Journal of Applied Psychology
1994, Vol. 79, No. 4, 481-492

0021-9010/94/$3.00

Does Mental Practice Enhance Performance?

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Mental practice is the cognitive rehearsal of a task prior to performance. Although most researchers contend that mental practice is an effective means of enhancing performance, a clear consensus is precluded because (a) mental practice is often defined so loosely as to include almost any type of mental preparation and (b) empirical results are inconclusive. A meta-analysis of the literature on mental practice was conducted to determine the effect of mental practice on performance and to identify conditions under which mental practice is most effective. Results indicated that mental practice has a positive and significant effect on performance, and the effectiveness of mental practice was moderated by the type of task, the retention interval between practice and performance, and the length or duration of the mental practice intervention.

Mental practice refers to the cognitive rehearsal of a task in the absence of overt physical movement. When a musician practices a passage by thinking it through or when an athlete prepares for an event by visualizing the steps required to perform the task, he or she is engaging in mental practice.

A number of studies have examined the effects of mental practice on performance. Whereas the research of Kelsey (1961) and Ryan and Simons (1982) supports the efficacy of mental practice for enhancing performance, Beasley (1978) reported negative results. An astute reviewer may be able to estimate the direction and magnitude of effect of the relationship between mental practice and performance from the preponderance of evidence across the majority of studies. For example, Richardson (1967a) concluded that most studies support the efficacy of mental practice on performance. However, Richardson, and later Corbin (1972), noted that this evidence was inconclusive. Because different studies use different types of tasks, with different types of subjects, and report different study statistics, it is difficult if not impossible to integrate these disparate research studies on an intuitive level to draw firm conclusions on the effectiveness of mental practice. The purpose of this study was to integrate the literature on mental practice, summarize the overall effects of mental practice on performance, and specify the conditions under which mental practice is most effective.

Mental Practice and Performance

Mental practice is the symbolic, covert, mental rehearsal of a task in the absence of actual, overt, physical rehearsal. Richardson provided the standard definition of mental practice as "the symbolic rehearsal of a physical activity in the absence of any gross muscular movements" (1967a, p. 95). This approach has also been variously called *imaginary practice* (Perry, 1939), *covert rehearsal* (Corbin, 1967), *symbolic rehearsal* (Sackett, 1934), and *introspective rehearsal*, or *conceptualization* (Egstrom, 1964). It is important to distinguish this specific definition of mental practice from the broader term *mental preparation*. This more general term may include a variety of disparate techniques that share a goal of enhancing performance, including positive imagery, psyching-up strategies, attention focusing, relaxation, self-efficacy statements, and other forms of cognitive or emotional preparation prior to performance (cf. Caudill, Weinberg, & Jackson, 1983; Hall & Erffmeyer, 1983; Shelton & Mahoney, 1978). By comparison, we reserve the term *mental practice* to refer specifically to a training technique in which the procedure required to perform a task is mentally rehearsed in the absence of actual physical movement.

A typical study within this research domain requires subjects to mentally practice or mentally rehearse performing a task: Common instructions are to sit quietly, not move, and see yourself performing the task successfully from start to finish. Usually, a control (no-practice) group is included, as well as a group that receives actual physical practice on the task. At a given period following the mental practice or physical practice treatments, performance is assessed. If the performance of the mental practice subjects exceeds that of the control subjects, mental practice is said to have a positive effect on enhancing performance.

In some of the earliest mental practice studies, Sackett (1934, 1935) and Perry (1939) found that the mental practice of a task led to significant improvements in subsequent performance. More recent efforts, such as studies by Lee (1990) and Ross (1985), have also shown positive results of mental practice; however, the results of other recent research has been more equivocal (Andre & Means, 1986; Linden, Uhley, Smith, & Bush, 1989). Although Corbin (1972) has noted that the literature "raises more questions than it answers" (p. 115), most authors conclude that mental practice is a potentially valuable technique for enhancing performance (see Druckman & Swets, 1988).

In an effort to clarify the ambiguity in this research domain,

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Support for this research was provided by the Office of Basic Research, Army Research Institute. We thank Brian Mullen for his valuable collaboration.

The views expressed herein are ours and do not reflect the opinion, policy, or views of the Department of the Army or the United States General Accounting Office.

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Feltz and Landers (1983; updated in Feltz, Landers, & Becker, 1988) conducted a meta-analytic integration of the effects of mental practice on performance. However, both the basic philosophy and the specific criteria used to define studies that were included in this prior effort were quite different from that used in the present study. Feltz et al. (1988) described their selection procedure as including studies in which "the effects of some form of mental practice on motor performance" (p. 20) were examined. Accordingly, studies used in the Feltz et al. meta-analysis included those reporting combined mental practice–physical practice treatments (Bagg, 1966; Corbin, 1967; Ryan & Simons, 1983), combined mental practice–modeling interventions (Beckow, 1967; T. J. Murphy, 1977), combined mental practice and audiovisual instruction (Harby, 1952; Surburg, 1968), combined visual imagery–relaxation (Hall & Erffmeyer, 1983), and broadly defined psyching-up strategies (Shelton & Mahoney, 1978). It is important to note that these studies represent a broad range of different types of interventions. For example, in an attempt to enhance athletic performance, Shelton and Mahoney instructed subjects to use any type of psyching-up strategies that came to mind. Subjects reported using a variety of strategies to prepare for performance, including not only some type of mental practice but also emotional arousal, attentional focusing strategies, and other techniques. This study (included in the Feltz & Landers, 1983, meta-analysis) illustrates the importance of using stringent selection criteria to define a meta-analysis. If this broad psyching-up manipulation is included in a mental practice meta-analysis, it is difficult to ascertain what effect is being reported; that is, a positive effect on performance may derive not only from mental practice but also from emotional arousal, self-efficacy statements, or other variables represented in the various manipulations.

To provide a clearly defined and unambiguous test of the effects of mental practice on performance, we conducted a meta-analytic integration, using selection criteria that involved a precise, unidimensional operationalization of mental practice. Studies included in the current analysis had to provide a clear examination of the effects of mental practice, defined as the cognitive rehearsal of a task prior to performance. Studies in which the mental practice manipulation was, in fact, some composite of mental and physical practice, mental practice and modeling, mental practice and relaxation, positive imagery, or emotional arousal are not legitimate tests of the effects of mental practice on performance and were excluded. This exacting perspective is consistent with that of Kosslyn, Seger, Pani, and Hillger (1990) and S. M. Murphy (1990), who have argued that there are various types of mental imagery or mental preparation strategies, of which mental practice is one type.

Furthermore, our selection criteria specify that a hypothesis test must compare the performance of subjects engaging in mental practice with the performance of subjects engaging in no practice. Therefore, a study that contrasts a mental practice condition with a control condition (and which may also include other comparison conditions, such as physical practice) met this criterion. We did not include studies in which there was not an explicit no-practice control group with which to compare the mental practice group performance (e.g., Shelden, 1963; Start, 1962) or in which subjects in the mental practice group mentally practiced some task other than the one that they were later expected to perform (e.g., Kohl & Roenker, 1980). By defining precise and rigorous criteria for inclusion, we attempted to focus the current analysis exclusively on mental practice, not on more broadly defined mental preparation techniques. This approach results in a core set of studies that not only differs considerably from Feltz et al. (1988), but, more important, provides a clearly defined and precise test of the effects of mental practice on performance, rather than the effects of composite treatments or treatments that may not legitimately represent mental practice.

By integrating the mental practice literature in this manner, we pursued two primary goals. Given the apparent inconsistency of empirical results in the mental practice literature, our first goal was to establish the existence of the mental practice effect; that is, does mental practice enhance performance? By integrating the results of studies examining the effects of mental practice on performance, we can provide a very specific and precise summary of the overall effects within this research domain. Basic meta-analytic combinations of effect sizes and significance levels provide a gauge of the overall combined strength and probability of the effect of mental practice on performance. Therefore, our first goal in this analysis was to establish the overall magnitude of the effect of mental practice on performance.

This goal also involves an examination of the relative efficacy of mental practice versus physical practice on performance. A typical study in the mental practice literature has compared a mental practice treatment group with a control or no-practice group. Many studies also included a physical practice treatment group for comparison that received an equivalent amount of physical practice on the task. Because these tests of physical practice were in each instance conducted at the same time, with the same task, and with the same subject population as the corresponding tests of mental practice, these tests provide a useful point of comparison for the effects of mental practice versus physical practice. Studies reporting hypothesis tests for the performance of subjects under both mental practice and physical practice conditions provide the opportunity to examine the relative efficacy of mental practice versus physical practice with other factors held constant.

Our second goal in this analysis was to test hypotheses regarding the nature of the relationship of mental practice to performance; that is, under what conditions is mental practice most effective? Some researchers (e.g., Ryan & Simons, 1981) have argued that the effectiveness of mental practice is limited to tasks with a large cognitive component. Others have claimed that mental practice is dependent on the experience level of the trainee, and that previous experience with the task is a prerequisite for the effective use of mental practice (e.g., Corbin, 1967). As Jowdy and Harris (1990) noted, "without an examination of the mechanisms underlying the effects of mental practice, there is not a clear understanding of why and how it works" (p. 191).

Therefore, our second goal was to examine the extent to which the effect of mental practice varied as a function of these types of theoretically relevant and practically important moderators. By examining these relationships at the meta-analytic level, we could assess the extent to which these factors moderate the effects of mental practice on performance and provide valuable practical information on conditions under which mental practice is most effective. We expected the following five factors to moderate the relationship between mental practice and performance: the type of task, the retention interval (the time interval between practice and assessment), the experience level of trainees, the duration or length of practice, and the type of control group used.

Effects of Moderators

Type of Task

A number of researchers have suggested that the effectiveness of mental practice may be limited to tasks that contain a large symbolic component (Ryan & Simons, 1981; Sackett, 1934). That is, mental practice may be effective only for tasks that involve mental or cognitive events, whereas mental practice may be ineffective for physical tasks for which actual physical practice may be necessary. However, evidence supporting this proposition is equivocal, as studies have shown significant mental practice effects for cognitive tasks (Sackett, 1935), as well as for physical or motor tasks (Egstrom, 1964; Mendoza & Wichman, 1978). To address this issue, we examined whether mental practice was moderated by the extent to which the task was primarily cognitive as opposed to physical.

Retention Interval

One element that varied across different tests of mental practice was the retention interval, or time period, between the last mental practice period and the actual performance measurement. Whereas some researchers gauged the effects of mental practice immediately after the practice period, others extended the delay period for days afterwards. For example, Puretz (1987) examined the performance of a group of subjects 2 days after the mental practice session, Clark (1960) tested one group following a 7-day delay, and Kovar (1967) tested performance of a group of subjects following a 28-day period. One would generally expect a negative relationship between the strength of effect of mental practice and the length of the retention period. That is, the effects of mental practice should be expected to weaken as the retention interval increases. A question of related interest is the extent to which the effects of mental practice weaken over time. In other words, over what time period is mental practice effective? By extracting the retention interval for each hypothesis test included in the meta-analysis, we were able to examine the extent to which the effectiveness of mental practice decays over time. This question has direct implications for effectively implementing (and providing refresher training for) mental practice.

Experience Level

Although many studies included naive or novice subjects, other studies explicitly used subjects who had experience with the task being practiced. Schmidt (1982) has suggested that mental practice may be more beneficial in the early stages of learning, when cognitive or verbal activity is prevalent; thus, novices or those with less experience with the task may realize greater benefit. However, other researchers have argued that prior experience with the task may support the efficacy of mental practice (e.g., Corbin, 1967). For example, Clark (1960) found that experienced basketball players benefited more from the mental practice of a foul-shooting technique than novices. In fact, Zecker (1982) has suggested that mental practice may actually prove detrimental to those with little experience with the task, as the learner has not yet developed an accurate cognitive representation of the task. To examine whether the effectiveness of mental practice was moderated by experience with the task, we coded each hypothesis test for subjects' prior experience with the performance task.

Duration of Practice

The duration of the mental practice intervention varied across studies from 30 s (Weinberg & Jackson, 1985) to 80 min (Kelly, 1965). In general, we expected that more practice would lead to enhanced performance. However, some researchers (Corbin, 1972; Weinberg, 1982) have cautioned against too much mental practice, arguing that extended mental practice may result in a loss of motivation and concentration. In one of the earliest studies of mental practice, Sackett (1935) examined the relationship between the amount of mental practice and performance. Results demonstrated the effectiveness of mental practice over no practice; however, there was no conclusive evidence of any significant increases in performance from greater amounts of practice. Sackett concluded that there is some optimal length for mental practice and that a point may be reached in which further practice is detrimental, a view that has been subsequently voiced by others (Corbin, 1972; Richardson, 1967a; Weinberg, 1982). Nevertheless, the nature of the relationship between the amount of mental practice and performance is unclear.

To examine the question of how much training is required to produce positive effects on performance, we extracted the length or duration of mental practice for each hypothesis test included in the analysis. Two indexes of mental practice duration were examined: the number of trials or sessions and the total duration of practice.

Type of Control

Richardson (1967b) questioned whether the gain in performance attributed to mental practice may be a result of actual learning or a result of the increased motivation attributable to receiving some type of treatment versus no treatment. Thus, he argued that in many cases, the effectiveness of mental practice may be due to the increased attention that trainees receive relative to a no-practice control group. We addressed this question by examining studies that used a no-contact control group versus those that used an equivalent control group. A no-contact, or wait-list, type of control group typically receives no contact between initial assignment to treatment or control groups and data collection. For example, in Wichman and Lizotte's (1983) study, treatment subjects received four sessions of mental practice over a 4-day period before performance assessment, whereas the control group was simply told to return on the assigned date for testing. By comparison, an equivalent control group engages in some nontreatment activity for a period equivalent to the practice time of the treatment group. In Linden et al.'s (1989) study, treatment subjects met for 6 min of mental practice on Days 2–5 and 7–10, whereas controls met for 6 min of nonrelated activity on the same days. By coding each hypothesis test for whether a no-contact or an equivalent control group

Table 1
Physical and Cognitive Dimensions Used in Rating Tasks, According to Task Domain

Domain and dimension	Activity
Physical	
Muscular strength	exert force, apply speed and power, lift, pull
Endurance	sustain physical activity resulting in increased heart rate
Coordination	flex, twist or bend limbs of the body, maintain balance, coordinate movements of the arms, legs, or body in skilled action
Cognitive	
Perceptual input	search for and acquire information, observe, read, monitor, scan, identify, locate
Mental operations	compare and contrast information, organize, analyze, categorize, generate hypotheses, apply principles
Output and response	make decisions, solve problems, make judgments, evaluate

was used, we examined the extent to which the effect of mental practice was moderated by the type of control group.

Method

In accordance with the procedures specified in Cooper (1982), Mullen (1989), and Mullen and Rosenthal (1985), we conducted an exhaustive search of the literature to locate relevant studies, using the ancestry approach, the descendancy approach, the invisible college approach, and key word searches (specifically, *mental practice*) of computerized databases, such as *Psychological Abstracts* (PsycINFO), *Dissertation Abstracts International*, and *National Technical Information Service*. We also manually searched the reference lists of relevant articles and books and searched through major psychological journals and association proceedings.

Studies were selected for inclusion in this meta-analysis if they reported (or allowed the retrieval of) tests of performance under a mental practice condition in comparison with a no-treatment control condition. In addition to the basic statistical information (statistical test of the hypothesis, corresponding degrees of freedom, sample size, and direction of effect), we coded each data point for the predictors described earlier: retention interval (i.e., number of days between the last practice trial and the performance test); duration of practice (length in minutes of the mental practice training, as well as number of trials); experience (i.e., *experience with the performance task* = 1, *novice at performance task* = 0); and type of control (*equivalent control group* = 1, *no-contact control group* = 0).

Furthermore, we rated each hypothesis test according to the type of task: physical versus cognitive. Ryan and Simons (1981) have noted a problem with distinguishing between physical tasks and cognitive tasks in practice, which is that this distinction is often extremely slippery because most tasks are likely to contain both physical and cognitive components. Therefore, to examine the effect of task type, we followed the abilities requirements approach (see Fleishman & Quaintance, 1984) to categorize each task according to the primary physical and cognitive activities required to perform the task. Hogan (1991) has argued that the structure of physical tasks can be described by three dimensions: (a) strength, (b) endurance, and (c) movement quality (see Table 1). The cognitive task domain can be described by three primary activities: (a) perceptual input, (b) mental operations, and (c) output and response. Although this simple taxonomy is not meant to be a comprehensive description of cognitive performance, most models of cognitive performance¶include at least these three elements (see Howell & Cooke, 1989; Turnage & Kennedy, 1992; Wickens, 1984). Two judges were asked to read a description of each task and to assign a total of 100 points across all six dimensions, reflecting the extent to which the task required each of the physical and cognitive dimensions. The judges exhibited a considerable degree of reliability on these ratings of how much a task involved cognitive dimensions versus physical dimensions (interjudge agreement $r = .866$, Spearman–Brown effective reliability $R = .928$). Note that the judgments of how much a task involved cognitive dimensions were complementary to (summing to 100 with) the judgments of how much a task involved physical dimensions.

The hypothesis tests included in this meta-analysis are presented in Table 2. Examination of the characteristics of the studies in Table 2 reveals that most were published relatively recently (with publication dates ranging from 1934 to 1991) and that both journal articles (24) and dissertations (11) are included. Studies that did not meet the criteria for inclusion in the database and were omitted included those in which basic statistical information was not retrievable (e.g., Ulich, 1967) and studies in which there was no control group (e.g., Shelden, 1963). However, the majority of studies that were excluded were those in which mental practice was combined with some other treatment—such as a combined mental–physical practice intervention (e.g., Bagg, 1966; Isaac, 1992; Ryan & Simons, 1983) or combined mental practice–self-talk techniques (Palmer, 1992)—and those studies in which the mental practice intervention was, in fact, some more broadly defined type of mental preparation technique, such as modeling, self-arousal, or positive imagery (Austin & Miller, 1992; Wilkes & Summers, 1984). Given the inclusion criteria, we located 35 studies with 100 separate hypothesis tests, representing the behavior of 3,214 subjects.

In the analyses reported below, hypothesis tests were subjected to standard meta-analytic procedures (see Mullen, 1989; Rosenthal, 1991). Combination of significance levels and combination of effect sizes gauge the combined probability and strength (respectively) of the effect of mental practice on performance. Diffuse comparisons of significance levels and effect sizes gauge the heterogeneity of study outcomes. Focused comparisons of effect sizes are used to determine whether effects vary in a predictable way as a function of theoretically relevant predictors. Formulas and computational procedures for these meta-analytic techniques have been presented by Mullen (1989), Mullen and Rosenthal (1985), and Rosenthal (1991).

Results

General Effects

Table 3 shows the results of the combinations of significance levels and effect sizes for the 100 hypothesis tests included in the meta-analytic database, with each study weighted by its sample size. The results of the combinations of significance levels and effect sizes for the 62 hypothesis tests in which mental practice was used revealed that the combined effects of these hypothesis tests were small to moderate in magnitude ($r = .255$, $d = .527$) and significant ($z = 9.731$, $p < .001$). A substantial fail-safe number of $N_{\text{fail-safe}}$ ($p = .05$) = 4,129 indicated that it would take over 4,100 additional, undiscovered studies averaging no effect of mental practice on performance to reduce the obtained relationship to the .05 level; thus, the overall effect obtained is quite tolerant of future null results. The diffuse comparison of significance levels, $\chi^2(61, K = 62) = 194.212$, $p < .001$, and the diffuse comparison of effect sizes, $\chi^2(61, K = 62) = 186.832$, $p < .001$, indicated that the hypothesis tests produced significantly heterogeneous results.

For comparison, the results of combinations of significance levels and effect sizes for the 39 hypothesis tests in which physical practice was used revealed that the combined effects of these tests were moderate to strong in magnitude ($r = .364$, $d = .782$) and significant ($z = 9.768$, $p < .001$). The focused comparison of the difference between the overall magnitude of the effect for mental practice and the magnitude of effect for physical practice was significant ($z = 3.946$, $p < .001$), indicating that the overall effects of mental practice and physical practice differ.

There were no studies in this database that reported reliability coefficients for the performance measures used, so adjustments for attenuation were not attempted. The observed effect size for mental practice of .255 would be an underestimate if, in fact, the performance estimates were not perfectly reliable. Although the data did not allow precise estimates to be derived, for illustrative purposes we may provide a speculative estimate of the effect size obtained on the basis of several reasonable reliability values. Thus, if the reliability of the performance measures were .80, this would render an obtained mental practice effect size of .319; a reliability of .70 would render an effect size of .364; a reliability of .60 would render an effect size of .425; and a reliability of .50 would render an effect size of .510.

Note that in Table 1, most articles contribute multiple effect sizes (e.g., Clark, 1960, provided six hypothesis tests). In this analysis, each hypothesis test was treated as an independent observation—an assumption of independence that is false. This inflates the significance levels of the combined probability tests. One alternative would be to pool the results within each study into a single hypothesis test; however, this approach would sacrifice valuable information, such as differences in the duration of training or the retention interval. This type of violation has no effect on the mean r or mean d indices of effect size; however, appropriate caution should be applied in interpreting combined probability and chi-square values.

In summary, results indicated that mental practice has a moderate and significant impact on performance. However, the effects of mental practice are weaker than the effects of physical practice.

Type of Task

The degree to which the task involved more cognitive components was a significant predictor of the extent to which mental practice improved performance ($r = .378$, $z = 4.456$, $p < .001$). In other words, mental practice was more effective the more the task required cognitive activities.

We conducted separate analyses of the effect of mental practice for physical tasks and cognitive tasks by blocking on the physical–cognitive continuum. A median split renders 30 cognitive hypothesis tests and 32 physical hypothesis tests. The results of combinations of significance levels and effect sizes for the hypothesis tests using more physical tasks revealed that the combined effects of the hypothesis tests were small in magnitude ($r = .166$, $d = .337$) and significant ($z = 5.511$, $p < .001$). The results of the combinations of significance levels and effect sizes for the hypothesis tests using more cognitive tasks revealed that the combined effects of these tests were moderate in magnitude ($r = .327$, $d = .692$) and significant ($z = 8.027$, $p < .001$). The focused comparison of effect sizes obtained for physical versus cognitive tasks was significant ($z = 4.496$, $p < .001$).

The primary purpose of the preceding analysis was to determine the extent to which the effectiveness of mental practice was determined by whether the task was primarily cognitive or physical. However, for exploratory purposes, it is informative to consider the more specific predictions that are allowed by this analysis, by examining the extent to which the specific physical and cognitive dimensions contributed to the prediction of mental practice. Examining the structure of physical tasks, one finds that the negative relationship between the extent to which a task involves physical activities and the effectiveness of mental practice is primarily determined by the strength component ($r = -.358$, $z = 3.856$, $p < .001$), to a lesser degree by coordination ($r = -.239$, $z = 2.798$, $p < .01$), and that endurance accounted for little or no variability ($r = -.015$, $z = 0.147$, $p > .1$). Thus, the more a task includes strength and coordination requirements, the less effective is mental practice. For the cognitive domain: The more a task required mental operations, the more effective was mental practice ($r = .435$, $z = 5.147$, $p < .001$). Output and response activities ($r = .395$, $z = 5.083$, $p < .001$) as well as perceptual input activities ($r = .260$, $z = 2.976$, $p < .01$) were somewhat weaker, yet potent predictors.

In summary, mental practice is effective for both cognitive and physical tasks; however, the effect of mental practice is significantly stronger the more a task involves cognitive elements.

Retention Interval

The data indicated a significant negative relationship between the length of the retention interval and the magnitude of the mental practice–performance effect ($r = -.216$, $z = 2.453$, $p < .01$). Thus, the longer the delay between practice and performance, the weaker the effects of mental practice on performance.

In itself, the effect of the retention interval is not surprising, in that deterioration in the effects of practice over time is well documented. However, by using the regression formula (Fisher's $Z = .334 - .011$[RETENT]), we derived an estimate of the extent to which mental practice is degraded based on a given retention interval. These results are shown in Table 4.

As expected, the strongest effect of mental practice (Fisher's $Z = .334$) was obtained with the shortest interval period (0 days, or when performance was tested immediately after practice). Note that the initial effects of mental practice were reduced to approximately one-half of their initial magnitude ($0.334/2 = 0.17$) if the retention period was extended to 14 days. Finally, after approximately 21 days, the beneficial effects of mental

Table 2
Studies Included in the Mental Practice Meta-Analysis

Study	Statistic	Practice test	*N*	Cohen's d^a	Exp	Ret	Task	Dur	No. of trials	Con
Andre & Means (1986)	$t(63) = 0.428$	M	22	0.108	0	—	27.5	225	45	1
	$t(63) = 0.215$	M	22	0.054	0	—	27.5	225	45	1
Beasley (1978)	$t(187) = -3.185$	M	189	−0.466	0	1	77.5	5	7	1
	$t(178) = -3.258$	P	180	−0.488	0	1	—	5	7	1
Clark (1960)	$t(48) = 0.92$	M	15	0.266	1	7	17.5	—	30	—
	$t(48) = 1.41$	M	23	0.407	1	7	17.5	—	30	—
	$t(48) = 1.59$	M	26	0.459	0	7	17.5	—	30	—
	$t(48) = 0.98$	P	16	0.283	1	7	—	—	30	—
	$t(48) = 1.47$	P	24	0.424	1	7	—	—	30	—
	$t(48) = 2.69$	P	44	0.777	0	7	—	—	30	—
Conly (1968)	$t(76) = 0.514$	M	40	0.118	1	0	15	1	1	0
	$t(76) = 1.25$	M	40	0.287	0	0	15	1	1	0
Cronk (1967)	$t(59) = -0.953$	M	16	−0.248	0	3	2.5	24	240	0
	$t(59) = 1.57$	P	16	0.409	0	3	—	24	240	0
Egstrom (1964)	$t(116) = 0.294$	M	19	0.055	1	0	47.5	30	6	0
	$r(116) = 0.289$	M	39	0.604	0	0	47.5	30	6	0
	$t(116) = 1.693$	P	19	0.314	1	0	—	30	6	0
	$r(116) = 0.486$	P	38	1.112	0	0	—	30	6	0
Gondola (1966)	$t(30) = 1.71$	M	22	0.624	0	10	17.5	35	7	0
	$t(30) = 1.137$	P	22	0.415	0	1	—	35	7	0
Hackler (1971)	$t(22) = 1.980$	M	24	0.844	0	7	40	—	75	0
	$t(22) = 2.735$	M	24	1.166	0	0	40	—	75	0
	$t(10) = 1.455$	M	12	0.920	0	0	40	—	75	0
	$t(22) = 2.434$	P	24	1.038	0	0	—	—	75	0
	$t(22) = 1.841$	P	24	0.785	0	7	—	—	75	0
	$t(10) = 0.601$	P	12	0.380	0	0	—	—	75	0
Hird, Landers, Thomas & Horan (1991)	$t(22) = 7.307$	P	24	3.116	0	9	—	28	7	1
	$t(22) = 5.463$	M	24	2.329	0	9	52.5	28	7	1
	$t(22) = 5.587$	P	24	2.382	0	9	—	28	7	1
	$t(22) = 1.936$	M	24	0.826	0	9	72.5	28	7	1
Jeffrey (1976)	$r(39) = .254$	M	20	0.525	0	0	80	12	6	1
	$r(39) = .463$	P	20	1.045	0	0	—	12	6	1
Kelly (1965)	$t(56) = 0.411$	M	58	0.110	0	1	17.5	80	20	1
	$t(52) = 0.024$	M	54	0.007	0	1	17.5	80	10	1
	$t(53) = -0.051$	P	55	−0.014	0	1	—	80	20	1
Kelsey (1961)	$t(11) = 2.92$	M	12	1.761	1	1	2.5	5	20	0
	$t(11) = 3.61$	P	12	2.177	1	1	—	5	20	0
Kovar (1967)	$t(131) = 0.68$	M	32	0.119	0	0	17.5	10	12	0
	$t(131) = -0.827$	M	32	−0.145	0	28	17.5	10	12	0
	$t(131) = 0.383$	M	32	0.067	0	35	17.5	10	12	0
	$t(131) = 0.260$	P	32	0.045	0	0	—	10	12	0
	$t(131) = 0.827$	P	32	0.145	0	28	—	10	12	0
	$t(131) = 1.150$	P	32	0.201	0	35	—	10	12	0
Lee (1990)	$t(16) = 1.15$	M	17	0.575	1	0	7.5	1	1	1
	$t(46) = 2.44$	M	47	0.720	1	0	7.5	1	2	1
Linden, Uhley, Smith & Bush (1989)	$t(10) = 0.85$	M	11	0.538	1	1	17.5	6	4	1
Madrid (1971)	$t(58) = 0.668$	M	60	0.175	0	0	75	8.3	10	0
Mendoza & Wichman (1978)	$F(1, 28) = 19.75$	M	16	1.680	0	1	35	30	6	0
	$F(1, 28) = 63.57$	P	16	3.014	0	1	—	30	6	0
Nigro (1983)	$t(85) = 3.216$	M	36	0.698	0	0	30	—	24	1
	$t(55) = 4.836$	M	24	1.304	0	0	65	—	24	1
	$t(55) = 6.815$	P	24	1.838	0	0	—	—	24	1
Noel (1980)	$Z = 0.966$	M	6	0.858	1	10	17.5	30	4	0
	$Z = -1.919$	M	8	−1.847	1	10	17.5	30	4	0
Perry (1939)	$t(30) = 1.49$	M	32	0.544	0	1	30	2.5	5	0
	$t(30) = 3.81$	M	32	1.391	0	1.5	85	5	5	0
	$t(22) = 5.70$	M	24	2.430	0	1.5	57.5	5	5	0
	$t(28) = 5.50$	M	30	2.079	0	1	95	5	5	0
	$t(26) = 2.27$	M	28	0.890	0	1.5	77.5	5	5	0
	$t(30) = 2.91$	P	32	1.063	0	1	—	2.5	5	0
	$t(30) = 7.70$	P	32	2.812	0	1.5	—	5	5	0
	$t(22) = 4.00$	P	24	1.706	0	1.5	—	5	5	0
	$t(28) = 8.56$	P	30	3.235	0	1	—	5	5	0
	$t(26) = 4.29$	P	28	1.683	0	1.5	—	5	5	0

(*table continues*)

Table 2 (*continued*)

Study	Statistic	Practice test	*N*	Cohen's *d*[a]	Exp	Ret	Task	Dur	No. of trials	Con
Phipps & Morehouse (1969)	$r(70) = .304$	M	72	0.638	0	0	5	50	5	0
	$r(70) = .214$	M	72	0.438	0	0	5	50	5	0
	$r(70) = .021$	M	72	0.042	0	0	10	50	5	0
Puretz (1987)	$t(63) = 0.574$	M	16	0.145	0	0.02	12.5	5	1	0
	$t(63) = 0.816$	M	16	0.206	0	7	12.5	5	1	0
	$t(63) = 0.147$	M	16	0.037	0	2	12.5	5	1	0
	$t(63) = -0.472$	P	16	−0.119	0	0.02	—	5	1	0
	$t(63) = -0.121$	P	16	−0.030	0	2	—	5	1	0
	$t(63) = -0.669$	P	16	−0.169	0	7	—	5	1	0
Ross (1985)	$t(10) = 1.304$	M	12	0.825	1	0	82.5	—	3	1
	$t(10) = 2.671$	P	12	1.689	1	0	—	—	3	1
Ryan & Simons	$t(30) = 4.848$	M	32	1.770	0	0	7.5	5	10	0
	$t(30) = 6.746$	P	32	2.463	0	0	—	5	10	0
Sackett (1934)	$r(38) = .301$	M	40	0.631	0	0	90	—	38.3	0
	$r(38) = .495$	P	40	1.139	0	0	—	—	67.5	0
Sackett (1935)	$r(48) = .726$	M	50	2.111	0	0	90	—	35	0
	$r(48) = .613$	M	50	1.552	0	0	90	—	7	0
	$r(48) = .642$	M	50	1.675	0	0	90	—	21	0
Samuels (1969)	$t(238) = 6.493$	M	70	0.842	0	0	75	5	1	0
	$t(238) = 7.335$	P	70	0.951	0	0	—	5	1	0
Shappell (1977)	$t(68) = 2.174$	M	26	0.527	0	1	85	—	20	1
	$t(68) = 10.517$	P	27	2.551	0	1	—	—	20	1
Shick (1970)	$r(8) = .353$	M	10	0.755	1	—	20	42	14	0
Smith & Harrison (1962)	$t(54) = -0.495$	M	20	−0.135	0	0	70	1	6	1
	$t(54) = 1.979$	P	20	0.539	0	0	—	1	6	1
Stebbins (1968)	$t(88) = 0.061$	M	39	0.013	0	0	35	—	18	0
	$t(88) = 1.646$	P	35	0.351	0	0	—	—	18	0
Steel (1952)	$t(28) = 1.08$	M	30	0.408	0	1	40	80	200	0
	$t(28) = 2.07$	P	30	0.782	0	1	—	80	200	0
Twining (1949)	$Z = 1.829$	M	24	0.805	0	1	40	—	1,470	0
	$Z = 3.066$	P	24	1.605	0	1	—	—	4,410	0
Weinberg & Jackson (1985)	$t(69) = 2.342$	M	24	0.564	1	0	2.5	0.5	1	1
	$t(69) = 2.255$	M	24	0.543	1	0	2.5	0.5	1	1
	$t(69) = 2.748$	M	24	0.662	1	0	5	0.5	1	1
	$t(69) = 1.179$	M	24	0.284	1	0	7.5	0.5	1	1
Wichman & Lizotte (1983)	$F(1, 31) = 5.1$	M	35	0.811	0	0	42.5	24	4	0

Note. Dashes indicate that data were not reported in the study. M = mental practice test; P = physical practice test; Exp = experience with performance task: 1 = *experienced*, 0 = *novice*; Ret = retention interval (expressed in days) between the last practice trial and performance; Task = mean ratings of the extent to which the task required cognitive activities: 0 = *low cognitive* and 100 = *high cognitive*; Dur = duration (in minutes) of the mental practice session; Con = type of control group: 1 = *equivalent*, 0 = *no contact*.

[a] Positive effect sizes indicate a positive effect of mental practice on performance. Note that the *d*s reported for effect size in Table 1 were derived directly from the correlation coefficient, *r*. All meta-analytic computations were based on Fisher's transformation of *r*.

practice fall below the .10 level conventionally defined as a *small effect*, following Cohen's (1977) guidelines. For comparison, Table 4 also indicates that the effects of physical practice within the studies in this database are somewhat more robust than the effects of mental practice. It should be noted that the data provided no evidence of a nonlinear relationship for the reported retention or the practice duration functions. Such effects have been observed in other training contexts; however, the present data failed to reveal any nonlinear effects.

Effects of Experience

Separate analyses of the effects of mental practice were conducted for experienced and novice subjects. The results of combinations of significance levels and effect sizes for the 16 hypothesis tests in which subjects had previous experience with the performance task revealed that the combined effects of these tests were moderate in magnitude ($r = .224$, $d = .460$) and significant ($z = 5.043$, $p < .001$). The results of the combination of significance levels and effect sizes for the 46 hypothesis tests in which subjects had no previous experience with the performance task (i.e., were novices) revealed that the combined effects of these tests were moderate in magnitude ($r = .260$, $d = .539$) and significant ($z = 8.681$, $p < .001$). The focused comparison of effect sizes for experienced and novice subjects was not significant ($z = 1.246$, $p > .1$), indicating that the tendency for novices to exhibit stronger mental practice effects was not significant.

However, this overall basic effect of experience is qualified by the type of task. The 62 hypothesis tests using mental practice were cross-blocked (Mullen, 1989) according to task type and experience. For novice subjects, the results indicated stronger effects of mental practice for cognitive tasks than for physical tasks ($z = 5.259$, $p < .001$). For experienced subjects, there was

Table 3
Combinations of Significance Levels and Effect Sizes and Focused Comparisons for Mental Practice and Physical Practice

		Effect size			z	
Practice	K	Fisher's Z	r	d	Significance	Focused comparison
Mental	62	0.261	.255	.527	9.731	3.946
Physical	38	0.382	.364	.782	9.768	

Note. All $ps < .001$.

no significant difference for cognitive or physical tasks (z = 0.019, $p > .1$). Thus, experienced subjects benefit equally well from mental practice, regardless of task type. Novice subjects benefit more from mental practice on cognitive tasks than on physical tasks.

Duration

The data indicated no significant relationship between the number of practice trials and the magnitude of effect of mental practice (r = .019, z = 0.214, $p > .10$). Thus, the number of practice trials is not a significant predictor of the effect of mental practice on performance.

There was a significant negative relationship between the duration of mental practice and the magnitude of effect (r = −.185, z = 1.879, p = .03). Thus, as the overall length of the mental practice intervention increases, the beneficial effect of mental practice on performance decreases. In other words, although the overall effect of mental practice on performance is positive (as shown in Table 2), the longer someone mentally practices, the less beneficial it becomes. Using the regression formula (Fisher's Z = .288 + [-.0013(DURATION)]), we estimated that the mean effect size for mental practice reported in Table 2 (Fisher's Z = .261) may be attained with a length of practice of approximately 20.8 min. Therefore, a practical guideline for implementing mental practice suggests an overall training period of approximately 20 min.

Type of Control

The effect of mental practice on performance for the 20 hypothesis tests using equivalent control groups was small in magnitude (r = .122, d = .246) and nonsignificant (z = 1.053, $p >$ .10). The effect of mental practice for the 39 hypothesis tests using no-contact control groups was somewhat larger (r = .327, d = .693) and significant (z = 12.337, $p < .001$). However, the focused comparison of effect sizes obtained for equivalent versus no-contact control groups was not significant (z = 1.173, p > .10). Therefore, although there is a trend for mental practice to be more effective in comparison with a no-contact control group than in comparison with an equivalent control group, this difference is not significant.

Table 4
Effect of Retention Interval on Magnitude of Effect

Retention interval (days)	Magnitude of effect (Fisher's Z)	
	Mental practice	Physical practice
0	.334	.520
7	.255	.449
14	.176	.378
21	.098	.308

Discussion

As a means of enhancing performance, mental practice is sometimes viewed with skepticism; for example, Druckman and Swets (1988) included mental practice in a review of several training techniques described as "outside the mainstream" of traditional science (p. vii). We believe that there are two reasons for this caution: (a) Mental practice is often melded together with various other mental preparation approaches, from psyching-up strategies to more esoteric visualization techniques, and (b) claims regarding popular applications of these techniques are sometimes exaggerated (see Austin & Miller, 1992). In this meta-analytic integration of the mental practice literature, we have attempted to address both of these shortcomings by defining mental practice in a precise manner and by integrating data within this research domain to summarize the effects of mental practice on performance.

First, the results of this analysis indicate that mental practice is an effective means for enhancing performance. However, the data also indicate that mental practice is less effective than overt, physical practice. This is not surprising when one considers what mental practice offers and what it does not offer. Mental practice offers the opportunity to rehearse behaviors and to code behaviors into easily remembered words and images to aid recall. Mental practice does not offer direct knowledge of results or visual and tactile feedback. Thus, whereas we find that mental practice is less effective than physical practice in enhancing performance, it still exerts a significant positive effect on performance.

Second, results indicated that the type of task is a significant moderator of the effectiveness of mental practice: The effect of mental practice on performance is stronger the more the task involves cognitive elements. However, results further indicated that mental practice is effective for both cognitive and physical tasks, even for tasks as dissimilar as determining volumetric analyses of chemical substances (Beasley, 1978) and welding (Hackler, 1971).

Third, the positive effect of mental practice on performance declines over time, a not altogether surprising phenomenon. Moreover, on the basis of this analysis, we were further able to estimate the nature of this relationship: After approximately 2 weeks, the beneficial effects of mental practice have been reduced to one-half of their original magnitude, and after approximately 3 weeks, the increase in performance due to mental practice has substantially dissipated. These estimates provide practical guidelines for implementing mental practice: To gain the maximum benefits of mental practice, one should implement refresher training on at least a 1- to 2-week schedule.

Fourth, the results of this analysis qualify the claim that mental practice is more effective for experienced trainees than for novices. Indeed, our analysis revealed a nonsignificant trend for mental practice to be more effective for novices. However, this trend was qualified by an Experience × Task Type interaction. Experienced subjects benefited equally well from mental practice, regardless of task type. Novice subjects benefited more from mental practice on cognitive tasks than on physical tasks. This result is consistent with Ryan and Simons's (1983) argument that if an experienced individual has already learned the component motor skills of a physical task, then mental practice may be sufficient to enhance performance without additional physical practice and feedback. For novices, who have not formed an approximation of the skill, the symbolic rehearsal provided by mental practice may not be sufficient to guide performance. This suggests that mental practice may be more effective, everything else held constant, if novice subjects are given schematic knowledge before mental practice of a physical task.

Finally, our data provide support for the claim that more mental practice is not necessarily better. Many researchers have held that extended mental practice may lead to a loss of concentration and that there is an optimal length for mental practice interventions, although the exact nature of this limitation is unclear (see Corbin, 1972; Richardson, 1967a; Weinberg, 1982). For example, Corbin (1972, p. 106) argued that "relatively short" practice sessions are optimal. Results of the present analysis provide an empirical basis for this argument and reveal that the longer the duration of mental practice, the weaker the effect. More precisely, our results indicated that the number of practice trials is not a critical parameter but that the total duration of training is. Furthermore, the data suggested that approximately 20 min total duration may be an optimal mental practice intervention.

However, these results raise the question of why extended mental practice does not enhance performance. Why does more mental practice produce diminishing results? Perhaps the benefits from mental rehearsal are established in a relatively short-term period and continued practice is of diminishing value. It is possible that whereas mental practice offers the opportunity for rehearsal, these benefits are self limiting, and continued mental practice without knowledge of results or the opportunity for feedback may degrade motivation and perhaps increase negative affect (i.e., boredom). Thus, as a result of extended physical practice, the trainee typically receives feedback reflecting increasing proficiency; however, the trainee may not perceive a similar payoff from increased mental practice.

We have argued (along with others, see Murphy, 1990) that mental practice has been defined so broadly as to include almost any form of mental preparation prior to task performance. Accordingly, we adopted a precise and rigorous approach to defining the domain of research and to including studies in this analysis. This decision resulted in a more tightly focused research effort and in the exclusion of a number of studies that did not report a clear and unambiguous manipulation of mental practice per se. It is important to distinguish what, at least for the purposes of this study, mental practice is and is not. We defined *mental practice* as the cognitive rehearsal of a task in the absence of overt physical movement. Specifically, this definition refers to mental practice as a technique in which the skills or behaviors required to perform a task are mentally rehearsed before performance. The primary emphasis in this procedure is on the cognitive rehearsal of a task sequence. We distinguished mental practice from other types of mental preparation strategies, in which the primary emphasis is to increase arousal (psyching up), to enhance positive affect (positive imagery), to eliminate negative thoughts (self-talk), or to achieve a vivid visualization of some event. The reader should be cautioned that the term *mental practice* may be applied in the literature to a variety of training techniques or interventions that are conceptually quite different.

Consistent with the goal of examining the mechanisms underlying mental practice, the results of this study illuminate the discussion about why mental practice enhances performance. Although a number of studies have demonstrated the mental practice phenomenon, theoretical accounts for the effectiveness of mental practice differ. Next, we consider three such theories: the psychoneuromuscular approach; a psuedomotivational account; and the cognitive, or symbolic, explanation.

The psychoneuromuscular explanation claims that mental practice causes minute innervations to occur in the muscles that are actually used in the physical performance of the skill being learned. This account dates back to Jacobson (1932) and even Carpenter (1894). This explanation holds that the muscular activity caused by mental practice is similar to (but of lower magnitude than) that produced by the actual physical movements. This innervation is alleged to provide kinesthetic feedback to the learner, and thereby strengthens the motor program that governs the skill involved. Unfortunately, there is a general absence of recent neurophysiological evidence to support these ideas of low-level innervation leading to enhanced performance. Furthermore, the present results do not support this interpretation. The psychoneuromuscular account suggests that the effects of mental practice would be greater for physical tasks (which would be expected to produce more muscular innervations) than for cognitive tasks. However, the pattern of results reported in this analysis indicates that the effect of mental practice was stronger the more a task required cognitive activities. The demonstration in our analysis of the effects of mental practice on tasks that require minimal muscular activity (i.e., cognitive tasks) suggests that low-level innervation of muscular activity may not be a compelling account for the effects of mental practice.

A second explanation for mental practice effects is that mental practice is an epiphenomenon. Corbin (1967) and Richardson (1967b) noted that most studies show a strong effect of physical practice and a weaker effect of mental practice relative to a control group. Because in most studies the control group gets nothing and the mental practice group gets something, the effects of mental practice may be be attributed to a Hawthorne effect. Thus, Richardson argued that the superiority of physical practice may be due to learning and that the gain from mental practice may be because the mental practice group receives some attention relative to a typical no-contact control group. We investigated this possibility by examining the effects of mental practice in studies using no-contact control groups versus studies using equivalent control groups. Although results indicated a tendency for the effect of mental practice to be stronger with a no-contact control group comparison, there was no significant difference in the effects of mental practice for those studies using equivalent control groups and those using no-contact control groups.

A third theory is the cognitive, or symbolic, explanation. The principal idea, as originally proposed by Sackett (1934), is that mental practice facilitates those skills in which there is a symbolic control of the movements involved. This is certainly supported by the overall pattern demonstrating mental practice to be more effective for cognitive tasks in comparison with physical tasks. In addition, some researchers (Corbin, 1967; VanLehn, 1989) have argued that with experience, people develop a mental plan of the movements involved. Experts are more likely to have more sophisticated schemata and are better at "chunking" new information (e.g., Posner, 1989). This might explain the overall interaction between task type and experience. Thus, experienced subjects may benefit more from mental practice on the physical tasks because they have the requisite schematic knowledge to imagine the accurate and precise outcomes associated with the imagined performance. As suggested by Finke (1989), the novices who mentally practiced a physical task may not have sufficient schematic knowledge about successful task performance and may be spending their effort imagining task behaviors that could turn out to be somewhat counterproductive. Furthermore, note the precise form that this significant interaction takes: Experienced subjects benefit equally well from mental practice, regardless of task type. Novice subjects benefit more from mental practice on cognitive tasks than from mental practice on physical tasks. This might be because novice subjects with a physical task lack the schematic knowledge (representing a mental plan of the movements involved) necessary for the benefits of mental practice to be optimized. Further research should explore these possibilities.

In summary, the results of this study indicate that mental practice is an effective means for enhancing performance, although less effective than physical practice. Thus, for tasks that are dangerous to train for physically, for tasks in which there are seldom opportunities for physical practice, or as a means of supplementing normal training, mental practice should be considered as an effective training alternative.

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Received November 20, 1992
Revision received November 5, 1993
Accepted November 5, 1993 ■