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Rubbing Your Stomach While Tapping Your Fingers: Interference Between Motor Planning and Semantic Judgments

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Previous research (Klatzky et al., 1989) shows that the time required to make sensible/nonsensible judgments about an action-object phrase (e.g., "rub your stomach") is reliably faster when the phrase is preceded by a cue representing a specific prototypical hand shape (vs. a neutral cue). The current experiments investigated the effects of preparing for an alternate task (finger tapping vs. syllable vocalization) on facilitatory priming of sensibility judgments. Preparation for finger tapping reduced the magnitude of the priming effect more than preparation for vocalization, suggesting that resources accessed during semantic processing of action-object phrases are also used during manual response preparation. The results support the existence of a system representing manual actions that is limited in the number of activities that can be represented at one time and that is not so general that it represents manual and vocal tract movements.

Such abilities as planning for, practicing, and evaluating actions in advance of explicit performance or remembering movements after they occur seem to be essential aspects of human performance. Relatively little is known about the representational systems that mediate these abilities, and there is considerable controversy about their effects (Swets & Bjork, 1990). Two effects that have received considerable attention, for example, are the facilitation of performance by "mental practice" (reviewed by Feltz & Landers, 1983; Feltz, Landers, & Becker, 1988) and the facilitation of memory for verbal items by their enactment, either through pantomime or with physically present objects (reviewed by Cohen, 1989; Engelkamp, 1988).

Underlying these activities are several cognitive components (each having great theoretical complexity), including static representation of the body (e.g., Parsons, 1987a) and temporal change in mental representation (Freyd, 1987; Shiffrar & Freyd, 1990). Our own previous research has addressed mental representation of a particular aspect of the body and its movement, focusing on the shaping of the hand for functional interaction with an object. The hand shapes we have studied result from the crossing of two binary (or at least reasonably so) dimensions: (a) the size of the hand surface in contact with the object and (b) whether the hand shape is prehensile (grasping) or open. This combination of factors describes four broadly conceived hand shapes: the clench (large and prehensile), the palm (large and nonprehensile), the pinch (small and prehensile), and the poke (small and nonprehensile). That these shapes have common English names suggests that they may constitute well-defined cognitive categories (see Rosch, 1978). Furthermore, there are strong associations between objects and the hand shape(s) typically used in interacting with them (Klatzky, McCloskey, Doherty, Pellegrino, & Smith, 1987).

Given the apparent stereotypy of many manual interactions with objects and the involvement of a well-defined hand shape, we investigated whether priming of a hand shape could facilitate semantic judgments about such interactions (Klatzky, Pellegrino, McCloskey, & Doherty, 1989). In one set of studies, subjects were asked to indicate whether a particular action on an object (described by a verb phrase) was plausible. For example, "rub your stomach" is plausible, but "climb a newspaper" is not. Prior to the decision about the action phrase, the subject was sometimes primed by a hand-shape cue. The results revealed that subjects were faster in judging a plausible action than when the hand-shape cue was replaced by a neutral signal.[1]

Such a priming effect was found for a variety of conditions. In most cases, we first trained subjects as to the meaning of particular priming cues by having them enact a shape, given the corresponding cue, for approximately 100 trials. A priming effect was found for verbal hand-shape primes that were designed to cue each dimension of the hand shape separately (e.g., "finger touch" for the size and prehensility of the poke shape vs. "hand grasp" for the clench). The priming effect was found as well for iconic primes, which pictorially represented the dimensions (e.g., | for poke and >>>> for clench). It was found under conditions of presentation as brief as a 250-ms prime–stimulus interval. And it was found in a condition in which the instructions did not encourage subjects to pay attention to the prime and, indeed, in which many subjects reported that they had not bothered to read the prime.

The priming effect was not found under one critical condition, however: when the training required subjects to name the hand shape (e.g., saying *poke*) in response to the prime

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[1] The comparison of neutral and informative primes is potentially confounded by a number of variables, such as physical form and repetition differences (see Jonides & Mack, 1984). However, we (Klatzky, Pellegrino, McCloskey, & Doherty, 1989) presented a number of converging indications that the effect resulted from a difference in the information content of the primes, not artifact. This included findings of prime effects when the primes were all similar in form, with different SOAs, and despite repetition differences. We have also reduced the potential for artifact by using both prime types mixed within a single session at equal probabilities.

cue, rather than enact it. We took this finding as evidence that the priming effect reflects processing at a level that is not purely semantic, but rather is more closely associated with the motor system. (We initially tried to minimize the effects of purely semantic association as well, by showing subjects pictures of the hand shapes at the start of training and never naming them directly.)

On the whole, our previous results (Klatzky et al., 1989) support the existence of a motoric system that, when activated, facilitates semantic processing about functional interactions with objects. In the present studies, we tested specific assumptions about that system. The assumptions were that (a) the system is limited in the number of movement events that can simultaneously be represented; (b) the same system that facilitates judgments about the plausibility of a potential action is used to prepare for explicit actions; and (c) the system acts more specifically than a generalized motoric activation—in particular, it is not used in preparing for speech as well as in preparing for manual action. We tested these assumptions with an interference paradigm designed to assess competition between priming of a hand shape and preparation for a second, overt motor task.

We report three studies. In Experiment 1, we verified that a priming effect occurs with two different response modalities: Subjects responded by pressing a key or by vocalizing their yes or no response. In Experiments 2 and 3, we used an interfering task, in which subjects had to prepare simultaneously for a semantic plausibility judgment and a four-finger tapping sequence (or, in the control group, a four-syllable vocal sequence). The principal hypothesis was that preparation for tapping would reduce the magnitude of the priming effect more than preparation for syllable vocalization would, because only the former would share resources with the system that mediates hand-shape priming.

To clarify, suppose that sensibility judgments require access to motor representations (specifically, of the hand) and that the prime activates such representations in advance of the action to be judged. Assume further that the system that allows such representations to be activated has limited resources. Interference might arise between the prime-induced activation of a motor representation and the preparation and scheduling of an alternative manual response, because both require access to common resources. If interference does occur, then the end result should be a reduction in the magnitude of the priming effect. The comparison of the two interfering tasks was used to show that interference is not due to gross capacity sharing between semantic and motor tasks (e.g., Friedman, Polson, & Dafoe, 1988), but is specific to preparation for manual action.

Experiment 1

Method

Subjects

Twenty-four undergraduate students in the introductory psychology course at the University of California, Santa Barbara, participated in the experiment to fulfill a course requirement.

Stimuli

The stimuli included four icons representing the hand shapes. The icons conveyed information about the two shape dimensions by mapping the prehensile (flexion) and nonprehensile (extension) shapes into the > and | symbols, respectively, and by mapping size into the number (1 or 4) of symbols present in the cue. The poke shape was represented by |, the pinch by >, the palm by ||||, and the clench by >>>>. The four hand-shape icons were used during both the initial training and the main experiment. An * served as a neutral icon during the main experiment only.

Twenty sensible and 10 nonsensible object–action phrases for each of the four hand-shape categories were used as targets during sensibility judgment trials, yielding a total of 80 sensible and 40 nonsensible phrases. The phrases were essentially the same as those used in our earlier priming experiments (Klatzky et al., 1989). A sensible phrase described a reasonable action that could be performed with a particular object (e.g., "squeeze a tomato"), whereas a nonsensible phrase described an action that was highly unlikely to be done with an object (e.g., "squeeze a window"). Each sensible phrase was paired with one of the four hand shapes, in that a particular shape was likely to be used to perform the action it described. For example, "squeeze a tomato" was paired with the clench shape. In constructing sensible phrases, we tried to avoid strong a priori association between the verb and the object name (e.g., eliminating phrases such as "wring a towel") and to minimize the amount of verb repetition across phrases (e.g., limiting the number of times the verb *hold* was paired with different object names).

Nonsensible phrases were constructed by re-pairing the actions and objects in a particular shape class. Because of their nonsensibility, the phrases were rarely associated with the given hand shape (or with any shape).

Procedure and Design

Main experiment. The subject's task in each trial during the main experiment was to decide whether a target phrase was sensible or nonsensible. The target phrase was preceded by the brief presentation of an icon prime. The prime either provided no information about the hand shape implied by the upcoming target phrase (the prime was the neutral cue) or identified the hand shape completely by providing both prehensility and size information.

Instructions for the sensibility judgment trials did not direct subjects to interpret the prime, although they were told to look at it. They were told to make each sensibility judgment solely on the basis of whether the target phrase described a reasonable action that could be performed with the object.

Four blocks of 120 phrases each were constructed. Each block contained all 80 sensible and 40 nonsensible phrases, arranged in random order. Within a block, each phrase was assigned to one of the two priming conditions, with two constraints. First, over all blocks, every phrase appeared exactly twice in each of the priming conditions. Second, within a block, an equal number of nonsensible phrases from the four hand-shape categories appeared in each of the priming conditions. For example, 10 of the sensible clench phrases in a block were preceded by a neutral prime, with the remaining 10 preceded by the clench icon.

Presentation of the four blocks to subjects was arranged according to a Latin square. An IBM PC-AT controlled the display of stimuli and recorded subject responses and reaction times (RTs). The experiment contained a total of 128 conditions (2 types of response mode for making sensibility judgments × 2 priming conditions × 4 hand-shape categories × 4 blocks of trials × 2 sensibility values, with a 2:1

ratio of sensible to nonsensible trials) over 480 trials. There was one between-subjects factor, the response mode for producing sensibility judgments (keypress vs. voice), with 12 subjects randomly assigned to each group. The remaining factors were examined within subjects. The main experiment lasted approximately 1.5 hr and began after a short rest period following completion of the training phase. Subjects participated individually.

A trial proceeded according to the following time course. First, a fixation point (X) appeared in the center of the screen for 1,000 ms. Next, an icon from one of the two priming conditions (neutral vs. hand shape) was displayed in the center of the screen for 500 ms. The screen cleared for 250 ms, and then the target phrase was presented. Thus, the interval between onset of the prime stimulus and the target stimulus (stimulus onset asynchrony [SOA]) was 750 ms. The target phrase remained visible until the subject indicated a sensibility judgment. The RT was measured as the time between presentation of the target phrase and the onset of the subject's sensibility response.

Voice subjects wore a collar-mounted microphone and said yes when they judged the target phrase to be a sensible description of an activity being performed with an object and no when they judged the phrase to be nonsensible. A voice-activated relay signaled a computer-controlled clock, and the experimenter then entered the response into the computer. Keypress subjects indicated their responses on a button box, which consisted of a row of eight buttons and a space bar, interfaced to the computer. They pressed the fifth button (right index finger) to indicate sensible phrases and the fourth button (left index finger) for nonsensible phrases. In this case, the keypress signaled the clock and registered the response in the computer. None of the subjects received feedback about the appropriateness of their responses. After the subject responded, the screen cleared for 2,000 ms before the next trial began.

At the start of the experiment, each subject received 10 practice trials with feedback. The practice trials included both neutral and hand-shape primes and presented phrases from all four hand-shape categories. None of the practice phrases was used in the actual experiment.

Training phase. All subjects participated in a brief training phase before the main experiment started. First, the experimenter explained the icon cues to the subject and mimed the hand shape corresponding to each one. The experimenter did not mention a verbal label for the hand shape.

In each training trial, subjects were to produce a hand shape as rapidly as possible in response to the presentation of an icon. The subject initiated the trial by pressing the button box space bar in response to the appearance of a fixation point (X) in the center of the computer screen. The barpress started a timing routine and initiated the display of an icon on the screen. The icon was displayed until the subject responded. Subjects were told to press the space bar a second time as soon as they identified the hand-shape icon and then immediately to lift their right hand and produce the corresponding shape. The second barpress stopped the clock and cleared the computer screen. The RT for each trial (measured between icon onset and pressing of the space bar prior to making the hand shape) was displayed in the upper left-hand corner of the screen for 2 s so that the experimenter could monitor the subject's performance. The screen then cleared for 1 s before the next fixation point appeared, signaling that the subject could start another trial when ready. The experimenter subjectively evaluated whether the subject made the appropriate hand shape and recorded hesitations and errors as incorrect responses.

There were 10 series of eight trials each, distributed equally among the four hand-shape categories. Order of the trials within each series was randomized, as was the overall presentation order of the series. Like those in the priming studies described earlier (Klatzky et al., 1989), subjects in the present studies were required to reach a criterion RT level of 750 ms before beginning the main experiment. This ensured that they would be able to read the icon primes presented during sensibility judgment trials. There were provisions for additional training in case a subject failed to reach this level of performance during the last series of training trials; however, supplemental training was not necessary in any of these experiments. The entire training phase lasted approximately 15 min.

Results and Discussion

Training Phase

Mean RT was examined over blocks of trials for each hand-shape class. Trials in which a subject made an incorrect response or hesitated before responding were omitted from the analyses. Erroneous responses constituted approximately 7% of all trials. The top half of Figure 1 plots mean RT over blocks of 16 trials for each shape, showing a gradual decline to below the required asymptotic level.

Mean RTs were examined in an analysis of variance (ANOVA) with three factors: group (response mode), hand-shape class, and block of trials. There were main effects of block, $F(4, 88) = 53.09$, $p < .0001$, $MS_e = 0.077$, reflecting the decrease in RT over blocks, and shape, $F(3, 66) = 3.04$, $p < .05$, $MS_e = 0.021$, reflecting the tendency for the nonprehensile hand shapes—poke and palm—to be faster than the prehensile pinch and clench. There were also interactions between group and shape, $F(3, 66) = 2.99$, $p < .05$, $MS_e = 0.021$, and among all three factors, $F(12, 264) = 2.14$, $p < .05$, $MS_e = 0.012$. By Block 5, there were essentially no group or shape effects.

Main Experiment

As in the training phase, the data of interest were mean RTs for correct responses. Trials containing incorrect responses were omitted from all analyses. Any trial in which RT exceeded a subject's overall mean RT by 3 standard deviations or more was also omitted. In addition, any target phrase that elicited consistently incorrect responses (i.e., on at least three out of four presentations, from 25% or more of the subjects) was excluded from the data set for all subjects. One nonsensible target phrase from the pinch stimulus category was eliminated on this basis. The mean error rate over all subjects was approximately 5%.

The principal concern was with the sensible trials, for which two sets of analyses were performed. In the first set, we examined the effects of type of prime (hand shape or neutral) and hand-shape class (pinch, poke, clench, or palm), pooled over blocks of trials (one through four). Pooling over blocks allowed an additional analysis using items (i.e., target phrases) as the units of observation rather than subjects. An item analysis including blocks was not possible given the design. The potential stimulus pool used in these experiments was not indefinitely large, and whether the item analyses speak to generalization of priming is somewhat questionable. The item analyses do, however, give an indication of reliability over the items used. Thus, for all experiments reported, the results of

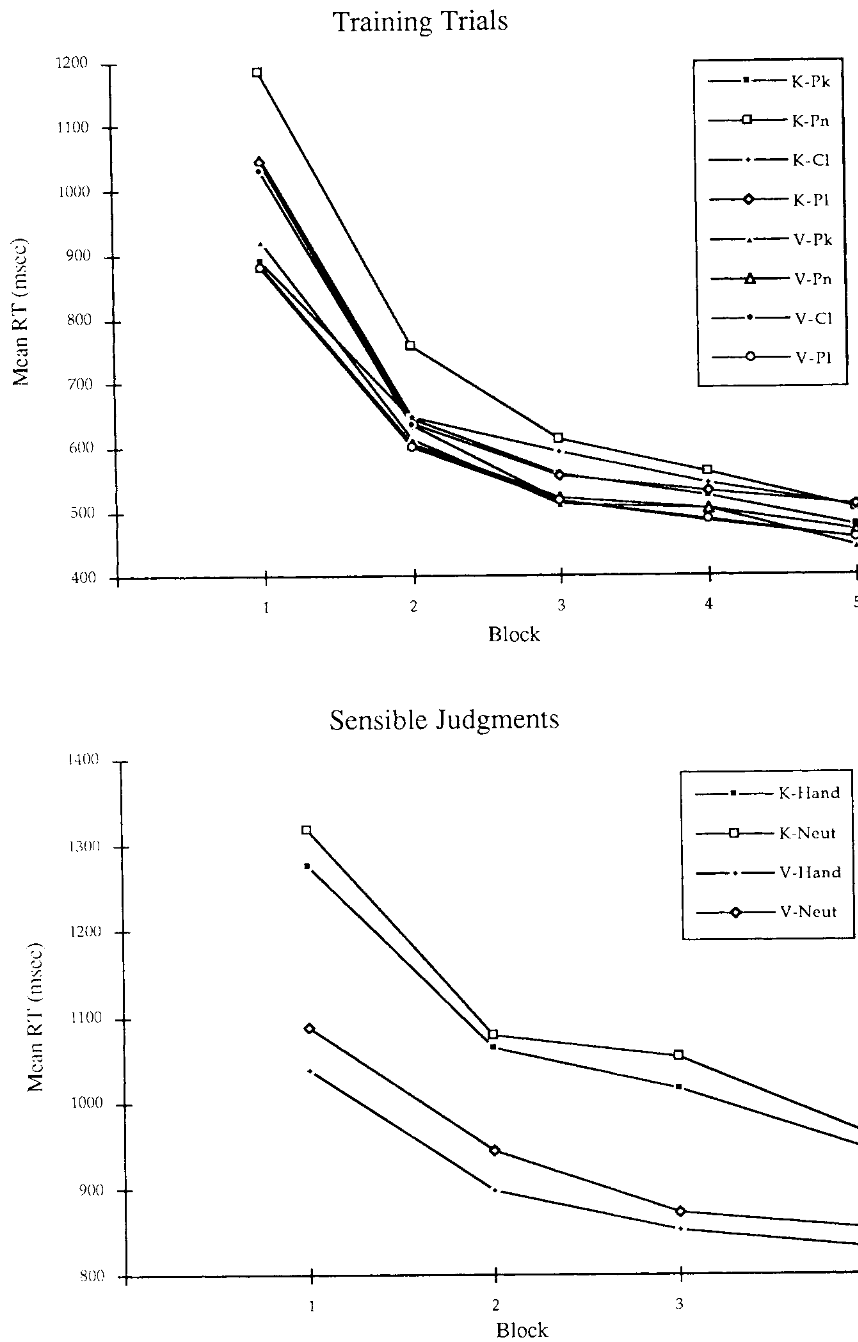

Figure 1. Mean reaction times (RT) in training trials (top panel) by hand shape and group, averaged over 16-trial blocks, and experimental sensibility judgment trials (bottom panel) by block of trials, prime, and group in Experiment 1. (K = keypress group, V = vocal group, Pk = poke, Pn = pinch, Cl = clench, Pl = palm, Hand = hand-shape prime, Neut = neutral prime.)

an item analysis are described only when they were not significant and the results of the subject-based analysis were significant.

Table 1 lists the mean RTs by prime, hand shape, and group, averaged over blocks. A subject ANOVA on group, prime, and shape revealed three main effects: For group, $F(1, 22) = 6.09$, $p < .05$, $MS_e = 0.222$, attributable to slower mean RTs for keypress subjects; for prime, $F(1, 22) = 31.38$, $p < .0001$, $MS_e = 0.001$, reflecting the presence of reliable priming effects; and for shape, $F(3, 33) = 5.88$, $p < .005$, $MS_e = 0.001$. As in previous analyses (Klatzky et al., 1989), the shape effect was not present when the data were analyzed over items, suggesting item-specific differences among hand-shape categories. None of the interactions were significant (all Fs < 1).

Table 1
Mean Reaction Times (in Milliseconds) in Priming Trials of Experiments 1–3, by Prime, Shape, and Group, Pooled Over Block

Group	Hand shape: Poke	Pinch	Clench	Palm	*M*
		Experiment 1: Sensible trials			
Voice					
Hand shape	912	912	876	912	903
Neutral	934	947	933	938	938
Keypress					
Hand shape	1,084	1,080	1,046	1,090	1,075
Neutral	1,125	1,096	1,082	1,102	1,101
M	1,014	1,009	984	1,011	
		Experiment 1: Nonsensible trials			
Voice					
Hand shape	1,076	1,094	1,072	1,081	1,081
Neutral	1,078	1,080	1,030	1,065	1,063
Keypress					
Hand shape	1,270	1,267	1,261	1,243	1,260
Neutral	1,289	1,240	1,204	1,249	1,246
M	1,178	1,170	1,142	1,160	
		Experiment 2: Sensible trials			
Tapping					
Hand shape	1,545	1,414	1,372	1,477	1,452
Neutral	1,520	1,444	1,361	1,470	1,449
Syllable					
Hand shape	1,149	1,105	1,046	1,128	1,107
Neutral	1,171	1,180	1,106	1,147	1,140
M	1,346	1,286	1,221	1,298	
		Experiment 2: Nonsensible trials			
Tapping					
Hand shape	1,670	1,635	1,640	1,629	1,644
Neutral	1,748	1,669	1,555	1,825	1,699
Syllable					
Hand shape	1,358	1,343	1,359	1,323	1,346
Neutral	1,417	1,385	1,317	1,373	1,373
M	1,548	1,508	1,468	1,538	
		Experiment 3: Sensible trials			
Tapping					
Hand shape	1,148	1,080	1,057	1,140	1,106
Neutral	1,115	1,099	1,097	1,136	1,112
Syllable					
Hand shape	1,073	1,004	995	1,067	1,035
Neutral	1,122	1,072	1,033	1,066	1,073
M	1,115	1,064	1,046	1,102	
		Experiment 3: Nonsensible trials			
Tapping					
Hand shape	1,253	1,266	1,168	1,280	1,242
Neutral	1,289	1,219	1,224	1,214	1,237
Syllable					
Hand shape	1,228	1,286	1,195	1,228	1,234
Neutral	1,319	1,290	1,250	1,248	1,277
M	1,272	1,265	1,209	1,243	

The lack of a significant Prime × Group interaction implies that the magnitude of the priming effect did not differ reliably between the keypress and vocal-response groups. The mean priming effects (averaged over shape) were +26 ms and +35 ms for keypress and vocal-response groups, respectively. Thus, the response mode did not appear to affect facilitatory priming to any extent. The group effect may reflect some form of generalized resource competition between the sensibility judgment and preparation for the keypress response; note that the groups did not differ in asymptotic training RTs, contraindicating any general slowness in the keypress group.

A second subject ANOVA assessed the effects of group, prime, and block, pooled over shape. The bottom half of Figure 1 plots the mean RT functions for sensible trials, averaged over the different hand shapes, by group and block. As can be seen, facilitatory priming occurred in all blocks.

The ANOVA yielded three main effects: For group, $F(1, 22) = 6.07, p < .05, MS_e = 0.223$; for prime, $F(1, 22) = 32.55, p < .0001, MS_e = 0.001$; and for block, $F(3, 66) = 69.10, p < .0001, MS_e = 0.01$. There was also a significant Block × Group interaction, $F(3, 66) = 2.97, p < .05, MS_e = 0.01$. None of the other interactions were significant (all Fs < 1). As before, the lack of a Group × Prime interaction implies that there were no reliable differences between the two groups in terms of the magnitude of facilitatory priming.

Table 1 also lists the mean RTs on nonsensible trials by prime and hand shape for each group. In contrast to judgments of sensible phrases, judgments of nonsensible phrases were not facilitated by hand-shape cues, and no systematic effect was expected. Furthermore, effects that were significant in a subject ANOVA on group, prime, and shape failed to reach significance in an item ANOVA and are therefore not discussed.

In summary, Experiment 1 replicated our previously obtained priming effect (Klatzky et al., 1989) and showed that essentially equivalent effects can be obtained with keypress and vocal responses. In Experiments 2 and 3, different groups used these two responses to avoid having subjects perform a motor task and respond in the priming task with the same effectors.

Experiment 2

In Experiment 2, sensibility judgments were made in the context of a dual-task paradigm. Subjects were required to prepare for both the sensibility judgment task and a motor task, either of which (but not both) could be called for on a given trial. Task preparation was ongoing during the priming interval. Thus, to the extent that subjects prepared for the motor task and this preparation competed with their processing of the prime, the priming effect was expected to be reduced. Two different motor tasks were contrasted: One group of subjects had to prepare on each trial for a manual tapping task; the other prepared for a syllable vocalization task.

The design of the study is shown in Figure 2. In the initial training phase, subjects were trained both on the priming cues, as in Experiment 1, and on the motor task (tapping or syllable) that would be intermixed with the subsequent sensibility judgments. (This training phase provided a baseline measure of the motor task RT when the task was performed without competition for resources.) In the main experiment, on any given trial, either the motor task was cued or a phrase

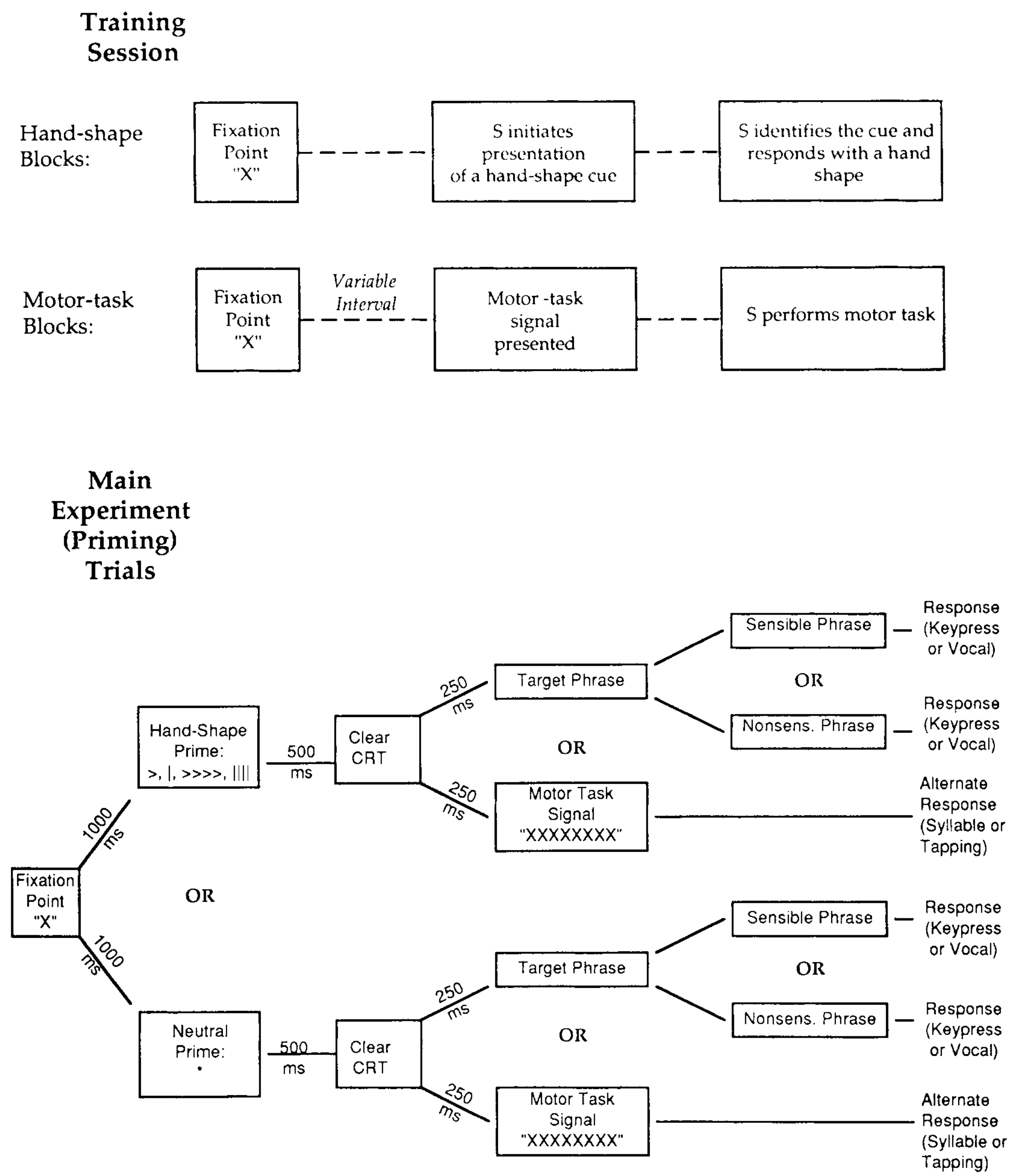

Figure 2. Time courses of training and sensibility judgment trials in Experiments 2 and 3. (S = subject, CRT = cathode-ray tube.)

was presented for the sensibility judgment task, with 50:50 probability. Because the subject did not know which of the two possible tasks to perform until after the prime had been presented, motor task preparation occurred at the same time as any prime-produced process. Instructions emphasized the need to perform whichever task was cued—sensibility judgment or motor task—as quickly and accurately as possible. Thus competition between the tasks, rather than selection of one, was encouraged.

If the priming effect is due to processing within a limited-capacity system specific to the hand, and if that same system plays a role in both semantic judgments and preparation for action, then having to prepare for a motor task involving the same system should reduce or eliminate facilitatory priming. However, if the motor task does not tap into the same system, then preparing for that task should not interfere with priming. On the basis of these assumptions, the prediction tested in Experiment 2 was that preparation for the tapping task would significantly diminish facilitatory priming effects, relative to the effects of preparation for the syllable task, which presumably involves a motoric system different from that activated by the hand-shape prime.

Method

Subjects

Twenty-four undergraduates in the introductory psychology course at the University of California, Santa Barbara, participated in the experiment to satisfy a course requirement.

Stimuli

The target phrases used during sensibility judgment trials were the same as those used in Experiment 1, with the exception of one item that was replaced because of a high error rate.

Procedure and Design

Main experiment. Subjects were randomly assigned to one of two groups of 12 subjects each. On a given trial, subjects in both groups either made a sensibility judgment or performed an alternate motor task. For one group, the alternate motor task was syllable vocalization, and for the other it was manual tapping.

The response for the sensibility judgment task was in the modality opposite that of the motor task. (Because Experiment 1 showed that response modality did not affect the magnitude of priming, this does not represent a meaningful confound between response modality and interference condition.) Thus, on each trial, the first group of subjects either made a sensibility judgment about a target phrase by pressing a yes or no key or vocalized syllables. These subjects are referred to as the syllable group. The second group of subjects either made a sensibility judgment by producing a vocal response (saying yes or no) or performed a series of button presses. These subjects are referred to as the tapping group. (Thus, the groups are named according to the competing motor task, not according to the way they responded to the sensibility judgment.)

The tapping task consisted of pressing a sequence of four different buttons on the button box used in Experiment 1. On trials calling for this response, subjects performed the sequence L2–L4–R4–R2, in which *L* and *R* referred to the left and right hands and the numbers referred to specific fingers (e.g., L4 represented the fourth [ring] finger on the left hand).

The syllable task called for vocalization of the sequence "bee dee dah bah." Note that the tapping response first moved between fingers (second to fourth) and then switched hands. To map this pattern as closely as possible, we designed the syllable series to first switch consonants (mapping to the fingers in the tapping sequence) and then switch vowel sounds (mapping to the hands). The relative difficulty of the two response sequences was equated as much as possible by presenting a list of candidate syllable series to a group of 12 preliminary subjects. These subjects rated the difficulty of the vocal responses relative to that of the tapping sequence, and the syllable series finally chosen for this study was rated as most similar to (i.e., as difficult to perform as) the tapping sequence.

Instructions for the sensibility trials were as in Experiment 1. The instructions for the motor task directed subjects to make their responses as rapidly and accurately as possible.

Four blocks of 120 trials each were constructed for use in the main experiment. Each block contained 60 sensibility judgment trials and 60 motor task trials, in random order. Thus, there were 240 sensibility judgment trials out of a total of 480 trials. Within each block, we equally divided the sensibility trials among the four hand-shape categories, using 40 sensible phrases (10 from each shape category) and 20 nonsensible phrases (5 from each category). Over all blocks, each phrase appeared exactly once in each of the two priming conditions (neutral vs. hand shape). Within each block, the four hand shapes were represented equally in terms of sensible phrases, and approximately equally in terms of nonsensible phrases, in each of the priming conditions. Presentation of the four blocks to subjects was arranged according to a Latin square.

In the main experiment, each trial followed a time course similar to that in Experiment 1. A fixation point (X) appeared in the center of the screen for 1,000 ms, followed either by one of the four hand-shape primes or by the neutral prime. The prime was displayed for 500 ms, and then the screen was clear for 250 ms. The subject then saw either a target phrase, indicating that a sensibility judgment was required, or a row of eight Xs, indicating that the motor task was to be performed. As in Experiment 1, the interval between onset of the prime and onset of the second stimulus (SOA) was 750 ms. The target phrase or the motor task cue remained on the screen until the subject responded. The occurrence of a response stopped the RT counter. For the syllable group, the response (keypress) identity was recorded directly by the computer; for the tapping group, the response (vocal) identity was entered by the experimenter. There was a 2,000-ms intertrial interval. Subjects did not receive feedback about their performance.

For the syllable task, the first syllable in the utterance "bee dee dah bah" signaled the RT counter via a voice-activated relay, and the experimenter entered any errors into the computer. For the tapping task, the subject's first buttonpress in the sequence signaled the clock. Subsequent buttonpresses were registered in the computer and then checked for errors.

At the beginning of the main experiment, there were 16 practice trials, with feedback. Half called for sensibility judgments involving the two priming conditions and sensible and nonsensible phrases from the four hand-shape categories. The remaining trials called for the motor task. The main experiment lasted approximately 2 hr and began after a short rest period following training.

Training phase. Before the main experiment, subjects participated in a brief training phase, structured as in Experiment 1. Subjects were trained to produce hand shapes in response to icon cues. In addition, subjects were trained on the motor task, syllable or tapping, that they would perform during some trials of the main experiment. During training on the motor task, the subject tapped or vocalized after presentation of the motor task cue (the row of eight Xs). A randomly varying interval (500–1,000 ms) occurred between the onset of the trial and the cue so that the motor task was like a simple RT task.

The training phase contained an equal number of trials on each task. The time course of both types of trials was patterned after the training session in Experiment 1. The experimenter monitored the subject's performance during both types of training, noting any hesitations or other errors. There were 12 blocks of eight trials each. The blocks alternated between training on the two tasks. In blocks devoted to training of hand-shape responses, trials were distributed equally among the four hand-shape categories in random order.

As in Experiment 1, each subject was required to reach a criterion RT level of 750 ms before beginning the main experiment. This criterion was set for both hand-shaping trials and motor task trials.

Results

Training Phase

Hand-shaping trials in which a subject made an incorrect response or hesitated before responding were omitted from the analyses; such trials constituted 10% and 7% of the trials for the tapping and syllable groups, respectively. Motor task trials in which subjects produced incorrect responses were also omitted. This corresponded to 8% and 3% of the trials for the tapping and syllable groups, respectively.

Hand-shaping and motor task trials were analyzed separately. Recall that there were two hand-shaping trials per shape category within each block of trials. Subjects who produced incorrect responses on both trials during a block had missing data for a particular hand-shape category and were therefore omitted from the analysis. Two subjects from the tapping group and one from the syllable group were eliminated on this basis.

Thus, the mean hand-shape RTs for 21 of the 24 subjects were examined in an ANOVA with three factors: group (syllable or tapping), block of trials (one through six, eight trials each), and hand-shape response (pinch, poke, etc.). There was a main effect of block, $F(5, 95) = 36.78$, $p < .0001$, $MS_e = 0.126$, as subjects produced hand shapes at increasingly faster rates with practice. There were no group or shape effects and no significant interactions. The RT functions for each hand-shape category over blocks of eight trials, averaged over the two groups of subjects, are plotted at the top left of Figure 3.

For motor task trials, the mean RTs for the 21 subjects with complete data were examined in an ANOVA with two factors: group and block of trials. There was a main effect of block, $F(5, 95) = 41.56$, $p < .0001$, $MS_e = 0.014$, but neither the group effect nor the Block × Group interaction approached significance (both Fs < 1). The absence of a group effect validated the pilot subjects' judgment that the two motor tasks were equal in difficulty. The graph at the bottom left of Figure 3 shows mean RT plotted over blocks, by group.

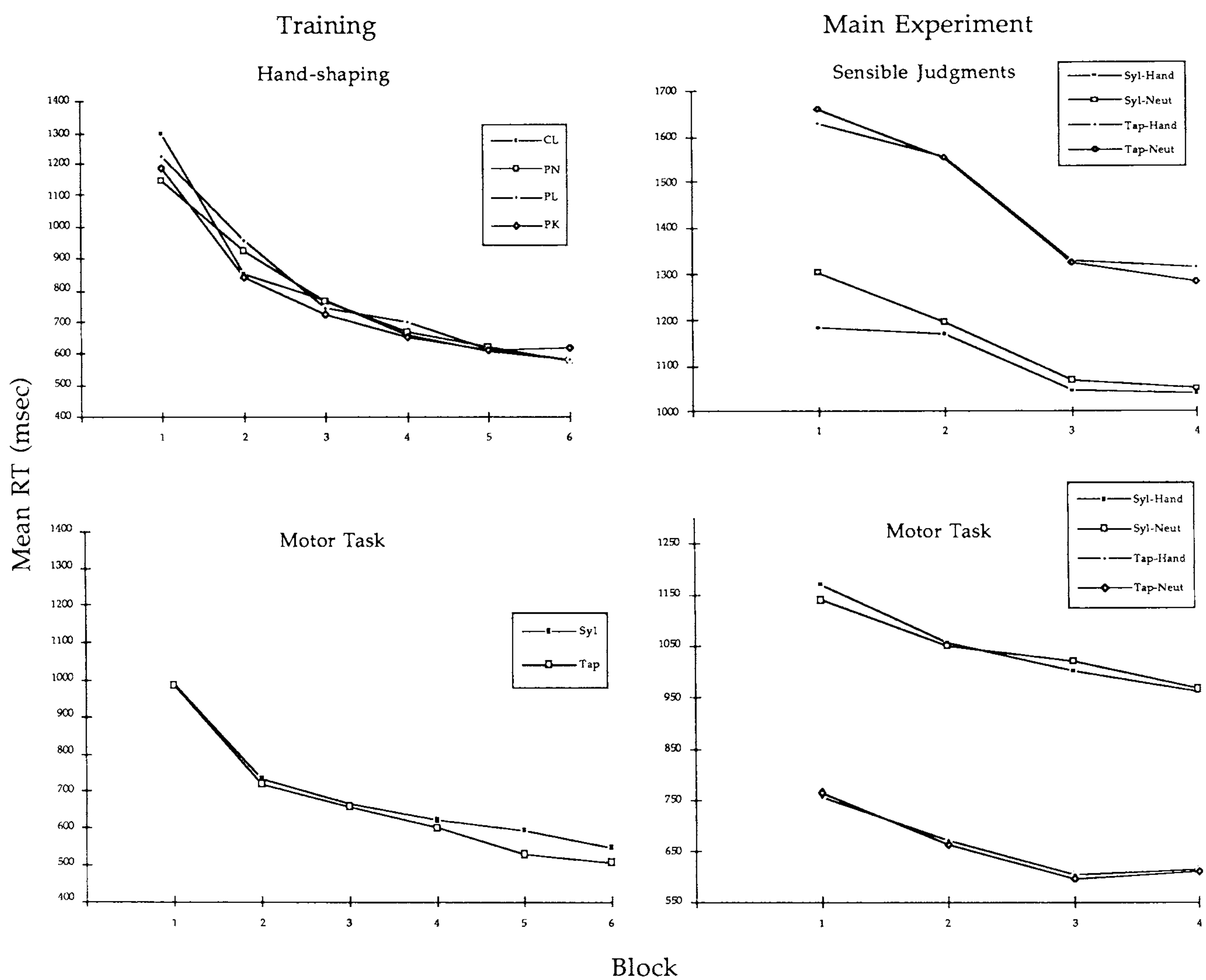

Figure 3. Mean reaction times (RT) in hand-shaping training trials (top left panel) averaged over group and over eight-trial blocks; motor task training trials (bottom left panel) by group over eight-trial blocks; and experimental sensibility judgment trials (top right panel) and motor task trials (bottom right panel), both by block of trials, group, and prime in Experiment 2. (CL = clench, PN = pinch, PL = palm, PK = poke, Syl = sylllable, Tap = tapping, Hand = hand-shape prime, Neut = neutral prime.)

Main Experiment

Sensibility judgments. The data of interest were mean RTs for correct responses. Before analyzing the sensibility judgment data, we omitted incorrect responses and outlying trials using the same procedure as in Experiment 1. One sensible target phrase (from the clench stimulus category) and two nonsensible phrases (one from the pinch category and one from the poke category) were eliminated because of incorrect responses on 25% or more of the trials. The mean error rates for sensibility judgments were 9% and 5% for the tapping and syllable groups, respectively. Incorrect responses in the motor task totaled 4% for each group and were eliminated along with outlying trials from the analyzed data. The analyses for sensible and nonsensible trials and for motor task trials are described separately.

For sensible trials, two sets of analyses were performed, as in Experiment 1. In the first set, we examined the effects of group (syllable or tapping), type of prime (hand-shape icon or neutral), and hand-shape class, pooled over blocks of trials (one through four). An item analysis served as a check against item-specific effects in the subject ANOVA. Table 1 lists the mean RTs for two factors, prime and hand shape, by Group.

Overall, hand-shape primes facilitated the sensibility judgments of the syllable group—the mean priming effect was +33 ms. In contrast, these primes were not as effective for the tapping group. Only judgments of phrases from the pinch category showed any evidence of facilitatory priming.

The subject ANOVA on prime, shape, and group revealed three main effects: For group, $F(1, 22) = 6.41$, $p < .05$, $MS_e = 0.775$; for prime, $F(1, 22) = 5.05$, $p < .05$, $MS_e = 0.004$; and for shape, $F(3, 66) = 14.65$, $p < .0001$, $MS_e = 0.009$. The group effect reflected consistently faster mean RTs for the syllable group and is discussed later. The prime effect indicated reliable differences between hand-shape-primed and neutrally primed trials. The shape effect reflected faster mean RTs for responses involving clench. The only significant interaction was that of Group × Prime, $F(1, 22) = 6.81$, $p < .05$, $MS_e = 0.004$, which indicated, as predicted, differential effects of primes in the two groups of subjects.

We conducted follow-up ANOVAs to test for facilitatory priming effects in each group separately. The tapping group showed neither a prime effect nor a Prime × Shape interaction (both $Fs < 1$). Thus, there is no evidence that the tapping subjects' sensibility judgments were facilitated by hand-shape primes. In fact, the mean priming effect for the group over all four hand-shape categories was −3 ms. In contrast, the syllable group exhibited an effect of prime, $F(1, 11) = 9.27$, $p < .05$, $MS_e = 0.005$; the Prime × Shape interaction was not significant.

In a second set of analyses, we assessed the effects of prime and block within each group, pooled over shape. A preliminary analysis also including group confirmed a group effect, $F(1, 22) = 6.47$, $p < .05$, $MS_e = 0.783$, as well as a Group × Prime interaction, $F(1, 22) = 6.74$, $p < .05$, $MS_e = 0.004$. The graph at the top right of Figure 3 plots the mean RT functions for the two priming conditions averaged over shape, by group and block. For the tapping group, there was only a main effect of block, $F(3, 33) = 23.52$, $p < .0001$, $MS_e = 0.03$. Neither the effect of prime nor the Prime × Block interaction were significant (both $Fs < 1$).

The same analysis for the syllable group revealed main effects of prime, $F(1, 11) = 10.38$, $p < .01$, $MS_e = 0.004$, and block, $F(3, 33) = 17.99$, $p < .0001$, $MS_e = 0.012$. There was also a significant Prime × Block interaction, $F(3, 33) = 3.52$, $p < .05$, $MS_e = 0.004$. A contrast analysis performed on this interaction revealed that the facilitatory priming effect was significantly greater in the first block (+120 ms) than in the three latter blocks (+26, +22, and +10 ms, respectively) combined, $F(1, 33) = 10.34$, $p < .01$, $MS_e = 0.004$. This contrast accounted for 98% of the interaction sum of squares, and the test of the residuals did not approach significance ($F < 1$). It is important to note that the priming effect in later blocks was reduced relative to the first block, but was still present. An ANOVA examining prime and block effects only in Blocks 2–4 revealed a main effect of prime, $F(1, 11) = 8.09$, $p < .05$, $MS_e = 0.001$, but no significant Prime × Block interaction ($F < 1$).

Table 1 shows the mean RTs on nonsensible trials by prime, hand shape, and group. Again, reliable effects in the subject analysis were not supported by the item analysis (the exception being an uninterpretable Prime × Shape interaction), and because no priming effects were predicted, no further discussion is needed.

Motor task performance. The analysis of motor task trials examined three factors: group, prime, and block. In this case, the prime factor referred to whether the cue for the motor task was preceded by a hand-shape prime (any one of the four hand-shape icons) or the neutral icon; it did not distinguish among different hand-shape classes. The ANOVA revealed a main effect of group, $F(1, 22) = 19.77$, $p < .0005$, $MS_e = 0.36$, reflecting faster mean RTs for the tapping group than for the syllable group. There was also an effect of block, $F(3, 66) = 15.37$, $p < .0001$, $MS_e = 0.018$, reflecting faster mean RTs with practice. There was no prime effect, and none of the interactions were significant.

Note that the group effect observed in the motor task trials was the reverse of the effect found during sensibility judgment trials (where the tapping group's responses for indicating sensibility judgments were reliably slower than the syllable group's). This suggests that tapping and syllable subjects had control over resources and differed in the resources they chose to devote to the sensibility judgment and alternative tasks. The graph at the bottom right of Figure 3 shows the mean motor task RT functions for the two priming conditions, by group. As can be seen, there was no evidence that hand-shape primes and neutral primes had differential effects on the speed with which subjects produced responses in the motor task. Thus the processing induced by the icon prime appears not to have interfered with the motor task and did not differentially interfere with the syllable and tapping tasks.

Discussion

The results indicate that preparation for the tapping task interfered more with the facilitatory priming effect than did preparation for the syllable task. This is unlikely a reflection of differential difficulty of the two tasks; recall that they were rated as equal in difficulty by independent raters. Moreover, the training trials were essentially a simple RT paradigm, with each task performed separately (i.e., without resource competition). Simple RT tasks are known to reflect response complexity (e.g., Sternberg, Monsell, Knoll, & Wright, 1978); hence, the equality of the training RTs supports the idea that the two motor tasks were essentially equal in difficulty. Nonetheless, they had markedly different effects on the sensibility judgment process. This is consistent with our assumption that preparation for the tapping task would compete for resources in the same system used in priming sensibility judgments.

There is also evidence, however, that the two groups of subjects differed in terms of the resources they allocated to the sensibility judgment and alternative tasks. Recall that in sensibility judgment trials, the tapping group's responses were significantly slower than the syllable group's, whereas in motor task trials, the opposite effect was observed. Moreover, the difference between groups in the motor task is in marked contrast to the equality of RTs for the same motor task in the training trials, in which the use of a single task meant that no resource competition was present. Thus it seems clear that, given competition between the two tasks, tapping and syllable subjects had different priorities, the former focusing relatively more on the motor task and the latter on the sensibility judgments. The end result for the tapping group was the absence of any facilitatory priming. (Considering the complete elimination of the priming effect in this condition, it seems that subject-controlled attentional priming constituted all of the effect; there is no evidence that an automatic component was left intact under manual interference.)

Differential allocation of resources raises the possibility that the priming effect vanished in the tapping group because subjects focused on the motor task, not because of direct competition between the prime and tap response. It is therefore critical to find evidence of interference when motor task performance is more equal across the two groups.

Another result suggestive of attentional effects is the decrease in facilitatory priming in later blocks for syllable subjects. Recall that in our earlier studies (Klatzky et al., 1989), we found that the magnitude of the priming effect was relatively consistent throughout the experiment. An explanation for the attenuation of priming in the present study is that the predictive value of the hand-shape cues was not as high as it had been previously. In the present experiment, hand-shape cues preceded sensible phrases approximately 17% of the time, compared with 33% in Experiment 1. Subjects may have noted that primes were helpful in judging phrases only infrequently. They may therefore have chosen not to attend to the primes as much as subjects in past experiments and instead turned their attention to performance of the alternative task.

Experiment 3

Experiment 3 was intended to motivate attention to the prime and to the sensibility task in general. Accordingly, we increased the proportion of trials in which the prime was relevant by reducing the number of motor task trials to half the number used in Experiment 2. This increased the percentage of trials in which hand-shape primes preceded sensibility judgments.

Method

The method of the main experiment was identical to that of Experiment 2, with one important exception: The number of alternate-response trials was reduced by half, from 240 to 120. There were 24 subjects, divided equally, as in Experiment 2, into two groups—tapping and syllable. Tapping subjects made vocal responses (yes or no) to indicate sensibility judgments and produced a sequence of buttonpresses during motor task trials. Syllable subjects pressed a yes or no key to indicate their sensibility judgment and vocalized a series of syllables during motor task trials. The time courses of both training and main experiment trials were unchanged from those of Experiment 2, and the length and content of the training session remained the same as before. The main experiment lasted approximately 70 min and began after a short rest period following completion of the training session.

Results

Training Phase

Hand-shaping and motor task trials were analyzed separately. As in Experiment 2, there were two hand-shaping trials per shape category within each block of trials. Subjects who produced incorrect responses on both trials for a shape category during one block had missing data and were therefore omitted from the analysis. On this basis, 2 subjects from the tapping group and 3 from the syllable group were eliminated. The error rates for hand-shaping trials were 11% and 9% for the tapping and syllable groups, respectively; the corresponding error rates for motor task trials were 8% and 7%, respectively.

The mean hand-shape RTs for 19 of the 24 subjects were examined in an ANOVA with three factors: block of trials (one through six, eight trials each), hand-shape response (pinch, poke, etc.) and group (tapping vs. syllable). The ANOVA revealed main effects of block, $F(5, 85) = 28.16$, $p < .0001$, $MS_e = 0.214$, and shape, $F(3, 51) = 2.98$, $p < .05$, $MS_e = 0.08$. There was no group effect, and none of the interactions approached significance. The top left of Figure 4 plots the RT functions for each hand-shape category over blocks of eight trials, averaged over the two groups of subjects.

For motor task trials, the mean RTs for the 19 subjects with complete data were analyzed in an ANOVA examining two factors: block of trials and group. There was a main effect of block, $F(5, 95) = 40.20$, $p < .0001$, $MS_e = 0.008$. Neither the group effect nor the interaction approached significance (both Fs < 1). The bottom left of Figure 4 plots mean RT over blocks, by group.

Main Experiment

Sensibility judgments. The data of interest were mean RTs for correct responses, with errors and outliers eliminated as before. By the same criterion as in past experiments, four nonsensible phrases (one from the pinch category, two from

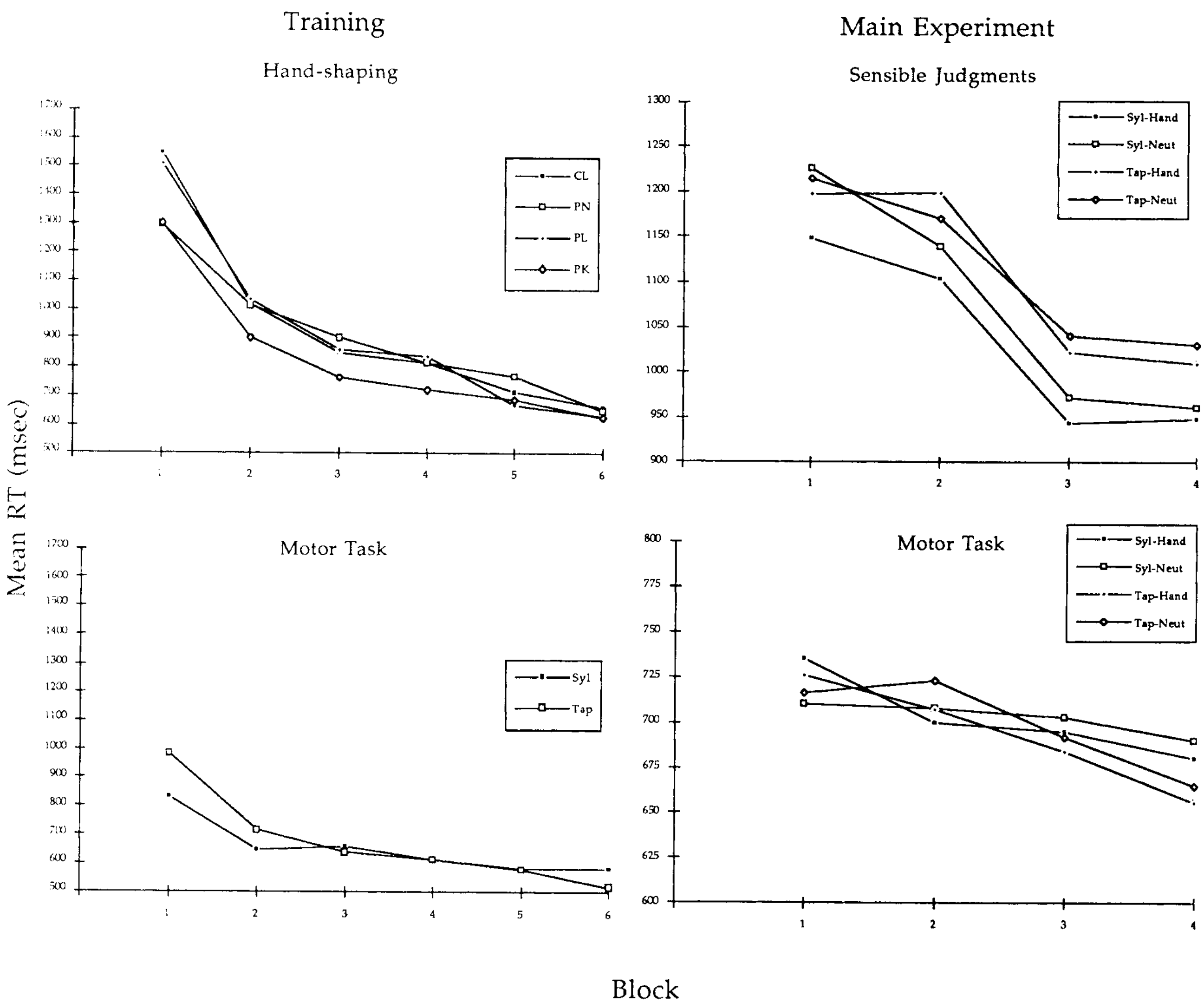

Figure 4. Mean reaction times (RT) in hand-shaping training trials (top left panel) averaged over group and over eight-trial blocks; motor task training trials (bottom left panel) by group over eight-trial blocks; and experimental sensibility judgment trials (top right panel) and motor task trials (bottom right panel), both by block of trials, group, and prime in Experiment 3. (CL = clench, PN = pinch, PL = palm, PK = poke, Syl = syllable, Tap = tapping, Hand = hand-shape prime, Neut = neutral prime.)

the poke category, and one from the palm category) were omitted. The mean error rates were 8% for the tapping group and 4% for the syllable group, similar to the error rates in Experiment 2.

Table 1 shows the mean RTs by prime, hand shape, and group. An overall ANOVA on prime, shape, and group revealed main effects of prime, $F(1, 22) = 7.26$, $p < .05$, $MS_e = 0.003$, indicating facilitatory effects of hand-shape cues, and shape, $F(3, 66) = 16.13$, $p < .0001$, $MS_e = 0.003$, reflecting faster mean RTs for pinch and clench phrases. In contrast to Experiment 1, the effect of group did not approach significance ($F < 1$). The interaction of Prime × Shape was significant, $F(3, 66) = 2.80$, $p < .05$, $MS_e = 0.002$, and the Group × Prime interaction was marginally significant, $F(1, 22) = 4.18$, $p = .05$, $MS_e = 0.003$. The latter interaction is more important, because it indicates differences between the tapping and syllable groups in the effectiveness of hand-shape primes.

Accordingly, follow-up analyses assessed the prime effect for the tapping and syllable groups separately. The effect of prime was not significant in the tapping group ($F < 1$); the mean priming effect over shapes was only +6 ms. A one-tailed test in each shape category also revealed no significant facilitatory effects. In contrast, the syllable group did show an effect of prime, $F(1, 11) = 21.01$, $p < .001$, $MS_e = 0.002$. Although there was no facilitatory priming evident for the palm-shape category, the Prime × Shape interaction was only marginally significant over subjects, $F(3, 33) = 2.64$, $.05 < p < .10$, $MS_e = 0.002$, and it did not approach significance when the data were analyzed over items. A one-tailed test of the priming effect in each shape category revealed significant effects for pinch, $t(11) = 2.23$, $p < .001$; clench, $t(11) = 2.75$,

$p < .01$; and poke, $t(11) = 2.23$, $p < .05$. Thus, for the syllable group, there were reliable facilitatory priming effects exhibited in three of the four shape categories, with a mean effect of +38 ms, comparable to the effect for the syllable group in Experiment 2.

In the second set of analyses, we assessed effects of prime and block, by group and pooled over shape. A preliminary analysis including group showed no overall group effect ($F < 1$) and a marginal Group × Prime interaction, $F(1, 22) = 4.04$, $.05 < p < .10$, $MS_e = 0.003$. The graph at the top right of Figure 4 plots the mean RT functions for the two priming conditions. For tapping subjects, there was only a main effect of block, $F(3, 33) = 47.92$, $p < .001$, $MS_e = 0.005$. Neither the effect of prime nor the Prime × Block interaction was significant (both $Fs < 1$). The same ANOVA for the syllable group revealed main effects of prime, $F(1, 11) = 20.76$, $p < .001$, $MS_e = 0.002$, reflecting the facilitatory priming effect, and block, $F(3, 33) = 46.65$, $p < .0001$, $MS_e = 0.007$. The Prime × Block interaction was marginally significant, $F(3, 33) = 2.68$, $.05 < p < .10$, $MS_e = 0.002$, reflecting a tendency toward decreased priming over blocks, but a decrease that was substantially less than that in Experiment 2, as was intended by the change in procedure.

Table 1 shows the mean RTs for prime, hand shape, and group on nonsensible trials. Again, no effects were consistent over items.

Motor task performance. In the analysis of the motor task, we examined three factors: prime, block, and group. Our main concern was with the group effect, which the change in procedure had been intended to eliminate. Incorrect responses and outlying trials were omitted as before. The mean error rates were 3% for the tapping group and 4% for the syllable group, again comparable to the error rates for motor task trials in Experiment 2. The ANOVA revealed a main effect of block, $F(3, 66) = 9.37$, $p < .0001$, $MS_e = 0.002$, but there were no prime or group effects (both $Fs < 1$) and no significant interactions. The graph at the bottom right of Figure 4 shows the mean RT functions for the two priming conditions, by group. There was no between-groups difference in the speed with which the two different types of motor task were produced. This is in contrast to Experiment 2, in which tapping subjects were reliably faster than syllable subjects. This suggests that tapping subjects' previous tendency to focus on the motor task, at the expense of the sensibility judgments, was mitigated by the reduction in the number of prime-irrelevant trials. The results also indicate that hand-shape primes had no reliable effect on the speed with which subjects performed the motor task sequence, as was found in Experiment 2.

Discussion

The results of Experiment 3 replicate and strengthen our finding in Experiment 2 that preparation for the manual tapping task interfered more with the facilitatory priming effect than did preparation for syllable vocalization. Again, the training RTs for the groups were comparable, indicating that in a single-task situation, the tapping and syllable tasks required equivalent resources. The procedural change in Experiment 3 appears to have equated the groups' allocation of resources to their respective motor tasks in the context of the priming trials, because, in marked contrast to Experiment 2, the RTs for the motor tasks in the main experiment were equal across groups. In addition, the syllable group's previously observed advantage in the sensibility judgments was not found in Experiment 3. Thus we seem to have eliminated the grossly discrepant resource allocations across the two tasks. This makes it possible to compare directly the groups' performance on the priming trials, with an assumption that they had equivalent residual resources for those trials.

Under these circumstances, the previously observed difference in priming was obtained. The fact that the syllable group could take advantage of the prime indicates that the tapping group should have had resources available to do so. Yet they showed no priming effect. Apparently, some portion of the available resources was relatively specific to the hand. Competition for this restricted resource pool between preparation for tapping and the primed hand shape precluded a priming effect.

General Discussion

The present results support our prediction that there would be interference between cognitive activation of hand shapes and preparation for a manual tapping sequence. Our previously established (Klatzky et al., 1989) priming effect was replicated in Experiment 1: Subjects primed with a hand-shape cue more quickly made sensibility judgments about actions that involved that same hand shape. This occurred for both manual and vocal responses to the sensibility judgment. Experiments 2 and 3 showed that the priming effect was eradicated when subjects prepared for a manual tapping task during the priming interval. It was not eradicated, however, when the preparation was for a vocalization task of equal difficulty. In fact, in this case the priming effect in the first block of trials was at least as large as the priming effects observed when there was no secondary task.

These results support our general contention that there is a cognitively accessible system that represents information about the hand. These data can be understood by assuming that there is a pool of resources specifically associated with this system. When subjects in the tapping condition of our dual-task situation prepared for their motor task, they allocated some of these specific resources to their preparation. Subjects in the syllable group may have also allocated resources specific to the vocal tract to preparation for their motor task. Processing of the prime, however, tapped the hand-specific resource pool. Subjects who prepared for a tapping task thus had competition for resources from the specific pool, whereas those who prepared for a syllable task did not. The result was a priming effect in the latter group but not the former.

We hypothesize a system that represents motoric information but is accessible to the semantic system for speeding sensibility judgments. Our previous work (Klatzky et al., 1987, 1989) has shown that this system is not entirely semantic, in the usual sense of semantic representations as well-defined, abstract symbols (but cf. Shanon, 1988). The present findings expand our understanding of this system in three respects. The interference between preparation for a tapping task and the effect of a hand-shape prime suggests that a common representation is used for both tasks and that there are limits on its capacity to represent manual activities. (From a pure resource view, it is also possible that the representations of tapping and hand shaping are not one and the same but still compete for resources.) Furthermore, the results show that the system is not so general that it represents movements of both the hands and the vocal tract. This is indicated by the lack of interference between preparation for vocalization and priming.

Our findings thus constitute evidence for a motor system that is both abstract and reasonably specific with respect to represented actions. As we noted in the introduction, such a system has been invoked to account for a variety of effects, including mental practice and the effects of enactment on memory for verbal items. The present paradigms, by showing interference between semantic processing about actions (i.e., the sensibility judgment) and motor planning (i.e., for tapping), suggest that this level of representation could be a mediating link between cognitive knowledge about actions and actions themselves.

A number of critical issues remain to be addressed with tasks like the present one. One is the relationship between the system we hypothesize and visual imagery. What we have termed a competition for specific capacity may conceivably be competition for access to a representational medium like an image space (Kosslyn, 1980). There is evidence of a relationship between the mental enactment of action and visual imagery (e.g., Goss, Hall, Buckholz & Fishburne, 1986; Intons-Peterson & Roskos-Ewoldsen, 1989). Klatzky, Lederman, and Matula (1991) have suggested that one form of manual activity—exploratory movement of the hand—is represented within visual images, yet serves a functional role in judgments about haptic perception. Parsons (1987b) has provided evidence that imagined transformations of the hand (or in some cases foot) are used in making perceptual judgments. It seems likely, at least, that visual imagery is a phenomenological concomitant of mental action. If it is a necessary one, then visual imagery would be expected to interfere with the priming effect, as preparation for tapping did in Experiments 2 and 3.

Also of interest is whether the type of representation implied by the present priming effect plays some direct role in action initiation. This would be consistent with the ideomotor theory of motor control, which Greenwald (1970) has developed and related to earlier ideas of James (1890) and Lotze (1852). According to ideomotor theory, an image or representation of previous sensory consequences of action comes to serve as a discriminating signal for subsequent performance. An initial training phase is necessary to develop the sensory image, much as is provided in the current paradigm.

Another issue is the level of specificity of the system that underlies motor priming effects. We know that interference does not occur between hand-shape representation and preparation for vocalization. Would interference occur between hand-shape priming and preparation for a nonmanual motor response other than speech, such as movement of the leg? It seems unlikely that a system for action representation would be restricted entirely to the hand, but further studies are needed to explore this point. A related issue is whether the system represents the motor effector in some general way or represents a specific action. The presence of priming effects for distinct hand shapes strongly implies the latter, because generalized activation of the hand would presumably accrue to the neutral cue as well as to the shape-specific ones. Indeed, for mental practice to be effective, it would have to involve motor elements specific to the action to be performed, not merely generalized activation of the relevant effectors.

Our understanding of static visual imagery has grown considerably in the last two decades. An internal representation of the body and its movement promises to be more elusive for a number of reasons—the likelihood of less access to conscious experience, the complexity involved in controlling multiple degrees of freedom, and the need to accommodate temporal change in a reasonably smooth way. The potential importance of this problem, however, seems to be commensurate with its difficulty.

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Hill Appointed Editor of the *Journal of Counseling Psychology*, 1994–1999

The Publications and Communications Board of the American Psychological Association announces the appointment of Clara E. Hill, PhD, University of Maryland, as editor of the *Journal of Counseling Psychology* for a 6-year term beginning in 1994. As of January 1, 1993, manuscripts should be directed to

Clara E. Hill, PhD
Department of Psychology
University of Maryland
College Park, Maryland 20742

Manuscript submission patterns for the *Journal of Counseling Psychology* make the precise date of completion of the 1993 volume uncertain. The current editor, Lenore W. Harmon, PhD, will receive and consider manuscripts until December 31, 1992. Should the 1993 volume be completed before that date, manuscripts will be redirected to Dr. Hill for consideration in the 1994 volume.