrm{e}} = 2{,}983$.

Discussion

Subjects were substantially slower overall in Experiment 2 compared with Experiment 1. This is very likely because subjects must retain in short-term memory a more extensive set of intentions in Experiment 2 on account of the absence of a categorical mapping. (See Gottsdanker, 1980, for an illustration of how such a preparation effect could yield the well-known effect of number of alternatives in choice RT tasks, which could well be basically the same phenomenon.) When the subjects are trained with a mapping consisting of four items arbitrarily paired with responses, but they practice only a subset of two of these items, they do not successfully transfer their learning onto the untrained items. This directly contradicts the overall mapping strength hypothesis and the response execution hypothesis. The second finding is much more surprising: Performance with the trained items deteriorates to the point of being almost as poor as performance with the untrained items. Thus, the fact that subjects have seen and responded to the trained stimuli more than 750 times does not give these stimuli any substantial advantage over entirely new stimuli, even though the response mapping is unchanged. This issue will be examined further in Experiment 3.

Experiment 3: Training Transfer (Uncategorizable) 2

In Experiment 2, subjects practiced a speeded choice task with an uncategorized S-R mapping. In the second phase, new items were added to this uncategorized mapping. Performance was drastically impaired, roughly equally for the items that were previously trained and for those items that were not. One aspect of that experiment that may be important in producing this outcome is the fact that in the second phase, the total number of potential stimuli that could be presented on any given trial was doubled, from 6 to 12. (This permitted a direct comparison with Experiment 1, in which the number of stimuli was also doubled in the second phase.) Experiment 3 followed Experiment 2, but held the number of stimuli constant from the first phase to the second phase. To accomplish this, 2 stimuli were mapped onto each response in the first phase, and then in the second phase, only

1 of those stimuli, plus an additional (new) stimulus, was mapped onto the same response. In this design, the new stimuli of the transfer phase were not included in the initial instructions.

Method

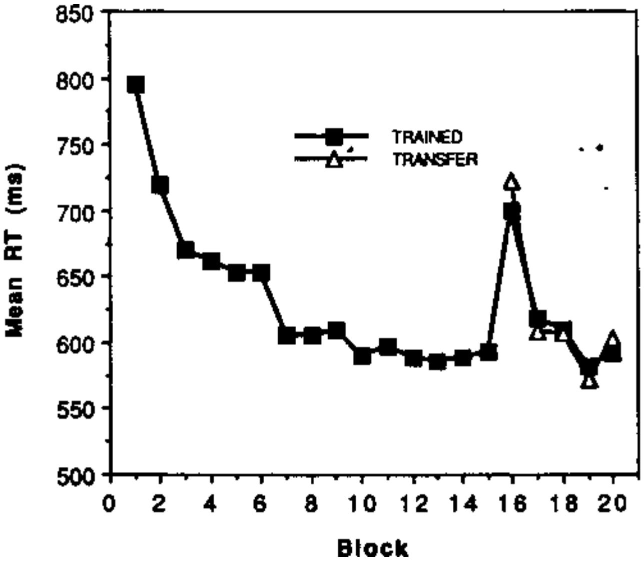
A total of 18 subjects participated. There were three characters mapped onto each of the response keys. The characters [P], [L], and [F] were mapped onto the left response key; the characters [V], [Z], and [D] were mapped onto the middle response key; and finally, the characters [K], [T], and [J] were mapped onto the right response key. However, subjects presented with only a subset of these stimuli in each phase. In the first phase, each subject had two items mapped onto a given response (e.g., a subject might have [P] and [L] mapped onto the left key). In the transfer phase, one of those stimuli, plus the third, were mapped onto that response (e.g., the subject just mentioned would have [L] and [F] mapped onto the left key). The assignment of stimuli to phases was counterbalanced across subjects. This required three groups of subjects. One group was trained with [P] and [L] on the left response, another group was trained with [L] and [F] on the left response, and a final group was trained with [F] and [P] on the left response. Subjects were told that there would be a change in the set of stimuli presented in the second phase of the experiment, as well as the nature of this change, and they were instructed to turn over the reference card between phases for instructions.

Results

Figure 3 presents the mean correct response times as a function of block and training condition. There was a fairly steady decline in response times over the first 10 blocks, followed by fairly consistent performance through the 15th block. The introduction of the transfer stimuli in the 16th block produced a dramatic increase in RTs for that block (for both old and new items), followed by a decline, which appeared to reach the earlier level of performance by the end of the experiment. Several question were examined in the following analyses.

First, is there transfer to the new items? To assess this, we compared overall performance during the first 5 blocks of trials with the performance on the new (transfer) items over the first 5 blocks after their introduction (i.e., Blocks 16-20). For this analysis, the factors were block and condition (initial vs. transfer). The average RT for the initial blocks was 700 ms, whereas the average was 622 ms for the transfer condition. This difference was significant, $F(1, 17) = 37.7, p < .001, MS_e = 7{,}223$, indicating that new items are responded to more quickly than were old items during their initial learning. In short, some positive transfer is observed.

Second, how does performance compare for the new (transfer) items versus the old (already trained) items during the last 5 blocks? An ANOVA was performed with two factors: block (16-20) and condition (new vs. old). The mean RT for new items was 619 ms, whereas the mean for the old items was 622 ms. The difference was not significant, $F < 1$. The interaction between block and new versus old was also not significant, $F = 1.003$. The remarkable slowing of the trained items between the 15th and the 16th blocks was again significant, $F(1, 17) = 36.1, p < .001, MS_e = 2{,}805$.



block and condition (trained vs. transfer).

Error Rates

The mean percentage of errors was computed for sets of five blocks. For the first three sets of five (training) blocks, these percentages were 4.7, 5.2, and 6.1, respectively. For the final five (transfer) blocks, the error rates were 4.7% for old items and 5.9% for new items. The latter difference was not significant, $F(1, 17) = 2.2, p > .15, \mathrm{MS}_e = 0.0034$.

Discussion

There are two important aspects to the findings of Experiment 3. First of all, the results again show a substantial slowing when the new mapping is introduced. Unlike the results in Experiment 2, this effect was not sufficient to bring performance back to the level of the beginning of the experiment. In fact, there was some partial general positive transfer evident in the data (approximately one block's worth of practice). The comparison of this result with the findings of Experiment 2 makes it seem likely that this general transfer was obscured in Experiment 2 by the increase in the size of the potential stimulus set. This general transfer effect could be caused by several things. One would be a speedup in the response execution stage, and another would be the adoption of a more uniform and liberal speed-accuracy tradeoff function (note that error rates actually may have increased somewhat over the course of this experiment).

The second main result here is that in the second phase of the experiment, subjects were responding no faster to the stimuli that they had practiced for 750 trials than to entirely new stimuli. This result confirms the finding of Experiment 2, which will be discussed later.

Experiment 4: Transfer to a Shuffled Mapping

If the practice effect originates in the strengthening of links involved in response selection, then if the stimulus set remains the same but the mapping of stimuli to responses is switched, there should be a disastrous effect on performance. In Experiment 4, subjects performed 15 blocks of trials using a mapping with categorical structure. The mapping was changed for the final 5 blocks, so that the same categories appeared, but each was mapped onto a different response than in training. As in the previous two experiments, both new and old items were presented in the last 5 (transfer) blocks.

Method

A total of 16 subjects participated. Equipment included NEC Multisync II monitors, in addition to the Princeton Graphics monitors. The categorical stimulus set from Experiment 1 was used. For the first 15 blocks, the mapping was digits-letters-symbols, from left to right, whereas in the last 5 blocks, it changed to letters-symbols-digits. As in the earlier studies, new stimuli were introduced in the last 5 blocks, after the mapping switch. Subjects were told that the mapping would switch between the 15th and 16th blocks, at which time the computer notified them to turn over their reference card; they were allowed 30 s to examine it.

Results

Figure 4 presents the mean correct response times as a function of block and training condition. Response times declined over the first 15 blocks. The introduction of the transfer stimuli in the 16th block produced a dramatic increase in RTs for that block, followed by a rapid decline. Several questions were examined in the following analyses.

First, is there transfer to the new items? To assess this, we compared overall performance during the first 5 blocks of trials with the performance on the transfer items over the first 5 blocks after their introduction (i.e., Blocks 16-20). The average RT for the initial blocks was 649 ms, whereas the average was 641 ms for the transfer condition. This difference was not significant, $F(1, 15) = .15, p > .7, MS_e = 13,843$. In short, there was no positive transfer observed here.

Second, how does performance compare for the new (transfer) items as compared with the old (already trained) items during the last 5 blocks? An ANOVA was performed with block (16-20) and condition (new vs. old). The mean RT for new items was 641 ms, whereas the mean for the old items was 669 ms. The difference was significant, $F(1, 15) = 8.1, p < .02, MS_e = 3,928$.

The mean percentage of errors was computed for sets of five blocks. For the first three sets of five (training) blocks, these percentages were 7.6, 5.0, and 5.0, respectively. For the final five (transfer) blocks, the error rates were 8.84% for old items and 4.80% for new items. This difference, indicating superior performance for the new items, was significant, $F(1, 15) = 21.6, p < .001, MS_e = 0.0030$.

Discussion

Results indicate that the switching of the mapping so that the same categories were mapped onto different stimuli produced a drastic impairment in performance. This supports those accounts that locate the practice effect at the level of response selection. It is quite inconsistent with accounts that locate much of the effect exclusively at response execution or perception. The second main finding here is that responses to the new (transfer) items are faster than responses to the old (trained) items in the transfer blocks, which indicates response competition from links connecting particular items with the responses. This is consistent with either the shortcut hypothesis or the inclusive links hypothesis. Note, however, that the magnitude of this response competition appears to be quite small, a point that will be discussed later.

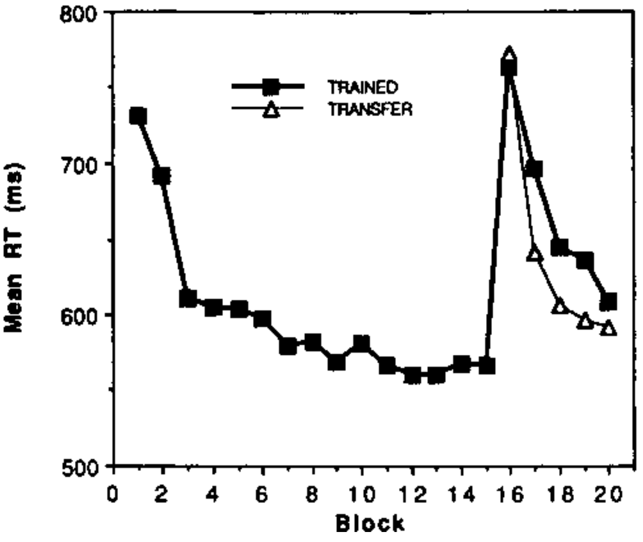


Figure 4. Mean reaction times (RT) in Experiment 4, as a function of block and condition (trained vs. transfer).

Experiment 5: Transfer to Different Hands

So far, the evidence has been consistent with the view that subjects primarily strengthen a mapping from the categories to the responses, thereby speeding up the stage of response selection. What is not clear, however, is whether the links that are strengthened specify the actual motor responses or, rather, a more abstract spatial description of the response. Experiment 5 examined the question of whether the practice effect in speeded choice tasks transfer from one hand to another when responses are made with a different hand but the mapping is simply translated, rather than being shuffled as in the previous experiment. In Experiment 5, a categorizable mapping was used, but the subject switched response hands for the final (16th-20th) blocks. The mapping to the new hand was a translation of the mapping from the first 15 blocks (i.e., the stimulus mapped onto the rightmost response key for the first 15 blocks was still mapped onto the rightmost response key for the final 5 blocks). As in the previous two experiments, both new and old items from the categories were presented in the last 5 blocks.

Method

A total of 14 subjects participated. The experiment used only NEC Multisync II monitors. The categorical stimulus set from Experiment 1 was used. For the first 15 blocks, the right response keys were [,], [.], and [/], and the corresponding left response keys were [z], [x], and [c]. The first three fingers of each hand were used. One half of the subjects used their left hand for the first 15 blocks and switched to their right hand for the remaining 5 blocks. The other half used the reverse assignment of hands. New stimuli from the trained categories were introduced in the last 5 blocks, after the mapping switch. Subjects were told at the beginning that they would need to switch hands after the 15th block, and the computer reminded them of this fact at the appropriate time.

Results

The data from 1 subject were lost. Figure 5 presents the mean correct response times as a function of block and condition. Response times declined over the first 15 blocks. The hand switch in the 16th block seems to have produced some transient increase in RTs for that block, followed by a rapid decline. In the 16th-20th blocks, performance was not significantly different for stimuli that were previously trained and for those that were not, $F < 1$. In those blocks, there was no significant interaction between block and trained versus new. The slight benefit for old over new times in the 1st transfer block (Block 16) was tested separately; it was not significant, $F(1, 12) = 1.07, p > .30, MS_e = 2{,}536$.

The mean percentage of errors was computed for sets of 5 blocks. For the first three sets of five (training) blocks, these percentages were 6.5, 5.3, and 5.3, respectively. For the final five (transfer) blocks, the error rates were 5.5% for old items and 6.7% for new items. The latter difference was not significant, $F(1, 12) = 1.1, p > .30, MS_e = 0.0042$.

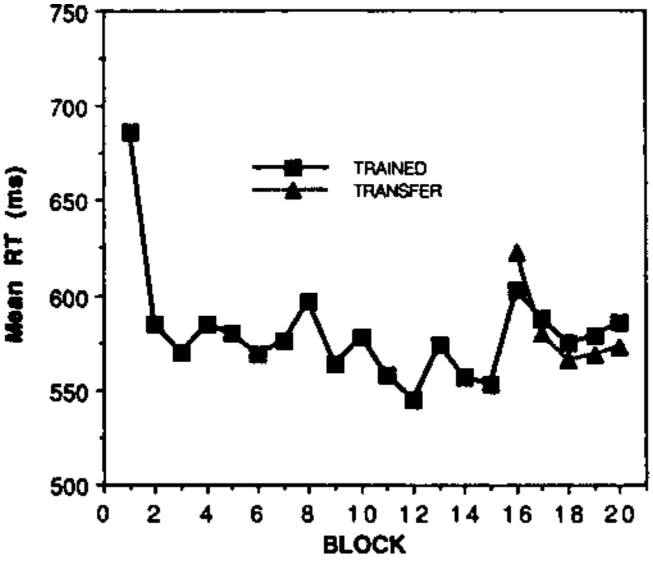


Figure 5. Mean reaction times (RT) in Experiment 5, as a function of block and condition (trained vs. transfer).

Discussion

Results show excellent transfer from one hand to another; therefore, the learning that occurs is not strengthening of links that lead to generation of particular motor responses. If it were, we would expect poor transfer, as in the previous experiment. (It is conceivable that what is strengthened is something that generates a response plan that does specify the finger to be used, but this plan can somehow be edited early in the transfer phase; in either case, there is far more flexibility about hand than there is about relative spatial position.) The results also replicate the finding of the first experiment: Excellent transfer is obtained for new items in the trained categories. As in the previous experiment, there seems to be a tiny extra benefit for trained items over new items in the transfer phase, but this disappears within one block. This indicates that when the mapping is categorical, learning is not occurring primarily by strengthening links from individual items (characters) to responses, as the shortcut hypothesis proposed.

General Discussion

The experiments reported here were designed to explore the locus of the learning that takes place as speeded choice tasks are practiced. Sizable practice effects were observed in all of the experiments. Over the course of 750 trials of training, this typically produced several hundred milliseconds of speedup. We now review the main results of the transfer studies and discuss what they tell us about the locus and nature of practice in these speeded choice tasks.

First, when a categorical mapping is used, so that all of the stimuli assigned to a given response are drawn from the same category, the practice effect transfers well to new items from the trained categories (Experiments 1 and 5). This result indicates that learning is not exclusively at the level of perceiving or categorizing individual stimuli; if it were, new items from the trained categories should not benefit, as no stimulus-specific links should exist.

Second, when the mapping is not categorical, performance deteriorates when new items that were included in the original instructions to the subject, but that were not previously trained, are included (Experiments 2 and 3). This result indicates that the practice effect does not result from a speedup in responding per se; if it did, transfer to new stimuli with the same response should produce a benefit. It also refutes the overall mapping strength hypothesis, which claimed that the entire mapping presented in the instructions is strengthened when links representing any portion of that mapping are exercised. Taken together, Results 1 and 2 strongly confirm Welford's (1976) proposal that it must be response selection that is the primary locus of the practice effects in speeded choice tasks.

Third, when the mapping is not categorical, and old (practiced) items are presented together with new items included in the initial instructions but never practiced, performance on the old items suffers (Experiments 2 and 3). This is the most surprising result. It is inconsistent with either the highest link hypothesis or the shortcut hypothesis. Both of these hypotheses agree in predicting that with the uncategorized mapping, the pathway from the stimulus identity to the response will be strengthened. If so, this should have provided benefits for these practiced items after introducing new stimuli in the transfer phase. We will discuss this unexpected finding in more detail shortly.

Fourth, when the mapping is categorical but the mapping itself changes after 15 blocks of practice, performance for the old items is drastically impaired, returning to no better than the initial level of performance (Experiment 4). This result strongly confirms the hypothesis that there is a learning effect at the level of response selection. Facilitation in response execution, perceptual identification, or categorization should have been insensitive to the switch of category-to-response mapping.

Fifth, after the shuffling of the mapping, performance for the old items, which were trained with the old mapping, is slightly inferior to performance with new items in the same categories. (This is another result from Experiment 4.) It suggests that with categorizable mappings, links (although perhaps rather weak ones) are formed from character identities to responses, as proposed by the shortcut and inclusive links hypotheses. This may also account for the slight extra benefit for old over new category members observed in the first posttransfer block of both Experiments 1 and 5.

Sixth, excellent, but not perfect, transfer is observed when the response hand is switched, but the spatial mapping is unaltered (Experiment 5). This indicates that what is facilitated is the selection of the response at a somewhat abstract level, rather than a particular motor action. The response apparently corresponds to the relative spatial location of the key to be depressed.

Some Conclusions About Practice Effects

The results allow us to propose a tentative picture of what is generating practice effects on speed of responding in simple choice tasks. With modest numbers of highly familiar stimuli and a set of simple motor responses, very little general speedup in perception, categorization, or motor responses is occurring. Welford's (1976) suggestion that the locus of practice effects is in response selection is confirmed. It may be that response selection is the major locus of practice in these tasks because the categorization and motor processes involved here are already heavily practiced and benefit little from additional practice. By contrast, the links between the stimulus identity and the response are specific to the task and are not previously practiced, and hence benefit more. This response selection learning fits the pathway specific assumption stated at the beginning of the article: There is no evidence that the entire mapping presented in the instructions is strengthened, as the overall mapping strength hypothesis would have it.

Given that the effects are in response selection, the next question concerns the particular pathways that are strengthened. Possibilities include a strengthening of links from the highest level nodes, the lowest level nodes, or both. Taken together, the results reported here indicate that links at the highest level are the most affected. However, there is also evidence that shortcut links between lower level (character-specific) nodes and the responses are created and strengthened as well. This is indicated by the better performance for new than for old items in the shuffled-mapping transfer test of Experiment 4 and the suggestion of transient benefit for trained over untrained category members in Experiments 1 and 5. In summary, the inclusive links hypothesis is essentially correct, but the bulk of the effect seems to fit the highest links hypothesis. These results all converge nicely with the additive factors experiments described at the beginning of the article, which showed that practice interacted strongly with factors believed to affect response selection (e.g., number of alternatives; Mowbray & Rhoades, 1959).

However, one result that arose in both Experiments 2 and 3 suggests that some interesting and unexpected factor—beyond what has been described so far—contributes to determining performance. The inclusive (and mostly highest) link hypothesis fits all of the data reported here, with an important exception: the fact that old, already trained items are responded to more slowly after new items are added in the transfer phases of uncategorized mapping experiments (Experiments 2 and 3). The effect is sizable. According to the highest link hypothesis, these items should have had the benefit of the links strengthened by practice, which are at the lower level, given the fact that there are no higher categories in these uncategorized mappings. Nothing in the general models of Crossman (1959), Logan (1988), Newell and Rosenbloom (1981), or Schneider (1985) would have led one to expect this effect either.

What is happening here? The results suggest the hypothesis that when multiple items are mapped in a noncategorical fashion onto a set of responses, practice does not simply build and strengthen individual links from identity nodes to responses. Suppose, instead, that something like the following occurs: When no existing category already subsumes the different identities mapped onto a given response, a new, single ad hoc node is created to encompass them. Links from identities to this node and from the node to the response category are then strengthened through practice. When new stimuli are added to the mapping, as in Experiments 2 and 3, a new set of ad hoc nodes must be created.

Broader Connections

The issues raised here in the rather narrow context of speeded choice tasks have some interesting connections to other areas of research that are usually seen as being separate topics. One such area is verbal learning theory.

The verbal learning theorists used transfer of training as their primary means of examining the formation of associations (see Jung, 1968, for a review). The main difference from the present study was that these researchers usually examined the probability with which arbitrary responses that were paired with stimuli in paired-associate training could be produced (in situations with little emphasis on speed), rather than examining the latency to produce heavily practiced responses with near-perfect accuracy, as in the present work. It is reasonable to suppose, however, that these different tasks and different measures might reflect the same underlying associative mechanisms. Indeed, some of the present results are consistent with the findings from paired-associate recall. For instance, the fact that performance deteriorates with the shuffled mapping (Experiment 4) can easily be seen as a case of proactive interference. In the verbal learning tradition, this is the case in which learning an A-B list interferes with later learning of an A-Br list (with the same A and B items but different pairings; see Gagne, Baker, & Foster, 1950). Similarly, the negative transfer for old items compared with new items in the shuffled mapping experiment is also consistent with this interpretation. However, the most unexpected of the present results does not appear consistent with the findings of verbal learning studies. In Experiments 2 and 3, after practice with an uncategorized mapping, when new stimuli are introduced, performance deteriorated for old as well as for new stimuli. The most nearly equivalent situation in paired-associated learning would be the following: The subject practices an A-B list and then practices both an A-B list and a C-B list The corresponding result would be found if the latter practice produced retroactive and proactive inhibition to reduce performance on the A-B list. However, no such inhibition seems to occur (e.g., Bugelski & Cadwallader, 1956).

One interpretation of the difference between procedural learning as examined here and paired-associate learning as examined by verbal learning theorists is that the two represent different memory systems. Recent neuropsychological evidence has suggested this possibility. Patients with anterograde amnesia are often unable to learn in tasks termed *declarative*—such as paired-associate learning—and nonetheless appear to show normal learning in what are often termed *procedural learning tasks* (e.g., Corkin, 1968). Another alternative explanation for the difference is that the response measure used here is latency rather than accuracy. It is ordinarily assumed that both of these provide equivalent measures of learning, but this may not be correct.

Another question that the unexpected result of Experiments 2 and 3 naturally raises is how generally this finding can apply. Consider the following example from outside the laboratory. Suppose that a new kind of stop sign that drivers have never seen before were introduced, and either that new stop sign or the familiar stop sign were used. Intuitively, it seems unlikely that drivers would find themselves reacting just as slowly to the familiar sign as they did to the newly learned sign. Yet, this is what a straightforward extrapolation from the results of Experiments 2 and 3 would suggest. One obvious difference between these two cases, however, is the amount of training that people have had with the respective stimuli. Future researchers could examine whether this or other variables are responsible for this rather puzzling effect, which may have important implications for practical skill acquisition.

At the beginning of this article, we described a number of general accounts of practice effects that have been proposed primarily to account for the power function relating speed and amount of training (e.g., Crossman, 1959; Logan, 1988; Newell & Rosenbloom, 1981). We noted that none of these rather abstract models of practice made concrete predictions for the nature of transfer effects that we would observe in these tasks. For this reason, our results do not clearly confirm or disconfirm these models. On the other hand, the results demonstrate that the appropriate level of analysis for understanding practice effects in speeded choice tasks is not the task as a whole but rather certain critical stages of the task. In addition, the novel result of Experiments 2 and 3 provides as great a challenge for any of these models as it does for the simple functional conception of a *pathway speedup* that we have used in interpreting our data. We conclude by suggesting that further detailed analysis of transfer effects will be useful, particularly in tasks that differ from the conventional speeded choice tasks in the difficulty of the various discriminations required.

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Butcher, Geen, Hulse, and Salthouse Appointed New Editors, 1992-1997

The Publications and Communications Board of the American Psychological Association announces the appointments of James N. Butcher, University of Minnesota; Russell G. Green, University of Missouri; Stewart H. Hulse, John Hopkins University; and Timothy Salthouse, Georgia Institute of Technology as editors of *Psychological Assessment: A Journal of Consulting and Clinical Psychology,* the Personality Processes and Individual Differences section of the *Journal of Personality and Social Psychology,* the *Journal of Experimental Psychology: Animal Behavior Processes,* and *Psychology and Aging,* respectively. As of January 1, 1991, manuscripts should be directed as follows:

- For *Psychological Assessment* send manuscripts to James N. Butcher, Department of Psychology, Elliott Hall, University of Minnesota, 75 East River Road, Minneapolis, Minnesota 55455.
- For *JPSP: Personality* send manuscripts to Russell G. Geen, Department of Psychology, University of Missouri, Columbia, Missouri 65211.
- For *JEP: Animal* send manuscripts to Stewart H. Hulse, Johns Hopkins University, Department of Psychology, Ames Hall, Baltimore, Maryland 21218.
- For *Psychology and Aging* send manuscripts to Timothy Salthouse, Georgia Institute of Technology, School of Psychology, Atlanta, Georgia 30332.