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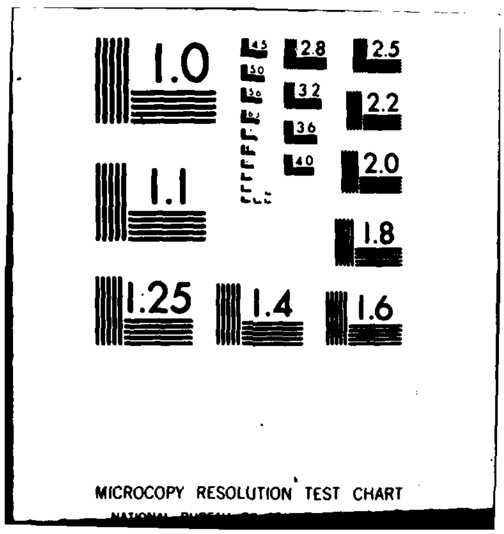
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**Ease of Tapping the Fingers in a Sequence Depends on the Mental Encoding**

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We examined the difficulty of tapping different sequences of five finger taps, one tap per finger, with only the order varying for different sequences. Different sequences have different levels of difficulty, depending upon their structure. The same sequence can be easy or difficult to perform, depending upon how it is encoded.

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Ease of Tapping the Fingers in a Sequence Depends on the Mental Encoding

The problem of specifying the serial order of behavior is a core problem in research on motor control.[2] Contemporary theories are concerned with how that ordering is specified, but once the actions are specified and their order is fixed, then the task of coordinating and scheduling their performance is thought to be straight-forward. Although it has long been known that organization can have a major effect on perception, studies of motor performance do not seem to have been concerned with these factors. This study examines organizational factors in a simple tapping task.

Consider the task of tapping each of the five fingers on one hand. Hold your hand over a table, wrist down, as you would if playing the piano or typing. Figure 1 shows three examples of our tapping sequences. Each column represents a finger; the column labels (a, b, c, d, e) specify the fingers from thumb to little finger. The three rows specify the order in which to tap the fingers; top row first, then the middle row, and bottom row last. Within a row, the fingers should be tapped in the order specified by the arrows in that row. If we let parentheses indicate the division of fingers into rows, the sequence indicated by Figure 1A is (a)(c b)(e d) and the sequence indicated by Figure 1B is (e)(b c d)(a).

After some practice, most people can learn to tap these sequences rapidly, tapping at a rate of four to five taps per second. If you try to tap each of the three sequences shown in Figure 1 (and we urge you to do so), you will probably discover that sequences 1A and 1B seem easier and more natural than sequence 1C. This is not surprising, as some finger tapping sequences may be better suited to the physical configuration of the hand than others. However, it is not the naturalness of the sequence alone that determines ease of performance. The same sequence may seem easier or harder, depending on its representation. Figures 1B and 1C both represent the same sequence (e b c d a), but sequence 1B seems much easier than sequence 1C.

We compared performance differences for different representations of identical motor sequences. To do this, we constructed pairs of sequences in which each member of the pair had a different representation for the same tapping sequence; Figures 1B and C show one such pair. All sequences specified exactly five taps in three rows. Within a row all arrows pointed in the same direction. Ten pairs of sequences were constructed so that one member had a psychologically "good" organization while the other did not. "Goodness" of organization was judged by

2. A good collection of contemporary theories and evidence can be found in Stelmach, 1978, and in Shaffer, 1976. Kent & Minifie, 1977, cover theories of ordering sounds in speech, and Rumelhart and Norman, in press, and Sternberg, et al. provide theories of serial order in typing.

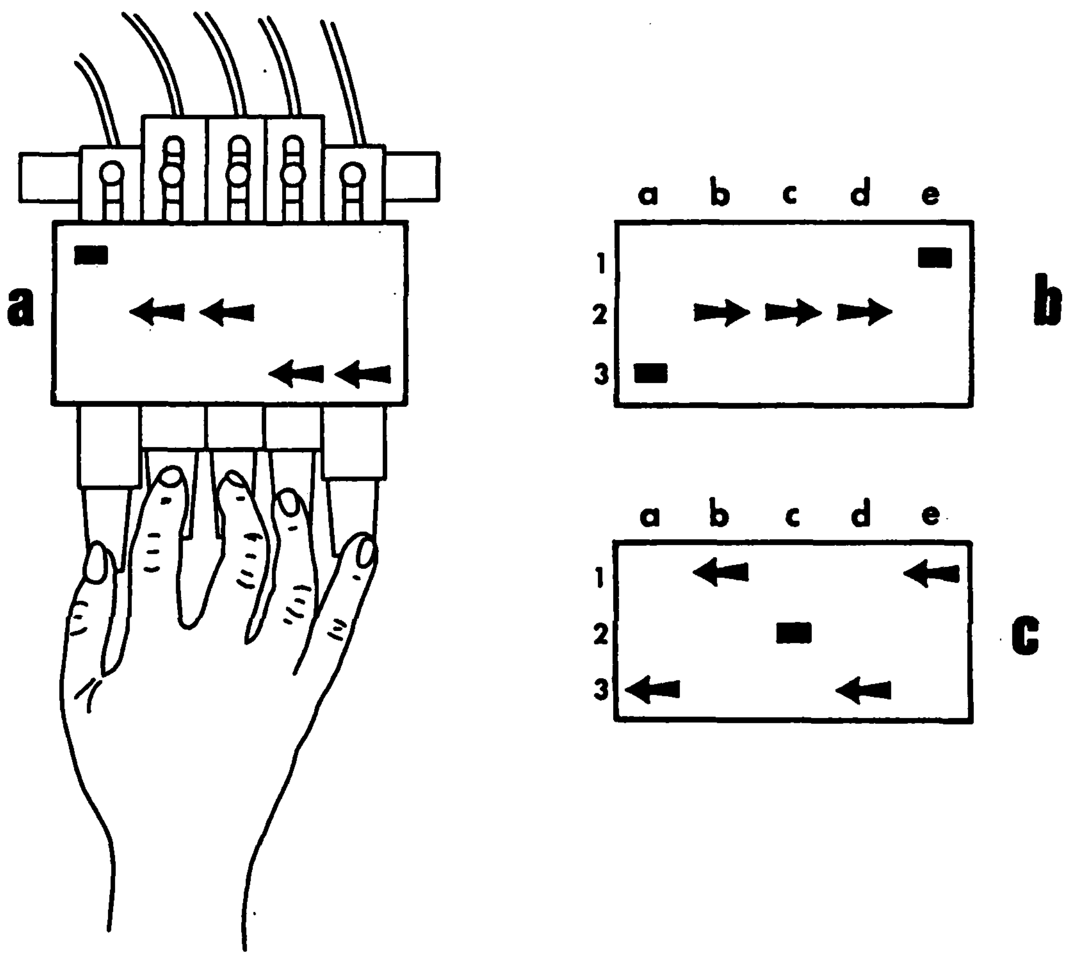


Figure 1. Three examples of tapping sequences. In the experiment, the hand is placed as shown in a, over the five keys. Bars and arrows on the rows of the card indicate the keys to be tapped, top row first, then the middle row, and finally the bottom row. Arrows indicate the order in which to tap the fingers. Panel a indicates the sequence (a)(c b)(e d). Parentheses indicate row groupings, but should be ignored in doing the tapping. It is instructive to try to tap each of the three different sequences specified by the three panels. Tap each sequence as rapidly as possible without error, pausing before repeating a sequence.

two principles: adjacency and symmetry. Under the adjacency principle, each row could only specify adjacent fingers (as in Figures 1A and 1B). Under the symmetry principle, each row had to be symmetric about the middle ("c") finger. Note that because of the requirement that each sequence have exactly five taps specified in three rows, each row had to specify either one, two, or three fingers. Five sequence pairs were selected in which one member had an organization based on adjacency, while the other member did not specify an adjacent or symmetric organization. Five pairs were selected in which one member specified a symmetric organization, while the other member did not specify an adjacent or symmetric organization. Six additional pairs were chosen for fillers in which neither member specified an organization based on adjacency or symmetry.

The sequences were tested on 16 UCSD students serving as subjects for pay or for course credit. Each subject performed in two sessions. In one session (the first session for half the subjects), the subject received the five pairs of stimuli that had one member based on adjacency, mixed with three filler pairs. In the other session, the subject received the five pairs of stimuli that had one member based on symmetry, plus the other three filler pairs.

To control for order effects, each symmetric pair was yoked to an adjacent pair. The stimuli were randomly ordered following the constraint that for each sequence, it could not appear with less than two intervening sequences between it and its same-sequence, different-representation mate. When averaged over subjects, each organized (adjacent or symmetric representation) stimulus appeared an equal number of times preceding and following its unorganized counterpart in the orders. Subjects were not informed that the stimuli contained different representations of the same sequence.[3]

Before the first session, subjects practiced on ten sequences constructed in the same way as the experimental sequences. They got five practice sequences at the start of the second session. The subjects were asked to tap the sequences as quickly as possible on a set of five adjustable metal keys, set up so as to conform to the natural finger placements when the seated subjects placed their hands at table height, in piano-playing position. Each sequence was specified by a pattern drawn on white cards (130mm x 65mm) placed on a holder directly over the tops of the keys so that each arrow or dash fell over the key it represented. For each sequence, the subject tapped the sequence when instructed to by a signal from the laboratory computer, 10 consecutive times. There was a delay of 800 milliseconds between the last keypress of a sequence and the signal to repeat. The latency of each keypress was recorded. A trial was considered in error if the appropriate five-

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3. During post-experimental questioning one subject reported that she had noticed that for one sequence there had been two different representations. The remaining subjects reported that they were entirely unaware of this manipulation.

keypress sequence did not appear within that interval.

For each sequence, the five fastest (of ten) error-free trials were analyzed.[4] The mean tapping time from the first keypress to the last, averaged over subjects, sets, and session is shown in Table 1. For both symmetric and adjacent pairs, the organized sequences were performed much more quickly than the unorganized ones. This effect holds for both forms of sequences, but is stronger for the adjacent ones. A four-way analysis of variance confirmed these differences. (For all effects reported here, $p < .05$.) The analysis also confirmed that there were differences between sets, that subjects were faster in the second session than in the first, and that the effect of the sequence type (adjacent or symmetric) depended on the particular set. In general, symmetric sets were performed faster than adjacent sets and the effect of organization was greater for the adjacent sequences. In addition, there were significantly fewer errors for organized sequences than for unorganized ones (1.4 errors per 10 tapping sequences versus 1.8 errors).

The interkeypress intervals provide more information about the two forms of organization. The average interkeypress intervals for the five fastest trials for each subject, collapsed across subjects, is given for the sequence (e b c d a) in Figure 2 in both its organized (adjacent) form, (e)(bcd)(a) and its unorganized form, (eb)(c)(da). The different conceptualizations produce significantly different patterns of response time. Similar differences are apparent for all the sequence pairs.

Our results provide evidence against a motor system that merely specifies action units regardless of the interrelationships among the units; the manner in which the action sequences are encoded determines performance. Some encodings are easier to execute than others, even when the final product is meant to be the same. A person's conceptualization of a motor task appears to be a major determinant of how well the task gets performed; good organization facilitates both speed and accuracy. Cognitive and representational factors can have important effects even at the "lower" levels of performance, causing otherwise identical tapping sequences to differ in difficulty.

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4. By using only the five fastest trials, we minimized the spurious effect of extremely lengthy trials that reflected a combination of factors, including learning, unfamiliarity with the task, and pauses. We got the same pattern of results whether we analyzed all trials, the five fastest trails, only the two fastest trials. Analyzing only the fastest times should minimize the size of the effect that we are studying, as we would expect the effects of coding to show up most in the initial trials, which are apt to be the slowest.

Occasionally, a subject would have fewer than five error-free trials for a stimulus. In that case we took the average of whatever number of error-free trials there were and compared that to the same number of fastest error-free trials of its different-representation mate.

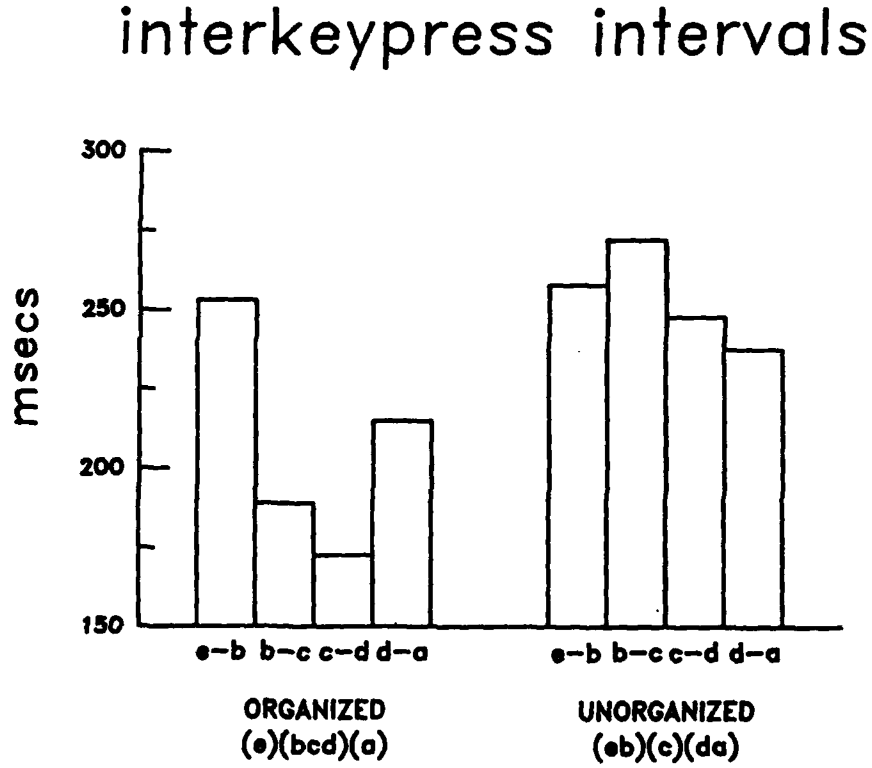


Figure 2. Mean interkeypress intervals for all subjects, for each of the transitions in the sequence (e b c d a), separately for the organized (adjacent) presentation (left panel) — (e)(b c d)(a) — and the unorganized presentation (right panel) — (e b)(c)(d a). The stimuli for these data appear in Fig. 1b (organized) and 1c (unorganized).

Table 1

Table 1. Tapping time in milliseconds from the first keypress to the last of the five fastest (of ten) error-free trials, averaged over all subjects, sets, and sessions. Standard errors are shown in parentheses.

| | Organizational form | |
|---|---|---|
| | adjacency | symmetry |
| organized sets | 878 (17) | 858 (20) |
| unorganized sets | 1023 (28) | 923 (27) |

## REFERENCES

Kent, R.D., & Minfie, F.D., Coarticulation in recent speech production models. Journal of Phonetics, 1977, 5, 115-133.

Rumelhart, D. E., & Norman, D. A. Simulating a skilled typist: A study of skilled cognitive-motor performance. Cognitive Science, 1982, in press.

Shaffer, L.H. Intention and performance. Psychological Review, 1976, 83, 375-393.

Stelmach, G.E. Information processing in motor control and learning. New York: Academic Press, 1978.

Sternberg, S., Monsell, S., Knoll, R.L., & Wright, C.E. The latency and duration of rapid movement sequences: Comparisons of speech and typewriting. In G.E. Stelmach (Ed.), Information processing in motor control and learning. New York: Academic Press, 1978.

## Cognitive Science ONR Technical Report List

8001. Donald R. Gentner, Jonathan Grudin, and Eileen Conway. Finger Movements in Transcription Typing. May 1980.

8002. James L. McClelland and David E. Rumelhart. An Interactive Activation Model of the Effect of Context in Perception: Part I. May 1980.

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