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# THE ADDITIVITY OF STIMULUS–RESPONSE COMPATIBILITY WITH THE EFFECTS OF SENSORY AND MOTOR FACTORS IN A TACTILE CHOICE REACTION TIME TASK *

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A tactile, two-choice, reaction time experiment is reported in which the effects of stimulus–response compatibility, response repertoire, and stimulus intensity are found to be additive. The implication of these results for the underlying information processing stage structure is discussed.

## Introduction

A classic finding in the choice reaction time (RT) literature is that RT is faster when stimulus and response correspond in the external space (compatible mapping) than when they do not correspond (incompatible mapping); e.g. Fitts and Deininger (1954). This effect is independent of the anatomical identity of the effectors involved in the task (Brebner et al. 1972) as well as of the amplitude (Guiard 1983) and velocity (Spijkers and Walter 1985) of the movement to be completed for the response. These findings suggest that the mapping effect in these tasks is mediated by an information processing stage (Smith 1968) in which stimuli and responses are paired within a common

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spatial code. Sanders (1980) has labelled 'response choice' an hypothetical stage having such properties which make it contrast with motor programming during which the parameters of the response movement are specified (see Rosenbaum 1980; Larish 1986; Lépine et al. 1989).

In the present note we report further empirical support in favour of this hypothetical distinction. A tactile, two-choice RT experiment was designed in which three factors were independently varied: Stimulus intensity, response repertoire and S–R mapping. The additive factor method (AFM) was adopted as our inferential framework (Sternberg 1969; for a recent examination of the AFM, see Miller 1988). According to the AFM, if two factors are found to have additive effects on RT, it implies that they each affect a separate information processing stage. If, on the other hand, two factors are found to have interactive effects, it implies that they each affect one or more stage(s) in common. Both logical considerations and empirical evidence suggest that stimulus intensity affects an early perceptual stage (e.g. Chocholle 1940; Hasbroucq 1987), while the repertoire of fingers devoted to the task affects motor programming (Shulman and MacConkie 1973). If S–R mapping affects the response choice stage, hypothetically following the perceptual processes and preceding the motor programming, its effects on RT should be additive with the effects of stimulus intensity and those of finger repertoire.

## Method

### *Stimuli and responses*

The stimuli consisted of brief mechanical taps to the fingertips. The taps were either strong (0.6 N) or weak (0.2 N). The responses consisted of key presses made with the thumb or index finger of the left or right hand.

### *Apparatus*

The stimuli were delivered, and the responses were made by means of four brass buttons mounted at the vertices of an aluminium square 12 cm to a side that was flush with the table top. Each button protruded 1 mm above the table surface and had a 3 mm hole in its center through which a piston could be driven upward by activating a solenoid (Guardian TP8 × 9). Since the thumb and index fingers rested on those buttons at all times, the upward thrust of the pistons comprised the stimuli. The tip of each piston rested 3 mm below the surface of the button. Upon activation, it took 5 ms

for the piston to strike the fingertip. The force of the tap was adjusted by varying the amplitude of the activating pulse.

A millisecond timer was started simultaneously with the activation of the solenoid. The timer was stopped when the subject pressed one of the buttons, each of which rested on a microswitch whose closure stopped the clock.

*Conditions and design*

There were three finger repertoires. The *within-hand* repertoire consisted of the thumb and index finger of the left hand; the *between-hands* repertoire consisted of the left and right thumbs; and the *between hands / between fingers* repertoire consisted of the left thumb and the right index finger. There were two stimulus intensity conditions defined by the force of the tap: strong and weak. Subjects were instructed to ignore intensity in making their response. Finally, there were two mapping conditions: compatible and incompatible. For the compatible mapping, subjects were instructed to respond with the finger that was stimulated; for the incompatible mapping, they were instructed to respond with the other finger in the repertoire. Repertoire and mapping were blocked; intensity was randomized within a block.

Each trial began with a warning signal consisting of the brief illumination of a neon light in the center of the square on which the buttons were mounted. Trials occurred at the rate of one every five seconds. There were 64 trials per block. The four intensity $\times$ finger combinations were randomly presented in each block with all transitions being equiprobable.

There were two sessions in the experiment corresponding to the compatible and incompatible mapping conditions. Each session was run on a different day. Half the subjects began with the compatible condition and had the incompatible condition on the following day; the other half of the subjects had the reverse order. Irrespective of the mapping, all subjects were run on all three repertoires in each session. These repertoires were arranged in a latin square with one block per condition. Each subject was run on two such latin squares per session. Only the data for the second latin square were analyzed.

Six subjects volunteered for this experiment and were paid on an hourly basis for their participation.

## Results

Median RTs were calculated for the left thumb, for each of the nine blocks of the second latin square in each mapping condition, for each subject. The three medians corresponding to the same repertoire condition in the second latin square were then averaged to yield a mean RT value per repertoire and mapping. An analysis of variance was performed on these data (6 subjects $\times$ 3 repertoires $\times$ 2 mappings $\times$ 2 intensities). There was no significant difference between the two 'between hands' repertoires; i.e. 'between hands' and 'between hands/between fingers'. These data were, therefore, collapsed and are henceforth called 'between hands'. All the reported contrasts are between the 'within' and these newly defined 'between' hands data.

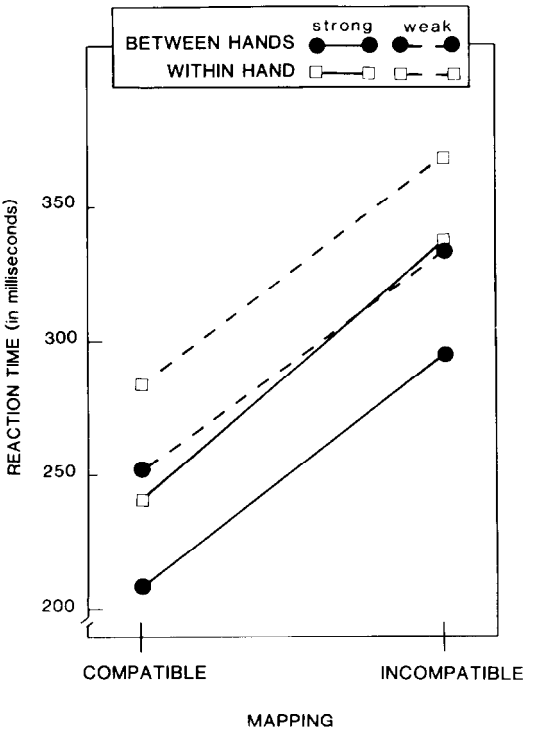


Fig. 1. RT as a function of stimulus–response mapping for within-hand and between-hands repertoires, and for strong and weak stimulus intensities.

The RT is shorter for the between than for the within hands repertoires (274 vs. 309 ms, $F(1, 5) = 12.33$, $p < 0.05$). RT is also shorter for compatible than for incompatible mapping (247 vs. 336 ms, $F(1, 5) = 43.21$, $p < 0.01$). Finally, RT is shorter for more intense than for less intense stimuli (272 vs. 311 ms, $F(1, 5) = 184.93$, $p < 0.001$). None of the interactions between any of the factors reached significance; all $F$ values were less than one, except for the intensity × mapping interaction which reached an $F$ value of 1.79 but was nevertheless non-significant ( $p = 0.24$). These results are illustrated in fig. 1.

Errors averaged 2.04 % and were not systematically related to any experimental factors.

## Discussion

The three factors manipulated in this experiment appear to have had additive effects on RT which, according to the AFM, suggests that they

each affected a different information processing stage (Sternberg 1969). Stimulus intensity probably affects an early stage, which could be preprocessing or identification. The effect of repertoire, reflecting the specification of the effector which takes place during movement programming, replicates the within/between hand difference originally reported by Kornblum (1965). The effect of S–R mapping, first evidenced by Fitts and Deininger (1954), affects an intermediate processing stage, response choice in the terminology proposed by Sanders (1980), during which the goal of action is selected by pairing of the abstract properties of the stimulus with those of the response (Theios 1975). The lack of any sign of a first- or second-order interaction between the three factors under consideration is clearly consistent with Sanders' (1980) proposition that S–R compatibility, as varied by mapping instructions, specifically concerns response choice. This result suggests that the understanding of S–R compatibility should be based on a modelling of the processes that occur during the response choice stage.

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