ASYMMETRIES IN HAND MOVEMENT DURING BLOCK DESIGN CONSTRUCTION

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Abstract—Changes in patterns of hand use were examined as a function of task demand characteristics. Using blocks, right- and left-handed male and female subjects were asked to simultaneously construct two replicas of presented patterns, one with each hand. With the presentation of visual-spatial patterns, a shift toward use of the left hand from baseline was observed. This change was least evident among right-handed females. The observed shift in hand use toward the left on a visuo-constructive block design task might suggest differential involvement of the right hemisphere with changes in task demand characteristics.

INTRODUCTION

Clearly, the two cerebral hemispheres in humans are not functionally identical. Generally, the left hemisphere in most humans is considered dominant in the processing of language functions, while the right hemisphere predominates in the processing of various spatial functions. While this functional asymmetry has been observed in the auditory (via dichotic listening), visual (tachistoscopic presentations), and somatosensory (dichaptic stimulation) modalities, the extent to which this asymmetry is manifested in active movements of the hands has been less well explored.

In examining the influence of cognitive processing on manual performance, the dual task approach has been commonly utilized by investigators. For instance subjects have been asked to perform prescribed manual movements such as dowel-balancing or finger tapping [13] while simultaneously engaged in other activities. In right-handed subjects, concurrent verbalization selectively disrupted right-handed dowel-balancing [9, 11] and right-handed performance on a manual sequencing task [14, 15]. Attempts to demonstrate interference with left-hand performance have produced largely equivocal findings. However, Heilige and Longsteth [8] and Kee et al. [10] report selective left hand reduction in unimanual finger tapping speed when subjects were asked to simultaneously solve a spatial problem.

A second and less frequently used approach is the examination of spontaneous hand movements while the subject is involved in other activities (e.g. speaking). Hampson and Kimura [6] found during performance of block manipulation tasks, that the frequency of left- or right-handed movements changed systematically with the cognitive nature of the task. Thus, during a verbal task, a greater proportion of right-hand use was observed during active block manipulation in right-handers relative to baseline; while during nonverbal tasks, a

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greater proportion of relative left-hand use was observed. The present investigation was
designed to further evaluate the relationship between presumably lateralized cognitive
functioning and relative hand movements. More specifically, the present study examined
whether hand-use in a visuo-constructive task would be modulated by activation of
"specialized cognitive capacities" which are thought to be most dependent on right cerebral
hemisphere functioning. To this end, we asked subjects to simultaneously construct two
replicas of a block design, one with each hand. Based on the findings of HAMPSON and
KIMURA [6], we hypothesized that activation of specialized capacities of the right cerebral
hemisphere would have a facilitatory effect on movements of the contralateral hand. In
addition, because of known influences of both handedness and gender on functional cerebral
organization [7], these factors were included in the present investigation.

METHOD

Subjects were 43 male and 44 female undergraduates from the State University of New York at Binghamton. The
subjects were recruited from the Introductory Psychology courses in partial fulfillment of the requirement for
research credit. Because of the unequal distribution of handedness in the general population, and our intent to
represent the entire range of handedness in this study, selective recruitment was necessary to obtain subjects in all
handedness groups except for the group we defined as clearly Right (see below). The present investigation was
performed as part of a larger study on lateral dominance and neuropsychological performance [4]. Subjects were
not explicitly told of the specific purpose of the present study concerning relative hand use, but did know their hands
were videotaped during block construction.

Apparatus and stimulus material

Eight blocks from the Block Design subtest of the WAIS-R [22] were used to construct designs from printed
pictures. The Block Design task was chosen because: (1) it has been shown to involve more right than left hemisphere
processing in studies of brain damaged patients [e.g. 21]; (2) the vast superiority of the right hemisphere in split-
brain subjects on this task [e.g. 5]; and (3) greater alpha rhythm disruption over the right hemisphere during block
design construction in normal subjects [e.g. 23]. The stimulus material consisted of four separate red and white
designs, bound into a booklet for presentation to the subject. These four designs are presented in Fig. 1. The
difficulty level of the four designs was equated along two stimulus dimensions: (1) "task uncertainty" a measure of
information provided by the stimulus; and (2) "perceptual cohesiveness" a measure of the "Gestalt quality" of the
design. Royer et al. have argued that the difficulty level (i.e. construction time) of a design is a direct function of these
two stimulus parameters [17, 18, 19]. Thus, in the present investigation these two variables were held constant
across the four designs. Designs were chosen which had task uncertainty values of eight bits and perceptual
cohesiveness values of four bits for a four-block (2 x 2 squares) arrangement [see 19 for details concerning these two
stimulus variables]. Further, two of the designs were symmetrical (about the vertical axis) and two were vertically
asymmetrical (Fig. 1).

Fig. 1. Designs used in the present study. "Task uncertainty" value was 8 and "perceptual
cohesiveness" value was 4 for each design.
PROCEDURE

Subjects (Ss) were tested in a well-lit room, seated across from the experimenter. Hand movements were monitored with a Sanyo video camera (model VC 1600X), mounted on a tripod next to the testing table. The camera was focused on the Ss hands to record the block design construction sequence. An RCA video cassette recorder (model VET 650) and a black and white television were located in an adjacent room and served to record and subsequently view the Ss block construction.

Handedness was determined by a variant of the laterality examination commonly administered as part of the Halstead-Reitan neuropsychological test battery (HRNTB). In addition to the seven items on the HRNTB (throw a ball, hammer a nail, cut with knife, turn a door knob, use scissors, use an eraser, write their name), each S was asked to demonstrate how they would perform three additional activities commonly employed in other handedness examinations: sweep, draw and brush teeth. Based on their response, Ss were placed into one of four hand preference groups for each sex: clearly Right (cR) group if all tasks on the laterality exam were performed with the right hand; leaning Right (IR) group if the right hand was used most often in performing the tasks; the leaning Left (IL) group if the left hand was used most often; and the clearly left (CL) condition if Ss used the left hand to perform all the tasks on the exam. These four handedness groups were utilized since other work in our laboratory has demonstrated differences among these groups on measures of block design performance [4]. Further, differences in functional cerebral lateralization among these four handedness groups have been reported previously [20].

Simultaneous block design

Ss were told that during the session the video camera would record their hand movements during block construction. Ss were instructed to construct simultaneously two copies, one with each hand, of designs from printed pictures. Each copy required the manipulation of four blocks. The first construction was used as a measure of baseline performance. The plain white surfaces of the blocks facing upward (analogous to the procedure utilized by Hampson and Kimura [6]), the blocks were presented vertically, about 1 in. apart with four blocks per hand, and placed equidistant laterally from midline in front of each hand. The Ss were instructed to produce simultaneously two white squares from the two sets of blocks presented. Following the baseline task, both sets of blocks were scrambled and Ss were asked to make two simultaneous copies of the four patterns. After the four stimulus tasks were completed, two additional baseline trials were presented to each S. These additional baseline trials were included as a further check on relative hand use. Since no differences were observed in relative hand use among the three baseline trials, they were collapsed into a single baseline score (see below). Throughout testing, the experimenter recorded the latency to correctly complete the two copies of each design.

Following testing, the Ss were asked: (1) which hand they believed they used primarily in constructing the four designs; (2) which design they found to be most difficult; and (3) to rate on a scale of 1-7 where 1 indicated easy and 7 most difficult, the difficulty of each design.

Behavioral observations and coding

After the test session was completed, the video tape was examined by an observer (the same observer was used for all Ss). From the tape, the observer scored hand movements during block placement as well as the pattern used (see below) in constructing each design.

Although Ss were asked to make two simultaneous copies of the design, the task was sufficiently difficult that typically one hand was slightly faster than the other in placing blocks. As such, review of the video tape allowed for the derivation of a “leading hand” score for each design. This was accomplished by examining block placement at homologous cell quadrants in each of the 2 x 2 arrangements (e.g. upper left quadrant of each construction) and determining which hand was faster in making each homologous placement. If the left hand was faster at any block homologue, a score of negative one (-1) was given, while if the right hand had lead, it would receive a positive one (+1). The four homologous position scores were then summed resulting in an overall “leading hand” score for each design, with a negative score indicating a left hand lead and a positive score indicating a right hand lead.

Although there are many different combinations that can be used by Ss in constructing the two simultaneous designs, recurrent patterns or “strategies” in construction were identified. The “position” strategy consisted of same quadrant placements in each of the two designs (e.g. upper left of each) while the “mirror” strategy consisted of making opposite quadrant placements (e.g. upper left of one arrangement and upper right of the other). Either the position or mirror strategy was used in about 70% of all designs constructed. As a result, in the present study the Ss strategy in performing each of the design tasks were coded as either a position, mirror or other strategy.

RESULTS

Hand use

To analyze the hypothesized task related shift in hand use, mean leading hand scores were calculated for both the baseline and stimulus task conditions, yielding a composite leading
hand score. That is for each S, the average of the four stimulus tasks "leading-hand" scores were calculated resulting in the composite leading hand score for the stimulus tasks. Similarly, a composite score was obtained for each S by taking the mean of the three baseline leading-hand scores.

The data on hand use were analyzed by a $2 \times 4 \times 2$ (sex × laterality group × task) ANOVA on S's composite scores, with sex and laterality group as the between group factors and task (baseline composite and stimulus composite) as the within-group factor. The hand use data for the baseline and stimulus tasks are presented in Fig. 2.

![Fig. 2. Lateral shifts in hand use for block manipulation. CL=clearly left, LL=leaning left, LR=leaning right, CR=clearly right.](image)

Not unexpectedly, left-handed S's showed a slight preference favoring the left-hand during baseline while right-handers displayed a slight right-hand preference (laterality group M.E.: $F(3, 79) = 4.45, P < 0.006$). No sex differences in baseline performance were observed.

Relative hand usage changed significantly from the baseline to stimulus task conditions (task M.E.: $F(1, 79) = 31.64, P < 0.001$). All groups displayed a task-related shift toward increased left-hand leading during the stimulus task condition relative to baseline. Further, this increase in left-hand leading was observed in 71% of all S's tested (i.e. 62 of 87), with no statistically significant differences across sex or laterality group conditions.

While no effects involving gender were observed in the overall ANOVA, several a priori planned comparisons were analyzed based on the interactions between sex and handedness commonly reported in the cerebral laterality literature concerning spatial ability [cf. 7]. Thus, the first analysis was designed to examine task-related shifts in hand use among the two right-handed groups (i.e. cR and cL) of both sexes. These data were analyzed by a $2 \times 2 \times 2$ (sex × laterality group × task) repeated measures ANOVA with task as the within-group factor. All groups exhibited a task-related shift toward increased left-hand utilization during stimulus task manipulation relative to baseline (task M.E.: $F(1, 41) = 12.86, P < 0.001$). However, as illustrated in Fig. 2, this relative shift was only significant in males (task × sex: $F(1, 41) = 5.15, P < 0.027$). A similar analysis was conducted on the two left-handed groups (i.e., cL and 1L). A task-related shift toward left hand leading also was observed in cL and IL group (task M.E.: $F(1, 38) = 18.54, P < 0.001$). However, among the left-handers, no effects involving gender or laterality group were significant.
The latency to complete each design was analyzed by a $2 \times 4 \times 2$ repeated measures ANOVA on sex and laterality group as between-group factors and task as within-group factor. As expected, subjects took significantly longer to complete the stimulus tasks (mean = 37.6 sec) relative to baseline (mean = 7.2 sec).

Despite the fact that all four stimulus tasks were equated for difficulty [cf. 18, 19], S's across groups took significantly less time to complete the first symmetrical design than the other three designs (task M.E.: $F(3, 237) = 31.89$, $P < 0.001$). These differences in latency across the four stimulus tasks suggest, contrary to Royer's contention, that the four tasks actually did differ in level of difficulty. Thus, while task uncertainty and perceptual cohesiveness may be important determinants of task difficulty in block design construction, they are clearly not the only determinants.

While there were no differences across groups in accuracy of stimulus task performance (i.e. all S's were able to construct the designs), females on average (mean = 41.5 sec), took somewhat longer than males (mean = 34.8 sec) to complete the tasks, although the differences did not reach statistical significance (sex main effect: $F(1, 79) = 2.54$, $P < 0.11$). These data are presented in Fig. 3. However, this trend toward a sex difference in latency to complete the tasks was most evident for the two designs classified as asymmetrical (sex x task interaction: $F(3, 237) = 2.95$, $P < 0.032$).

**Questionnaire responses**

When asked which hand was used primarily in simultaneously constructing the stimulus designs, 50% of the right-handed males, but only 23% of the right-handed females indicated a left-handed preference. Thus, this sex difference in subjective interpretation of primary hand use corroborates the leading hand data observed during active block manipulation (i.e. a significant task-related shift in hand use only in right-handed males but not in right-handed females). Among the left-handed groups, the already large left-hand preference remained large, with 88% of males and 83% of females reporting left-hand preferences during simultaneous task manipulation.

When S's were asked to rate the difficulty of each of the stimulus designs, the first
symmetrical design was perceived to be the easiest of the four. That is, only 5% of S’s rated this first design to be the most difficult while the other three designs were rated as equally difficult (range = 28 to 34%). The mean subjective difficulty rating (1 easiest and 7 most difficult), for the first symmetrical design was 2.4 while the other three designs were rated at 4.5 or 4.6 in perceived difficulty. Thus, these results on subjective stimulus design difficulty are consistent with the latency data indicating that the four stimulus designs were not equally difficult.

**Cognitive strategy**

The frequency of Ss using the position, mirror, or other strategy were tabulated and analyzed separately for both the baseline and stimulus task conditions. During baseline construction, Ss utilized a mirror strategy roughly one-half of the time, across sex and laterality groups. The position and other strategies were used 11 and 39.6% of the time, respectively, during baseline construction. During the stimulus-task condition, an apparent shift in strategy from that utilized during the baseline condition was observed ($\chi^2$ (7 d.f.) = 188.4, $P < 0.001$). Over one-half of all S’s (i.e. 58%) used a position strategy to solve the four stimulus designs compared to only 11% during baseline. The mirror strategy was used 18% of the time during the stimulus task condition.

Interestingly, different stimulus designs elicited different strategies in solving the block design problem. For instance, when a mirror strategy was used, it was used almost exclusively in solving symmetrical designs ($\chi^2$ (7 d.f.) = 55.2, $P < 0.001$). Thus, it is apparent that not only may S’s utilize their own strategy in problem solving during a block design task, but the stimulus characteristics of the designs themselves (e.g. symmetry vs asymmetry) also influence strategy utilization. This effect of stimulus characteristics on performance is consistent with previous observations in our laboratory concerning block design construction [4].

**DISCUSSION**

Simultaneous, bilateral presentation of verbal or “nonverbal” stimuli to either the auditory [1], verbal [2], or tactile [3] sensory systems result in better performance (i.e. speed, accuracy) in the sensory channel contralateral to the presumably specialized cerebral hemisphere. Thus, for instance, human right-handers process verbal information better when it is presented to the right ear or right visual-half field (i.e. left hemisphere), while visual–spatial information is processed more efficiently when presented to the left ear or left visual-half field (i.e. right hemisphere) [1, 2]. Far fewer studies have examined the effects of the nature of cognitive task demands on spontaneous manual movement [cf. 6]. The results of the present investigation show that during simultaneous, bilateral manual manipulation of a visuo-constructive task, an asymmetric pattern of relative hand movements can be observed depending on the cognitive demands of the task. Specifically, when required to construct copies of a block design simultaneously with each hand, male subjects displayed an increase in left-hand “leading” relative to baseline performance. These results are consistent with the work of HAMPSON and KIMURA [6] who reported systematic changes in the asymmetry of spontaneous hand movements during verbal and spatial tasks among right-handers (i.e. verbal tasks elicited a greater proportion of right-hand use while spatial tasks elicited a relatively greater proportion of left-hand use). Thus, the present results are
consistent with the hypothesis that hand use preference on a visuo-constructive task can be modulated by activation of specialized cognitive systems which are thought to be most dependent on right-hemisphere functioning.

Unlike the findings of Hampson and Kimura [6], in the present study female right-handers did not show a significant task related shift toward increased left-hand utilization during the spatial task compared to baseline. The differences between males and females in the magnitude of shifts in hand use in this study is consistent with the hypothesized sex differences in the cerebral lateralization of verbal and spatial functions [16]. However, the fact that sex differences in hand use were not observed among left-handed S's (i.e. both males and females displayed increased left-hand leading) indicates that sex differences in performance need to be qualified by considering interactions with handedness [cf. 7].

The results of the present study suggest that the nature of the cognitive processes required by the task demands can significantly affect which hand leads in bimanual construction. This interpretation is compatible with Kinsbourne's [12] attentional model of "priming" through task demand characteristics. The present results are also consistent with the interpretation outlined by Hampson and Kimura [6] that the observed task-related shift in hand use "reflects the engagement of lateralized problem solving systems within the two cerebral hemispheres" (p. 119). One way to test this hypothesis is to employ the paradigm outlined in the present study (i.e., simultaneous, bilateral block design) utilizing a verbal task. Thus, if the Hampson and Kimura hypothesis is the mechanism responsible, a verbal task should result in a shift toward increased utilization of the right-hand relative to baseline due to selective engagement of the left hemisphere. Such an experiment is currently underway in our laboratory.

It should be noted that the actual difference in performance between the two hands was small and subtle. Such subtle, but statistically significant difference between the hands is not surprising, however, if one examines the laterality literature using normal subjects. Results from dichotic listening tachistoscopic presentations, and dichaptic stimulation studies all typically yield results which are subtle, yet significant. Unfortunately, the subtlety of observed laterality effects in normal subjects is too often lost in the literature.

Although verbal stimuli reliably show a right-ear advantage [1] or right-field advantage [2], spatial tasks (e.g. geometric forms or drawings) are more variable with respect to lateralized effects. While attempts to develop measures of right hemisphere performance have been inconsistent and frustrating [1, 2], the simultaneous block design task appears to be a fruitful paradigm with which to further explore the nature of cerebral lateralization and its expression.

REFERENCES


