Journal of Experimental Psychology:
Human Perception and Performance
2001, Vol. 27, No. 2, 466–471

0096-1523/01/$5.00 DOI: 10.1037//0096-1523.27.2.466

The Up-Right/Down-Left Advantage Occurs for Both Participant- and Computer-Paced Conditions: An Empirical Observation on Adam, Boon, Paas, and Umiltà (1998)

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When up and down stimuli are mapped to left and right keypresses or "left" and "right" vocalizations in a 2-choice reaction task, performance is often better with the up-right/down-left mapping than with the opposite mapping. J. J. Adam, B. Boon, F. G. W. C. Paas, and C. Umiltà (1998) presented evidence that the up-right/down-left advantage is obtained when trials are participant paced but not when they are computer paced. In all, 3 experiments are reported that show no difference in magnitude of the up-right/down-left advantage between computer-paced and participant-paced conditions. The advantage was eliminated, however, in Experiment 3 when a response deadline was imposed. Response speed, rather than participant or computer pacing of trials, is crucial.

When up and down stimuli are mapped to left and right keypress or vocal responses, performance is better with the up-right/down-left mapping than with the up-left/down-right mapping (Dutta & Proctor, 1992; Proctor & Pick, 1999; Weeks & Proctor, 1990). Weeks and Proctor attributed the up-right/down-left advantage to asymmetric coding of the stimuli on the respective dimensions. They cited evidence to indicate that *up* is the polar referent for the vertical dimension and *right* for the horizontal dimension. According to their salient features coding hypothesis, stimulus–response (S-R) translation is more efficient for the up-right/down-left mapping than for the alternative mapping because the polar referent, or salient feature, for the vertical stimulus dimension is mapped to that for the horizontal response dimension. Umiltà (1991) accepted the central tenet of Weeks and Proctor's salient-features coding hypothesis, which is that the up-right/down-left advantage is due to asymmetric coding of the members of the S-R sets, but argued that "the salient-features coding hypothesis . . . applies only to codes that are verbal in nature" (p. 83). According to Umiltà's dual-strategy hypothesis, verbal codes have the salient features of up and right, but spatial codes are symmetric and do not have polar referents. Thus, the up-right/down-left advantage should be obtained when a verbal coding strategy is used but not when a spatial coding strategy is used.

Adam, Boon, Paas, and Umiltà (1998) recently reported a study that they interpreted as providing support for the dual-strategy hypothesis. Their first two experiments compared computer-paced conditions, in which the intertrial interval (ITI) was controlled by the computer, to participant-paced conditions, in which the participant performed an initiating action to start the next trial sequence. In their Experiment 1, the responses were left and right keypresses, and the trial sequence was initiated in the participant-paced condition by a right keypress. In their Experiment 2, they included conditions in which the responses were the vocal utterances "left" and "right", and the initiating action in the participant-paced condition was "blowing" into the microphone. In Adam et al.'s words,

> The results of the first two experiments demonstrate that participant-paced trials produced the up-right/down-left advantage but that computer-paced trials did not. According to the dual-strategy hypothesis, this pattern of results is due to an asymmetry in the processing of the stimulus, with computer-paced trials favoring the use of the spatial codes and participant-paced trials favoring the use of the verbal codes. (p. 1588)

Because the up-right/down-left advantage has been reported previously for studies that used computer-paced presentation (Dutta & Proctor, 1992; Proctor & Pick, 1999), including Adam et al.'s (1998) Experiment 3 in which ITI was manipulated, we thought it necessary to try to replicate the findings of Adam et al.'s Experiments 1 and 2. In three experiments, described below, we were not able to do so, finding no significant difference in the mapping effects for participant- and computer-paced conditions. After describing the experiments, we consider their implications for the dual-strategy hypothesis, as well as the status in general of support for that hypothesis.

Experiment 1

The method of Experiment 1 followed closely that of Adam et al.'s (1998) Experiment 1. As in their experiment, computer-paced and participant-paced procedures were used for trial initiation. According to Adam et al.'s dual-strategy hypothesis, "these two procedures would lead to differential information-processing strategies" (p. 1591). Verbal codes, which are asymmetric, should be used in the participant-paced condition, producing an up-right/down-left advantage. However, spatial codes, which are symmetric, should be used in the computer-paced condition, producing no up-right/down-left advantage.

We thank Yvonne Lippa, Claire Michaels, and Carlo Umiltà for helpful comments on drafts of this article.

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Method

Participants. A total of 96 undergraduate students enrolled in introductory psychology at Purdue University participated in partial fulfillment of a course requirement. All of the participants were right-handed and had normal or corrected-to-normal visual acuity as determined by self-report. They were randomly assigned to one of two conditions: participant paced or computer paced.

Apparatus and stimuli. The experiment was controlled by software developed with the Micro Experimental Laboratory 2 (MEL 2.0, Schnieder, 1995) system. Stimuli were presented on the display screen of an IBM-compatible microcomputer, and viewing distance was approximately 50 cm. Responses were made by pressing one of two keys, *V* and *N*, on the computer keyboard, which are separated by 2.5 cm, with the index finger of both hands.

Stimuli were standard uppercase Xs (0.3 × 0.4 cm; approximately 0.34° × 0.46° of visual angle). They were presented as white characters on a dark background, approximately 2 cm (2.30°) above or below a central fixation point "+" (0.25 × 0.3 cm; 0.29° × 0.34°). The keyboard and computer screen were aligned so that the midpoint between the two response keys and the fixation point were on the participant's sagittal midline.

Procedure. Each participant performed with two mappings, up-right/down-left and up-left/down-right, with the order counterbalanced across participants. Each participant performed 30 practice trials and 400 test trials for each mapping condition. The test trials were presented in four blocks of 100 trials (50 randomly assigned to each stimulus position), with a 1-min rest interval between trial blocks.

In the participant-paced condition, a trial began when the word READY (1.6 × 0.4 cm; 1.83° × 0.46°) was displayed in the center of the screen. To initiate the trial, the participant was required to press the right response key. After pressing the key, the word READY was replaced by the fixation point for 1 s. The stimulus was presented either above or below the fixation point, both of which remained on until the participant responded. The READY signal for the next trial came on 750 ms after the response. An incorrect response was followed by a 500-ms feedback tone of 500 Hz, after which the 750-ms interval before the next trial occurred.

In the computer-paced condition, a trial began when the fixation point appeared in the center of the screen. The rest of the procedure was the same as in the participant-paced condition.

Results

The data were analyzed following the procedure used by Adam et al. (1998). RTs shorter than 125 ms and longer than 1,250 ms were excluded; 0.40% of the trials were considered outliers using these criteria and removed from analysis. For each participant, the RT distributions for the up-right/down-left mapping and the up-left/down-right mapping were divided into 20% bins, and the mean RTs for the correct responses and the percentages of errors (PEs) were calculated for each bin (see De Jong, Liang, & Lauber, 1994, for more detailed description of this procedure). Analyses of variance (ANOVAs) were conducted on the mean RT and PE data, with mapping and bin as within-subject factors and initiation condition (computer paced, participant paced) as a between-subject factor. Mean RT and PE data, collapsed across bin, are shown in Table 1.

Table 1
Mean Reaction Times (RTs; in Milliseconds) and Percentages of Error (PEs) in Experiments 1, 2, and 3 as a Function of Mapping and Initiation Condition

	Up-right/down-left mapping		Up-left/down-right mapping	
Initiation condition	RT	PE	RT	PE
Experiment 1				
Participant paced	332	3.30	344	3.49
Computer paced	336	1.99	347	1.93
Experiment 2				
Participant paced	412	0.98	430	1.33
Computer paced	418	0.83	433	0.86
Experiment 3				
Participant paced	284	4.45	286	3.97
Computer paced	292	3.17	294	3.00

Reaction time. Mean RT was shorter with the up-right/down-left mapping (M = 334 ms) than with the up-left/down-right mapping (M = 345 ms), $F(1, 94) = 7.71$, $p = .0066$, MSE = 3,560. The initiation main effect was not significant ($F < 1$), and there was no two-way interaction of initiation condition with mapping ($F < 1$), indicating that the initiation condition did not affect the S-R mapping preference. The up-right/down-left advantage was 12 ms in the participant-paced condition and 11 ms in the computer-paced condition.

There was a main effect of bin, $F(4, 376) = 738.06$, $p < .0001$, MSE = 2,061, as imposed by the bin classification. The Mapping × Bin interaction was also significant, $F(4, 376) = 6.25$, $p < .0001$, MSE = 532, as was the Bin × Initiation interaction, $F(4, 376) = 2.50$, $p = .0424$, MSE = 2,060, but the three-way interaction of these variables was not ($F < 1$). As shown in Figure 1, the difference between the mapping conditions became larger as RT increased for both conditions. Also, the computer-paced condition tended to be slower than the participant-paced condition at the fastest bin (*M*s = 254 ms and 241 ms, respectively), with this difference changing across bins so that by the slowest bin the computer-paced condition (M = 474 ms) was faster than the participant-paced condition (M = 487 ms).

Percentage of error. Overall PE was 2.68%. There was no mapping main effect ($F < 1$). The main effect of initiation was significant, $F(1, 94) = 13.67$, $p = .0004$, MSE = 36.068. Error rate was higher with participant pacing (3.40%) than with computer pacing (1.96%). There was also a bin main effect, $F(1, 94) = 11.46$, $p = .0001$, MSE = 5.920, and initiation condition interacted with bin, $F(1, 94) = 3.48$, $p = .0083$, MSE = 5.920. More errors were made at the fastest bin than at the other bins, for which the error rates did not differ significantly (PE = 3.67%, 2.40%, 2.47%, 2.12%, and 2.73% for Bins 1–5). The elevation of the error rate at the fastest bin was larger for the participant-paced condition (4.96% for Bin 1, 3.00% for Bins 2–5) than for the computer-paced condition (2.37% for Bin 1, 1.86% for Bins 2–5).

Discussion

RT was shorter with the up-right/down-left mapping than with the up-left/down-right mapping, regardless of initiation condition, and the bin analysis showed that this advantage increased in magnitude as RT increased, as in Adam et al.'s (1998) study. Unlike their results, the computer-paced condition showed an up-right/down-left advantage of similar magnitude to that of the participant-paced condition. Thus, the experiment provides no evidence to support the hypothesis that spatial codes are used when

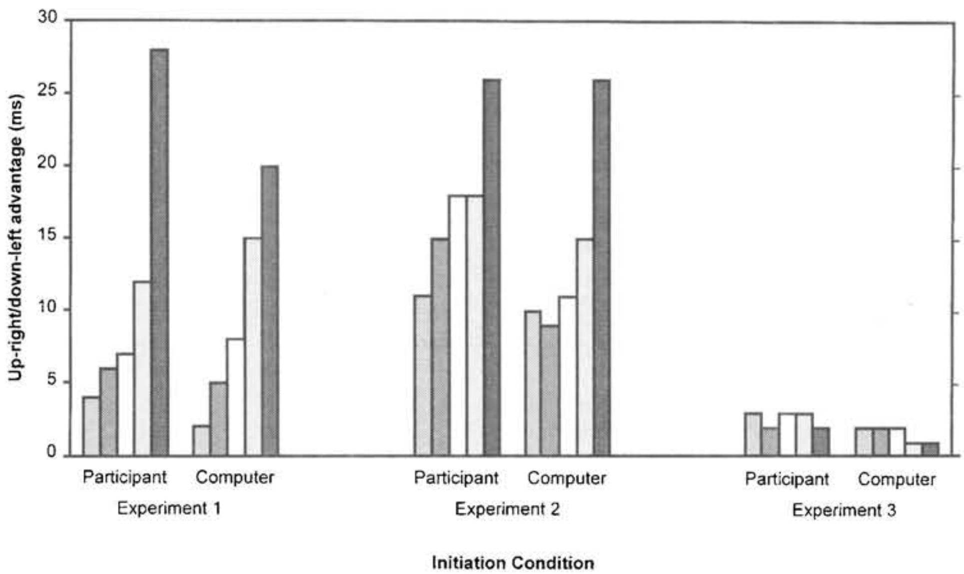

Figure 1. The up-right/down-left advantage as a function of reaction-time distribution bin and initiation condition in Experiments 1–3. For each initiation condition, the bars are ordered left-to-right from the first quintile to the fifth quintile.

presentation is computer paced and verbal codes when it is participant paced. It should be noted that the number of participants per condition in our experiment (48) was 4 times the number in their experiment (12), implying that the lack of significant effect of initiation condition on the up-right/down-left advantage in our experiment is not due to a lack of power.

Experiment 2

In Adam et al.'s (1998) Experiment 2, computer-paced and participant-paced initiation were again compared, with participants making vocal "left"–"right" responses to the vertically arranged stimuli in some trial blocks and keypress responses in other blocks. Experiment 2 also showed an interaction between mapping and initiation condition, although it only approached statistical significance ($p = .070$). Adam et al. described the main finding of the experiment as being "an up-right/down-left advantage that emerged only for participant-paced trials, not for computer-paced trials, and that was independent of response modality" (p. 1588).

Because we found no evidence that the up-right/down-left advantage was smaller with computer initiation than with participant initiation for keypresses in Experiment 1, we wanted to determine whether we could obtain any such evidence for vocal responses. Therefore, the main purpose of Experiment 2 was to replicate the vocal response condition of Adam et al.'s (1998) Experiment 2. With vocal responses, the mapping effect was examined under two initiation conditions, participant paced and computer paced.

Method

A total of 24 undergraduate students from the same participant pool as in Experiment 1 participated. The apparatus and procedure were similar to the previous experiment, with the exception that the participants made vocal "left"–"right" responses to vertically arrayed stimuli. Vocal responses were made into a microphone that was interfaced with the microcomputer through a MEL 2 response box.

As in Adam et al.'s (1998) Experiment 2, each participant performed with the two mapping conditions under two types of trial initiation. The order of the mapping and the initiation condition was counterbalanced across participants. Each participant performed 20 practice trials and 60 test trials for each mapping and type of trial initiation.

In the participant-paced condition, the word READY appeared in the center of the screen. To initiate each trial, the participant blew into the microphone, as in Adam et al.'s Experiment 2. After blowing into the microphone, the word READY was replaced by the fixation point "+" for 1 s. The stimulus was presented either above or below the fixation point. The stimulus and fixation point remained on until the participant responded. The next trial began 750 ms after the response. An incorrect response was followed by a 500-ms feedback tone, as in Experiment 1.

In the computer-paced condition, a trial began when the fixation point "+" appeared in center of the screen. The rest of the procedure was the same as in the other initiation condition.

Results

Of the trials, 0.82% were removed from analysis for being shorter than 125 ms or longer than 1,250 ms. An ANOVA was conducted on the RT and PE data, with the within-subject variables of mapping, bin, and initiation (see Table 1).

Reaction time. The main effect of mapping was significant, $F(1, 23) = 10.77$, $p = .0033$, $MSE = 2{,}874$. Responding was faster with the up-right/down-left mapping ($M = 415$ ms) than with the up-left/down-right mapping ($M = 431$ ms). The main effect of initiation condition was not significant ($F < 1$), indicating that mean RT for the participant-paced condition ($M = 421$ ms) was not reliably different from that for the computer-paced condition ($M = 426$ ms). It is important that the interaction between mapping and the initiation condition also was not significant ($F < 1$). As shown in Table 1, an 18-ms up-right/down-left advantage was found in the participant-paced condition and a 15-ms advantage in the computer-paced condition.

Bin interacted with mapping, $F(4, 92) = 2.59$, $p = .0419$, $MSE = 324$, and initiation condition, $F(4, 92) = 3.42$, $p = .0119$, $MSE = 421$. The former interaction reflects that the advantage for the up-right/down-left mapping increased with increasing RT in both initiation conditions (see Figure 1). The latter interaction reflects that RT was slower for the computer-initiation condition than for the participant-initiation condition in the fastest bin (*M*s = 331 ms and 319 ms, respectively), but faster in the slowest bin (*M*s = 545 ms and 552 ms for computer initiation and participant initiation, respectively), as in Experiment 1.

Percentage of error. PE was 1.00%. Only the Initiation × Bin interaction was significant, $F(4, 92) = 2.79$, $p = .0309$, $MSE = 5.792$. The interaction reflects primarily that the error rate was elevated in the first bin more for the participant-paced condition (1.74% for Bin 1 and 0.76% for Bins 2–5) than for the computer-paced condition (0.88% for Bin 1 and 0.84% for Bins 2–5).

Discussion

Experiment 2 showed an up-right/down-left advantage that was not affected by initiation condition. Mean RT was shorter with the up-right/down-left mapping than with the up-left/down-right mapping in the computer-paced condition as well as the participant-paced condition. Moreover, the changes in effect magnitude across RT bins were similar for the two initiation conditions. Thus, as with keypress responses in Experiment 1, there was no evidence of the up-right/down-left advantage varying in magnitude as a function of initiation condition.

On the surface, the results of our Experiment 2 seem inconsistent with Adam et al.'s (1998) description of the results of their Experiment 2, which was that, regardless of response modality (manual or vocal), the up-right/down-left advantage emerged only for participant-paced trials. However, Adam et al. based their conclusion solely on the absence of a statistically significant three-way interaction of mapping and initiation condition with response modality. The means for their vocal response conditions (see their Footnote 1) showed an up-right/down-left advantage of 5 ms for computer-paced initiation and 10 ms for participant-paced initiation. This difference of 5 ms between the up-right/down-left advantage for computer- and participant-paced trials is comparable in magnitude to the 3-ms difference we obtained. Therefore, although the conclusion that Adam et al. reached regarding the effect of initiation was different from ours, the results of the two experiments are quite similar.

Adam et al. (1998) predicted in the introduction to their Experiment 2 that "with the vocal response mode, the up-right/down-left preference should materialize for both short and long ITIs [the computer- and participant-paced conditions, respectively]" (p. 1587). Ironically, our conclusion that the up-right/down-left advantage for vocal responses is of similar magnitude for participant- and computer-paced trials conforms to this prediction but not to Adam et al.'s interpretation of their results. However, the up-right/down-left advantage averages only a little more than 10 ms across their experiment and ours, which is counter to another of their predictions, which was that use of vocal responses should enhance the up-right/down-left advantage.

Experiment 3

Adam et al. (1998) obtained shorter mean RTs in the computer-paced condition than in the participant-paced condition (a significant 25 ms difference in their Experiment 1 and a nonsignificant 10 ms, but only 3.5 ms for vocal responses, in their Experiment 2), whereas our results showed no significant difference. This discrepancy may be the crucial factor in the different outcomes for the up-right/down-left advantage obtained in the two studies, inasmuch as Adam et al. noted in their general discussion that the up-right/down-left advantage tends to be larger when responses are slower. In Experiment 3, we imposed a deadline of 450 ms to cause quicker responding in both the participant- and computer-paced conditions. If speed of responding is the crucial factor, there should be little or no up-right/down-left advantage when participants are encouraged to respond very quickly, as in this experiment.

Method

A total of 48 undergraduate students from the same participant pool as in Experiments 1 and 2 participated. One half of the participants were tested in the participant-paced condition and one half in the computer-paced condition. The method and procedure were similar to Experiment 1, except as noted. Participants were instructed that they had only 450 ms in which to respond. For any trial on which they had not responded by the deadline, a 500-Hz tone sounded and the trial was terminated. After each 100-trial block, feedback was provided regarding the mean RT for the block, the number of correct responses, and number of trials on which the deadline was exceeded. Emphasis was placed on continuing to try to beat the deadline on most trials.

Results

Of the trials, 0.42% were less than 125 ms and were removed from analysis. A response was not made within the 450-ms deadline on 2.92% of the trials, and an ANOVA that included mapping and initiation condition as factors showed no significant effects (*F*s < 1). Analyses of RT and PE for the remaining trials were conducted as in the previous experiments (see Table 1).

Reaction time. There was no main effect of mapping, $F(1, 46) = 1.29$, $p = .2624$, $MSE = 400$, with the RT being similar for the up-right/down-left mapping ($M = 288$ ms) and the up-left/down-right mapping ($M = 290$ ms). The initiation main effect was not significant, $F(1, 46) = 1.95$, $p = .1694$, $MSE = 3{,}835$, and there was no two-way interaction of initiation condition with mapping ($F < 1$). Neither the participant- nor computer-paced condition showed a significant up-right/down-left advantage in the mean data, the difference being 2 ms in both cases.

Other than the bin main effect, the only significant term involving bin was the Initiation × Bin interaction, $F(4, 148) = 2.65$, $p = .0349$, $MSE = 123$. The participant-paced condition was slightly faster than the computer-paced condition, with the difference increasing across bins (differences of 3, 5, 9, 11, and 12 ms for the first through fifth bins, respectively). Neither the Mapping × Bin interaction nor the three-way interaction of these variables with initiation condition was significant (*F*s < 1; see Figure 1).

Percentage of error. Overall PE was 3.65%. There was no mapping main effect or Mapping × Initiation Condition interaction (*F*s < 1). Responses tended to be less accurate overall in the participant-paced condition (PE = 4.21%) than in the computer-paced condition (3.10%), $F(1, 46) = 4.04$, $p = .0503$, $MSE = 37.372$). The bin main effect was also significant, $F(4, 184) = 5.51$, $p = .0003$, $MSE = 8.739$. The error rate was highest at the first bin and did not differ reliably across the other four bins (4.83% for Bin 1 and 3.35% for Bins 2–5).

Discussion

As in Experiments 1 and 2, there was no difference in the mapping effect for computer- and participant-paced conditions. However, unlike the previous experiments, which did not use a deadline procedure, no significant mapping effect was evident for either initiation condition. This outcome, along with those of Experiments 1 and 2, is inconsistent with Adam et al.'s (1998) claim that participant pacing leads to different results than does computer pacing, but it is consistent with the implication of the dual-coding hypothesis that speed of responding is of importance. According to the dual-strategy hypothesis, the absence of the mapping effect in this experiment indicates that participants relied on spatial or visual codes, in contrast to verbal codes. A similar interpretation, which we prefer, is that participants relied on what Kosslyn (1994) calls *coordinate spatial representations,* as opposed to categorical spatial codes.

General Discussion

Our experiments show no evidence that the up-right/down-left advantage occurs only when trials are participant paced. In each of the three experiments, two of which showed an up-right/down-left advantage (Experiments 1 and 2) and one of which did not (Experiment 3), there was no significant difference in the magnitude of the advantage between the two initiation conditions. Adam et al. (1998) initially hypothesized that computer pacing versus participant pacing would promote a verbal coding strategy because the ITI was longer in the participant-paced condition than in the computer-paced condition. They rejected this reasoning because the results of their Experiment 3 showed no effect of ITI on the up-right/down-left advantage for computer-paced presentation. Consequently, Adam et al. concluded, "In Experiments 1 and 2, the requirement to actively initiate the trial was the crucial mediating factor in the up-right/down-left advantage" (p. 1589). The conclusion that trial initiation mediates use of verbal coding is paradoxical because their Experiment 3 in fact showed an up-right/down-left advantage with computer-paced presentation in the both the RT and error data. Our experiments also provide no evidence that an initiating action is necessary to obtain the up-right/down-left advantage because the advantage was of similar magnitude for both computer- and participant-paced conditions.

Another factor that Adam et al. (1998) suggested was crucial to the up-right/down-left advantage is response speed, with the advantage increasing as responding becomes slower. Our results do support the hypothesis that response speed is a crucial factor because the up-right/down-left advantage was not evident when participants were required to respond within a deadline that reduced mean RT by approximately 50 ms. Moreover, the response speed factor provides a resolution to the discrepancy between Adam et al.'s results showing a difference between participant- and computer-paced conditions and our results showing no difference. For unknown reasons, their participants tended to respond quicker in the computer-paced conditions than in the participant-paced conditions, whereas ours did not. Thus, with procedures of the type used in our three experiments and in their Experiments 1–3, whether the trials are initiated by the participant or the computer does not seem to matter, but how fast the participants respond does.

If the crucial factor determining whether an up-right/down-left advantage occurs is how quickly the participants respond, one would expect a positive correlation between mean RT and the magnitude of the up-right/down-left advantage across experiments. Table 2 shows the overall mean RT and size of the up-right/down-left advantage for experiments that used physical location stimuli and keypress responses with the left and right index fingers. Only conditions were included that did not have additional visual stimuli that could have provided a frame of reference with respect to which the stimulus locations could have been coded as left or right. The data yield a Pearson r of .56 ($p = .028$), when all studies are included. One could question whether the crossed hands condition of Weeks and Proctor (1990), which yielded the slowest responses and the largest advantage, should be included as it is not a typical hand placement. With that condition excluded, the correlation is still positive (.32), although it is not statistically significant ($p = .27$). On the whole, these analyses provide additional evidence that speed of responding is crucial, although they must be taken with caution because many extraneous factors may influence RT across

Table 2
Overall Mean Reaction Times (RTs) and Magnitude of the Up-Right/Down-Left Advantage (in Milliseconds) With Keypress Responses in Relevant Published Experiments

Study	Condition	Overall mean RT	Up-right/ down-left advantage
Adam et al. (1998)			
Experiment 1	Computer paced	333	−11
	Participant paced	358	17
Experiment 2	Computer paced	348	−11
	Participant paced	363	12
Experiment 3	Three ITIs	360	7
Dutta & Proctor (1992)			
Experiment 2	First session	359	32
Ladavas (1987)[a]			
Experiment 1	Right-handed	328	28
Present study			
Experiment 1	Computer paced	342	11
	Participant paced	338	12
Experiment 3	Computer paced	293	2
	Participant paced	285	2
Proctor & Pick (1999)			
Experiment 4	Circle control	338	11
Proctor, Wang, & Vu (2000)			
Experiment 1	Spatial-manual	361	18
Weeks & Proctor (1990)			
Experiment 2	Uncrossed hands	421	25
	Crossed hands	447	56

Note. The participants in most studies were predominantly right-handed, either because participation was restricted to right-handers or, if not, because right-handers predominate in the population.
[a] The left-handed group in Ladavas's (1987) study was excluded because they showed the opposite mapping preference. ITI = intertrial interval.

experiments and the number of experiments is relatively small. The relation between response speed and the up-right/down-left advantage could be a function of an increasing likelihood within a given trial that an asymmetric stimulus code will be generated before response selection is completed. However, the absence of an up-right/down-left advantage when a response deadline was imposed in Experiment 3 suggests that the relation may arise from a mixture of strategies that different participants adopt.

The fact that the up-right/down-left advantage is not evident when mean RT is short but is evident when mean RT is long is consistent with the dual-strategy hypothesis. Because verbal coding takes time, slower responding is associated with increased use of a verbal coding strategy. Adam et al. (1998) cited their RT distribution bin analyses as additional evidence for the dual-strategy hypothesis. Specifically, for the participant-paced conditions in their study, the magnitude of the up-right/down-left advantage increased as RT increased. Both the participant- and computer-paced conditions of our experiments, which yielded the up-right/down-left advantage, also showed the advantage to increase across RT bins.

However, this pattern for the RT bins must be interpreted with caution because it seems to be a general characteristic of S-R mapping effects for relevant stimulus dimensions to responses and not to be an indicator of reliance on asymmetric verbal codes. De Jong et al. (1994, Experiment 1) varied the mapping of stimulus color (red or green) to response keys that were labeled according to color (red or green). The advantage for the compatible color mapping increased across bins for all three of the labeling conditions they examined, with the increase in advantage for the compatible mapping over the incompatible mapping from Bin 1 to Bin 5 averaging approximately 60 ms. Similarly, Roswarski and Proctor (1996, Experiment 4) found the advantage for a spatially compatible mapping over an incompatible mapping in a two-choice task in which the S-R sets varied along parallel, horizontal orientations to increase from approximately 40 ms in Bin 1 to 170 ms in Bin 5. As Umiltà (1991) noted, "With parallel S-R sets, . . . spatial S-R compatibility effects appear to be based on codes that are purely spatial in nature" (p. 85). In both De Jong et al.'s and Roswarski and Proctor's studies, the larger effect magnitude for slower RTs cannot be attributed to a strategy of using asymmetric verbal codes when response latencies are longer because the dimensions along which the stimuli and responses differ are parallel and not orthogonal. Thus, the distribution analyses for the up-right/down-left advantage cannot be taken as strong evidence for a shift across time from a symmetric spatial code to an asymmetric verbal code.

In summary, Adam et al. (1998) concluded that the need to initiate the trial was the critical factor inducing verbal coding and, hence, the up-right/down-left advantage. Our data provide no support for this conclusion. In each of the three experiments, we found no difference between participant- and computer-paced initiation conditions. Rather than type of initiation being the critical factor, our results imply that response speed is crucial. The up-right/down-left advantage was eliminated for both initiation conditions when a response deadline was imposed. The reduction of the up-right/down-left advantage when mean RT is short is consistent with an implication of the dual-strategy hypothesis that verbal coding should be less likely when responding is fast than when it is slow. Therefore, the present experiments provide no evidence against the dual-strategy hypothesis. However, several other predictions derived from the dual-strategy hypothesis that would more directly implicate verbal coding have been disconfirmed, and in a companion article (Cho & Proctor, 2001, this issue), we provide evidence that the up-right/down-left advantage is systematically influenced by whether the initiating action is left or right, an outcome that seems difficult to reconcile with the hypothesis. Thus, current evidence suggests a shift from symmetric spatial codes to asymmetric codes across time, as the dual-strategy hypothesis implies, but the asymmetric coding most likely does not reflect the fixed linguistic properties of verbal codes.

References

Adam, J. J., Boon, B., Paas, F. G. W. C., & Umiltà, C. (1998). The up-right/down-left advantage for vertically oriented stimuli and horizontally oriented responses: A dual-strategy hypothesis. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1582–1597.

Cho, Y. S., & Proctor, R. W. (2001). Effect of an initiating action on the up-right/down-left advantage for vertically arrayed stimuli and horizontally arrayed responses. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 472–484.

De Jong, R., Liang, C-C., & Lauber, E. (1994). Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus–response correspondence. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 731–750.

Dutta, A., & Proctor, R. W. (1992). Persistence of stimulus–response compatibility effects with extended practice. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 801–809.

Kosslyn, S. M. (1994). *Image and brain: the resolution of the imagery debate.* Cambridge, MA: MIT Press.

Ladavas, E. (1987). Influence of handedness on spatial compatibility effects with perpendicular arrangement of stimuli and responses. *Acta Psychologica, 64,* 13–23.

Proctor, R. W., & Pick, D. F. (1999). Deconstructing Marilyn: Robust effects of face contexts on stimulus–response compatibility. *Memory & Cognition, 27,* 986–995.

Proctor, R. W., Wang, H., & Vu, K.-P. L. (2000). *Influences of conceptual, perceptual, and structural similarity on stimulus–response compatibility.* Manuscript submitted for publication.

Roswarski, T. E., & Proctor, R. W. (1996). Multiple spatial codes and temporal overlap in choice-reaction tasks. *Psychological Research, 59,* 196–211.

Schneider, W. (1995). Micro Experimental Laboratory (Version 2.0) [Computer Software]. Pittsburgh, PA: Psychology Software Tools.

Umiltà, C. (1991). Problems of the salient-feature coding hypothesis: Comment on Weeks and Proctor. *Journal of Experimental Psychology: General, 120,* 83–86.

Weeks, D. J., & Proctor, R. W. (1990). Salient-feature coding in the translation between orthogonal stimulus and response dimensions. *Journal of Experimental Psychology: General, 119,* 355–366.

Received April 9, 2000
Revision received July 6, 2000
Accepted July 31, 2000 ■