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RESPONSE SELECTION IN SPATIAL CHOICE REACTION: FURTHER EVIDENCE AGAINST ASSOCIATIVE MODELS

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In a “consistent” spatial choice reaction task the same spatial relationship obtains between each stimulus and its correct response. In an “inconsistent” task this is not so. While Duncan (1977a) found both easy (spatially corresponding) and difficult (spatially opposite) responses to be slowed in inconsistent tasks, Smith (1977) found this only for the corresponding responses, the reverse holding for opposites. Reasons for this discrepancy are examined. The result of Smith (1977) depends on the use of different numbers of alternative responses in consistent and inconsistent tasks, a situation allowing no useful comparison between the two. Effects of consistency are related to others in the literature. The general conclusion is that, in these tasks, response selection is based not on a list of associations between individual stimuli and responses, but on operations or rules each of which will generate a set of stimulus-response pairs.

Introduction

Recently, Duncan (1977a, b) has distinguished two types of spatial choice reaction task. Figure 1 shows various mappings between a fixed set of stimuli (four lights in a horizontal array: represented from left to right by numbers 1 to 4) and responses (key-depressions; the four keys represented from left to right by letters A to D). Arrows connect stimuli to their correct responses. Tasks C-1 and C-2 are “Consistent”: the same spatial relationship obtains between each stimulus and

![Figure 1. S-R mappings of Experiment I.](image-url)
its correct response. The relationships in the two tasks may respectively be termed “Corresponding” and “Opposite”. Tasks I(4)-1 and I(4)-2 are “Inconsistent”: each involves both Corresponding and Opposite stimulus–response (S–R) pairs.

Duncan (1977a), studying these four tasks, described three major results: (1) For a given S–R pair [e.g. 1 – D of tasks C-2 and I(4)-2] reaction times (RTs) were longer in the Inconsistent than in the Consistent task. This was true of both Corresponding and Opposite S–R pairs. (2) In Inconsistent tasks there was some tendency for RTs to be reduced when, on successive trials, there was a “repetition” in the S–R relationship (though not in the particular stimulus and response). (3) The most common error in an Inconsistent task was an Opposite response made when a Corresponding response was required, or vice versa (e.g. task I(4)-1, stimulus 1, erroneous response D). All three results were extended and confirmed in the later experiment (Duncan, 1977b).

A simple model accounts well for these findings. Its principal component is the “spatial transformation”, an operation which will produce a response (R) bearing a fixed spatial relationship (T) to any suitable stimulus (S): 

\[ R = T(S) \]

Thus different transformations would produce, respectively, Corresponding and Opposite responses. In a Consistent task the same transformation is appropriate for all S–R pairs. Since this is not so in an Inconsistent task, on each trial the correct transformation must be chosen from two alternatives. The results are explained by supposing this choice: (1) to take appreciable time; (2) to show a “repetition effect” (cf. Bertelson, 1961); and (3) to be prone to error.

The theoretical significance of this model lies in the nature of the spatial transformation. This is an operation which will produce, not an individual S–R pair, but a set of similar pairs. In other words, it expresses a rule. The model is thus quite different from those which base response selection on a set of “associations” between individual stimuli and responses (e.g. Hawkins, MacKay, Holley, Friedin and Cohen, 1973; Theios, 1973, 1975); each association generates only a single S–R pair. The idea that rules of this sort are used in choice reaction performance is scarcely new (and that they are used in more complex tasks such as speech production is of course unimpeachable). It is suggested by the discussions of Welford (1958) and Shaffer (1965), and is demonstrated explicitly by Rabbitt and Vyas (1973). The virtue of the present demonstration lies mainly in its clarity: a clarity obviously necessary, since associative models of these tasks are still popular.

An experiment closely relevant to these issues was described recently by Smith (1977). Again the responses were key-depressions, but the stimuli were vibrotactile rather than visual: embedded in the response keys were plungers which delivered stimuli directly to the fingertips. Again, too, the contrast was drawn between Consistent and Inconsistent tasks. Returning to Figure 1, the experiment involved mappings C-1, C-2, I(2)-1 and I(2)-2.* The last two mappings require a little clarification. Though stimuli were delivered to four fingers, responses were

* The experiment of Smith (1977) involved many further conditions, not described here. In particular, the results were replicated with various numbers of alternative stimuli and responses.
made only with two. Thus in task I(2)-I, only responses C and D (right fore- and middle-fingers) were employed, both in Opposite responses to stimuli 1 and 2 (vibrations on left middle- and forefingers) and in Corresponding responses to 3 and 4. These will be termed Inconsistent (2) tasks, as distinct from the Inconstant (4) tasks of Duncan (1977a).

The results of Smith (1977) were rather different from those described above. While Corresponding responses were again slower in Inconsistent than in Consistent tasks, Opposite responses were faster. To account for these results Smith (1977) developed a mathematical model based again on associations between individual stimuli and responses. Essentially, the RT in any task was supposed to depend partly on the average associative strength of all S–R pairs. Thus in an Inconstant task, Corresponding (high-association) responses are slowed by the inclusion of Opposite (low-association) pairs, while Opposite responses are speeded by the reverse effect.

The discrepancy between the results of Duncan (1977a) and Smith (1977) should clearly be resolved. At first sight, the experiment of Smith (1977) seems flawed by the use of different numbers of responses in Consistent and Inconstant tasks. However, his result is supported by others in the literature. In particular, Forrin and Morin (1967) studied a “mixed” four-choice task involving two highly-practised S–R pairs (digit-naming pairs) and two unpractised pairs (geometrical symbols arbitrarily paired with digit names). Compared with equivalent “pure” four-choice tasks, responses to digits were slower, but responses to geometrical symbols faster, in the “mixed” task. The model of Smith (1977) could account well for this result.

Accordingly, it seems appropriate to isolate the critical difference between the experiments of Smith (1977) and Duncan (1977a), and in this light to consider other work. There are several factors to examine. The first is stimulus modality. Experiment I is an attempt to replicate both results using only visual stimuli.

**Experiment I**

**Method**

**Subjects**

There were 12 subjects, aged 21–30, half of each sex. Two who made more than 15% errors in at least one experimental condition were replaced.

**Task**

The four stimuli were single vertical lines, arranged in a horizontal row on an oscilloscope screen. They were viewed in a darkened room, from a fixed eye-mask. Each was of height 0.8 cm, and separated from the next by 1.8 cm. At the viewing distance of approximately 43 cm, the entire array subtended horizontally a visual angle of 7° 12′. Its centre coincided with that of the screen.

The responses were key-depressions, made with the middle- and forefingers of the two hands. The six S–R mappings of Fig. 1 were employed. On each trial, a single stimulus was presented, and a single response was required.

**Procedure**

Each subject served in a single experimental session, of approximately 1 h. This session consisted of six sections, each involving a different S–R mapping. The order of performance with the six mappings was counterbalanced across subjects, by Latin square.
Each section had three components: Instruction, Practice and Performance. In Instruction, the subject was shown a diagram of the stimulus lines and response keys, each with its appropriate number or letter (Fig. 1). Arrows joined stimuli to their correct responses. With reference to this, the experimenter pointed out in turn the four correct S–R pairs, proceeding from left to right across the stimulus array. In Practice, a short run of 24 responses was made. Performance consisted of a second run of 144 responses. These two runs were separated by approximately half a minute.

Each run was of the following structure. At the beginning, the word READY appeared for 2 s; next the four stimuli appeared sequentially from left to right, each remaining for 3 s and being separated from the next by 1 s; finally the word READY reappeared for a further 2 s, immediately followed by the first trial. On each trial, a fixation spot appeared in the centre of the screen, midway between the positions of stimuli 2 and 3, for 1 s, and was immediately followed by one of the four stimuli. This remained present until a response (correct or incorrect) was made, or for a maximum of 3 s, if no response was made in this time. The next trial then began immediately. Performance was thus self-paced, with a response–stimulus interval of 1 s. Each Practice run involved six presentations of each stimulus. Each successive block of 48 trials in a Performance run involved 12 presentations of each stimulus. Otherwise, stimulus sequences were random.

The subject was given no feedback concerning performance. Instructions were to perform as rapidly and as accurately as possible.

The experiment was run on-line on a Linc-8 computer. A record of every stimulus, response and RT was stored on magnetic tape. Summaries of the data were obtained by various computer programs. Trials immediately following errors, which are atypical in several ways (Rabbitt, 1966), were excluded.

Results

Table I shows mean correct RTs as a function of the type of task and the type of S–R pair. To give a more complete picture of the data, responses to stimuli 1 and 4 (Outer) have been separated from those to 2 and 3 (Inner). Each task in Figure 1 contributes two cells to Table I. Thus task I(4)–1 contributes cells (Inconsistent (4), Corresponding, Outer) and (Inconsistent (4), Opposite, Inner). Each value is the mean of 12 subject means.

<table>
<thead>
<tr>
<th>S–R pair</th>
<th>Consistent</th>
<th>Task Inconsistent (2)</th>
<th>Inconsistent (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corresponding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner</td>
<td>408</td>
<td>420</td>
<td>564</td>
</tr>
<tr>
<td>Outer</td>
<td>455</td>
<td>446</td>
<td>619</td>
</tr>
<tr>
<td>Opposite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner</td>
<td>531</td>
<td>422</td>
<td>567</td>
</tr>
<tr>
<td>Outer</td>
<td>586</td>
<td>485</td>
<td>642</td>
</tr>
</tbody>
</table>

The results of Duncan (1977a) were essentially replicated. Both Corresponding and Opposite responses were slower in Inconsistent (4) than in Consistent tasks. Corresponding responses were especially affected. The results of Smith (1977)
were also replicated, at least in part. Opposite responses were faster in Inconsistent (2) than in Consistent tasks. For Corresponding responses, however, there was little difference between these two.

The data were examined by analysis of variance. The three factors, all within-subjects, were: (1) Task (T), with levels Consistent, Inconsistent (2) and Inconsistent (4); (2) S–R Pair (P), with levels Corresponding and Opposite; and (3) Stimulus (S), with levels Inner and Outer. All three main effects were significant: T ($F = 34.2, df = 2, 22, P < 0.001$); $P (F = 48.8, df = 1, 11, P < 0.001)$; and $S (F = 45.4, df = 1, 11, P < 0.001)$. There were two significant interactions: $T \times P (F = 11.7, df = 2, 22, P < 0.001)$ and $P \times S (F = 6.4, df = 1, 11, P < 0.05)$. The effect of $P$ was substantially greater in Consistent tasks than in Inconsistent (2) or Inconsistent (4). It was greater with Outer than with Inner stimuli.

Effects of $T$ at each level of $P$ were further examined by matched-pairs t-tests. In the absence of a significant $T \times S$ interaction, data were collapsed across the latter variable. The required significance level was set at 0.01, since four tests were to be made. With Corresponding S–R pairs, RTs were significantly longer in Inconsistent (4) than in Consistent tasks ($t = 6.1, df = 11, P < 0.001$), but did not differ significantly in Inconsistent (2) and Consistent tasks ($t = 0.3$). With Opposite S–R pairs, RTs were again significantly longer in Inconsistent (4) than in Consistent tasks ($t = 3.1, df = 11, P = 0.01$), and were significantly shorter in Inconsistent (2) than in Consistent tasks ($t = 3.6, df = 11, P < 0.01$).

Table II shows error percentages.

### Table II

#### Experiment I: Error percentages

<table>
<thead>
<tr>
<th>S–R pair</th>
<th>Consistent</th>
<th>Inconsistent (2)</th>
<th>Inconsistent (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corresponding</td>
<td>2.4</td>
<td>2.2</td>
<td>4.5</td>
</tr>
<tr>
<td>Opposite</td>
<td>3.7</td>
<td>4.2</td>
<td>3.9</td>
</tr>
</tbody>
</table>

**Discussion**

Most importantly, Experiment I replicated the critical difference between the results of Duncan (1977a) and Smith (1977). Opposite responses were slowest in Inconsistent (4) tasks, intermediate in Consistent, and fastest in Inconsistent (2). Apparently stimulus modality is not the crucial factor determining the pattern of results.

Two differences from the earlier results deserve mention. First, the difference between RTs in Inconsistent (4) and Consistent tasks was especially marked with Corresponding S–R pairs. No such effect was obtained by Duncan (1977a), but it is the most usual result (Duncan, 1976), and was probably obscured in the earlier experiment by large individual differences. This point will be raised again later.
Second, Corresponding RTs were not shorter in Consistent than in Inconsistent (2) tasks, as found by Smith (1977). Plausibly this is a genuine influence of stimulus modality. Performance is particular fast in a Consistent, Corresponding task with vibrotactile stimuli (Leonard, 1959). Perhaps some unique feature of this task is disturbed in the Inconsistent (2) case.

**Experiment II**

The Inconsistent (2) and Inconsistent (4) tasks of Figure 1 differ in two ways. First, in the Inconsistent (2) tasks, S–R pairs of the same sort (i.e. those sharing a common S–R relationship) are on the same “side” of the task: their stimuli are on the same side of the display. In the Inconsistent (4) tasks this is not so. Second, there is the obvious difference in the number of response alternatives. In Experiment II, Inconsistent tasks involve four alternative responses, but S–R pairs of the same sort are on the same “side” of the task.

**Method**

**Subjects**

There were eight subjects, aged 19 to 26, half of each sex.

**Task**

The stimuli and responses were as before. The two Consistent and two Inconsistent (4) tasks are shown in Fig. 2. The new S–R relationship is termed Crossed.

![Figure 2. S–R mappings of Experiment II.](image)

**Procedure**

Each subject served in a single experimental session, of approximately 45 min. This session consisted of four sections, each involving a different S–R mapping. The order of performance with the four mappings was counterbalanced across subjects, by Latin square. Other details of procedure were unchanged from Experiment I.

**Results**

Table III shows, separately for Inner and Outer stimuli, mean correct RTs as a function of the type of task and the type of S–R pair. Each value is the mean of eight subject means.
RESULTS were similar to those obtained in the Consistent and Inconsistent (4) tasks of Experiment I. RTs were longer in Inconsistent (4) than in Consistent tasks. As in Experiment I, this result was especially marked with Corresponding S–R pairs.

The data were examined by analysis of variance. The three factors, all within-subjects, were: Task (T), with levels Consistent and Inconsistent (4); S–R Pair (P), with levels Corresponding and Crossed; and Stimulus (S), with levels Inner and Outer. There were significant effects of T ($F = 86.0$, $df = 1,7, P < 0.001$) and P ($F = 20.4$, $df = 1,7, P < 0.005$); and a single significant interaction, $P \times S$ ($F = 15.4$, $df = 1,7, P < 0.01$). The effect of P was greater with Inner than with Outer stimuli, a result opposite to that of Experiment I. The interaction $T \times P$ fell just short of significance ($F = 5.2$, $df = 1,7, P < 0.1$).

Effects of $T$ at each level of $P$ were further examined by matched-pairs $t$-tests. In the absence of a significant $T \times S$ interaction, the data were collapsed across the latter variable. The required significance level was set at 0.02, since two tests were to be made. With Corresponding S–R pairs, RTs were significantly longer in Inconsistent (4) than in Consistent tasks ($t = 8.5$, $df = 7, P < 0.001$). The same was true with Crossed S–R pairs ($t = 3.7$, $df = 7, P < 0.01$).

Table IV shows error percentages.

**Table IV**

*Experiment II: Error percentages*

<table>
<thead>
<tr>
<th>S–R pair</th>
<th>Consistent</th>
<th>Inconsistent (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corresponding</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Crossed</td>
<td>2.1</td>
<td>4.8</td>
</tr>
</tbody>
</table>

**Experiment III**

In the Inconsistent tasks of Experiment III, S–R pairs of the same sort are on different "sides", but there are only two alternative responses.
Method

Subjects
There were eight subjects, aged 19–23, half of each sex. One, who made more than 15% errors in one experimental condition, was replaced.

Task
The stimuli and responses were as before. The two Consistent and two Inconsistent (2) tasks are shown in Fig. 3. The new S–R relationship is termed Shifted.

![Diagram of S-R mappings](image_url)

**FIGURE 3. S-R mappings of Experiment III.**

Procedure
The procedure was unchanged from Experiment II.

Results
Table V shows, separately for Inner and Outer stimuli, mean correct RTs as a function of the type of task and the type of S–R pair. Each value is the mean of eight subject means.

<table>
<thead>
<tr>
<th>Corresponding</th>
<th>Consistent</th>
<th>Inconsistent (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner</td>
<td>440</td>
<td>648</td>
</tr>
<tr>
<td>Outer</td>
<td>468</td>
<td>592</td>
</tr>
<tr>
<td>Shifted</td>
<td>859</td>
<td>677</td>
</tr>
<tr>
<td>Outer</td>
<td>809</td>
<td>672</td>
</tr>
</tbody>
</table>

Results were similar to those of Smith (1977). Shifted responses were faster in Inconsistent (2) than in Consistent tasks, but Corresponding responses were slower. The data were examined by analysis of variance. The three factors, all within-subjects, were: Task (T), with levels Consistent and Inconsistent (2); S–R Pair...
(P), with levels Corresponding and Shifted; and Stimulus (S), with levels Inner and Outer. There were significant effects of P (\( F = 68-2, df = 1,7, P < 0.001 \)); T \( \times \) P (\( F = 77-9, df = 1,7, P < 0.001 \)); and a last significant interaction T \( \times \) P \( \times \) S (\( F = 16-3, df = 1,7, P < 0.005 \)). Table V shows that the T \( \times \) P interaction was especially marked with Inner Stimuli.

Effects of T at each level of P were further examined by matched-pairs \( t \)-tests. Data were collapsed across the variable S, since results were clearly similar with Inner and with Outer stimuli. The required significance level was set at 0.02, since two tests were to be made. With Corresponding S–R pairs, RTs were significantly longer in Inconsistent \( (2) \) than in Consistent tasks (\( t = 8-2, df = 7, P < 0.001 \)). With Shifted S–R pairs the reverse result was also significant (\( t = 3-9, df = 7, P < 0.01 \)).

Table VI shows error percentages.

**Table VI**

*Experiment III: Error percentages*

<table>
<thead>
<tr>
<th>S–R pair</th>
<th>Consistent</th>
<th>Inconsistent ( (2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corresponding</td>
<td>2.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Shifted</td>
<td>7.0</td>
<td>5.2</td>
</tr>
</tbody>
</table>

**General discussion**

These experiments point quite clearly to the general conclusion: spatial choice RTs are always longer in Inconsistent than in Consistent tasks, providing that both involve the same number of alternative responses. Hence the spatial transformation model of Duncan (1977a, b) is supported.

These results were obtained in a situation in which, during the course of the experiment, subjects changed several times from one S–R mapping to another. *A priori* it is possible that results would be different were the mapping constant: psychologically this might be rather a different situation. For several reasons this seems not to be so. Experiment I replicated the earlier results of Duncan (1977a) and Smith (1977) despite wide differences in procedure. Duncan (1977a) used a between-subjects design, individual subjects practising a single S–R mapping for 864 trials. Smith (1977) used a within-subjects design, but each task was practised on a different day. Certainly the particular order of mappings is immaterial: in Experiments II and III, the results described for the group held for every individual subject. In fact it is rather interesting that, when the mapping is repetitively changed, subjects with very little practice settle down to give a pattern of results similar to that seen when the mapping is constant.

It is probably impossible to give any simple account of the comparison between Consistent and Inconsistent \( (2) \) tasks, since a complex combination of factors may
underlie any difference between them. A difference in motor processes is most obvious: fewer responses need be distinguished in Inconsistent (2) tasks. Similarly for perceptual processes: in Inconsistent (2) tasks there is no requirement to distinguish perceptually (i.e. to identify separately) stimuli which require a common response. It is sufficient to extract only some feature shared by these stimuli, and not by stimuli requiring different responses. (This argument has been applied to many classification tasks; e.g. Rabbitt, 1967; Nickerson, 1973.) A closely connected but independent point is that such common features might also be used in response selection. In the Inconsistent (2) tasks of Experiment I, for example, the strategy might be: "Inner stimuli require a forefinger response, Outer stimuli a middle finger." Even to equate S–R relationships in Consistent and Inconsistent (2) tasks may make little sense, since the crucial factor must in part be the relative positions of stimuli and responses in their respective arrays, rather than relative physical positions. As an example, it is not at all clear that, in task I(2)-1 of Figure 1, response C (the leftmost in the array) is opposite to stimulus 2 in the same sense as is response C (the third response from the left) in task C-2. All in all, the comparison between Consistent and Inconsistent (2) tasks may be too complex to be useful.

The picture for spatial choice reaction, then, is fairly clear in support of the spatial transformation model. Various patterns of results have been obtained when, in other contexts, two different classes of S–R pairs have been mixed in a single task (cf. the present Inconsistent tasks). In particular, Morin and Forrin (1962) and Forrin and Morin (1966, 1967) have mixed together well-practised (digit-naming) and various types of unpractised pairs, comparing the results with equivalent "pure" (unmixed) tasks. The well-practised responses are always slower in "mixed" than in "pure" tasks, but unpractised responses may either be unaffected (Morin and Forrin, 1962) or even speeded (Forrin and Morin, 1967).

Forrin and Morin (1967) proposed a model which casts light on this issue. It will be recalled that, in their experiment, the well-practised S–R pairs were as usual digits and their (vocally-produced) names, while the unpractised pairs were geometrical symbols arbitrarily paired with digit names. The authors suggested that, in a "mixed" task, a first decision identifies the class of the S–R pair (digit or geometrical symbol), and subsequent within-class decisions identify the particular pair. These within-class decisions are similar to those of "pure" tasks: thus for digit-naming S–R pairs their duration is independent of the number of alternatives, but for geometrical-symbol/digit-name pairs the number of alternatives has a strong effect. Digit-naming RTs are longer in "mixed" than in "pure" tasks because of the necessity, in the former, for the first, between-class decision. With geometrical-symbol/digit-name S–R pairs this factor is more than offset by another. For these pairs, within-class decisions are sensitive to the number of alternatives. Consider the comparison between four-choice "mixed" and "pure" tasks. In the "mixed" case, the between-class decision is followed by a within-class decision distinguishing only two alternatives, since two of the S–R pairs in this task are digit-naming pairs. In the "pure" case, within-class decisions must distinguish four alternatives. The difference between two- and four-choice within-class decisions more than offsets any requirement for a between-class decision.
Results consistent with this account were described by Forrin (1975), who compared digit- and letter-naming RTs in "pure" tasks, involving only letters or digits, with RTs in "mixed" tasks, involving both letters and digits. Results were similar to those of the present experiments: performance was generally slower in the "mixed" tasks. For both letter- and digit-naming, RTs are relatively independent of the number of alternatives. Accordingly, on the model of Forrin and Morin (1967), all RTs should indeed have been lengthened in "mixed" tasks, since no factor offset the requirement for a between-class decision.

Returning to the spatial transformation model: this is really quite similar to the account of Forrin and Morin (1967). In both cases, when tasks involve S–R pairs from different classes, a first decision identifies the appropriate class, and subsequent processes identify the particular response. The necessity for the first of these decisions raises RTs above those of single-class tasks, unless this factor is more than offset by changes in the duration of other processes. In the spatial case it is plausible that it should not be. The time taken to apply a particular spatial transformation may be the same in Consistent and Inconsistent tasks. It is possible, in conclusion, to account for all these results within a common framework.

One last feature of the results should be mentioned. In Experiments I and II, the easy (Corresponding) responses were especially slowed in Inconsistent (4) tasks. Forrin (1975) obtained a similar result: digit-naming, which was faster than letter-naming, was especially slowed in the "mixed" tasks. Several explanations suggest themselves, perhaps the most obvious being that subjects may tend to make all responses of a given task at an approximately fixed speed, so that, if the task involves S–R pairs differing in difficulty, performance is slowed for easy pairs, but speeded for more difficult pairs. In the present tasks, such a tendency would exaggerate the difference between Consistent and Inconsistent RTs for Corresponding S–R pairs, but would reduce it for other pairs. Highly plausible possibilities of this sort deny us some otherwise tempting procedures. For example, by subtracting Consistent from Inconsistent RTs we might hope to estimate the duration of "transformation selection" in the latter. This procedure would be quite invalid given the above complication, or anything like it. Any attempt to draw quantitative conclusions from these results would probably be misplaced.

In conclusion, the theoretical significance of these results should be re-emphasized. Response selection in these tasks is not based on a set of individual S–R associations, but on operations (the spatial transformations) each of which will generate a set of S–R pairs. This argument might be put in a wider context. The experiments of the 1950s (e.g. Hick, 1952) brought out the importance of sets rather than individual S–R pairs; and in particular, of set size. Obviously properties of the set of alternatives determine the nature of a decision. Though this is a truism, its particular applicability to problems of S–R mapping is perhaps worth emphasis; since it is a truism with which associative models, emphasizing as they do the individual S–R pair, must always be uneasy.

This research was stimulated by discussions with Mr G. Smith. Particular thanks are due to Dr P. M. A. Rabbitt, who supervised the work; and to Mr S. Fearnley, whose Linc-8 programs were extensively used. The author was supported by Research Studentship No. G 77/4610 from the Medical Research Council.
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