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FORM AND NUMBER PROCESSING OF DOT PATTERNS IN THE DIVIDED VISUAL FIELDS: DIFFERENTIAL EFFECTS ON RESPONSE LATENCY, ACCURACY, AND CONFIDENCE RATINGS

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DIFFERENTIAL EFFECTS ON RESPONSE LATENCY, ACCURACY,
AND CONFIDENCE RATINGS.

by

MICHAEL J. MIKITISH

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1985

This manuscript has been read and accepted by the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

Jan. 18, 1985
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Abstract

FORM AND NUMBER PROCESSING OF DOT PATTERNS IN THE DIVIDED VISUAL FIELDS: DIFFERENTIAL EFFECTS ON RESPONSE LATENCY, ACCURACY, AND CONFIDENCE RATINGS.

by

Michael J. Mikitish

Advisor: Dr. Mitchell L. Kietzman

Visual processing was studied in a same-different discrimination task that used identical stimuli to test the effects of three distinct procedural tasks: (1) discrimination based on the number of dots (a blocked presentation condition); (2) discrimination based on the form produced by the dots (a blocked presentation condition); and (3) discrimination based on either the number or the form of the dots (a mixed presentation condition in which the subject could use both number and form). The stimuli were dot patterns consisting of 4, 5, or 6 dots. The dots were arranged to form one of four geometric figures and were tachistoscopically presented randomly and sequentially in pairs. The first pattern of the pair was presented to the central visual field and the second pattern to either the right or left visual field. The subject manually responded same or different to the pair of stimuli based on the number of dots and/or the geometric dot form. The subjects also indicated verbally the number and/or form of the dots in the second pattern and provided a confidence rating on the subjective accuracy of their verbal response. Dependent variables were manual accuracy and latency, verbal report accuracy, and confidence ratings.

The results showed that form processing was faster and more accurate than number processing in both the blocked and mixed presentations. However, the differences between number and form processing were found to depend upon the number of dots in the second pattern of a pair. Significant differences between number and form processing were only obtained when the number of dots in the second pattern was five or six. In addition, the results revealed that irrelevant information can interfere with the processing of relevant information. For example, the nonequivalent-numbered pairs were associated with lower manual accuracy in the blocked form task, and the nonequivalent-form pairs were associated with lower manual and verbal accuracy in the blocked number task. Finally, the results demonstrated that hemispheric differences in visual processing depend not only on the stimulus characteristics but also on the task demands given to the subject. For example, in both the blocked number and the mixed form and number tasks, a shift in visual field advantage from left to right for both manual and verbal accuracy was found as the number of dots in the second pattern increased from four to six. On the other hand, in the blocked form task, a shift in visual field advantage from right to left was noted as the number of dots in the second pattern increased from four to six. Of the dependent variables tested, verbal report accuracy was the one that was most sensitive to hemispheric differences.

I would like to thank my thesis sponsor, Professor Mitchell L. Kietzman for his advice, criticism, and suggestions.

I also wish to thank Professors Wilfred Gibson, James Tweedy, and Robert Zenhausern for their useful recommendations.

Finally, I would like to thank my patient and understanding wife, Rosa Maria, for helping me persevere. Without her, this research would have taken considerably longer to complete.

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CHAPTER 1

INTRODUCTION

General Introduction

Three models have been postulated to account for the order in which a visual stimulus with multiple features is processed. These are: first, the "bottom-up" sequence (Hubel & Weisel, 1968; Ward & Wexler, 1976; Selfridge, 1959); second, the "top-down" sequence (Lockhead & King, 1977; Navon, 1977, 1981; Pomerantz, Sager, & Stoever, 1977); and third, the "middle-out" sequence, in which processing of features is initiated at some sort of intermediate level first, followed by processing of both progressively higher and lower levels (Kinchla & Wolfe, 1979; Prinzmetal, 1981). (Each of these models is described in more detail beginning on page 6).

One way in which the three types of ordered processing have been studied is through the manipulation of task demands with a single set of stimuli. For example, many studies (Kinchla & Wolfe, 1979; Martin, 1977; Navon, 1977) have used the Stroop-type letter stimulus (Figure 1). This stimulus consists of a large letter made up of smaller letters that is presented to the subject to which he must identify the large letter (global processing task) or the small letters (local processing task). In general, the large letter is identified faster and more accurately than the small letters, suggesting that there is a "top-down" order to visual processing.

Several experiments (Alivisatos & Wilding, 1982; Boer &

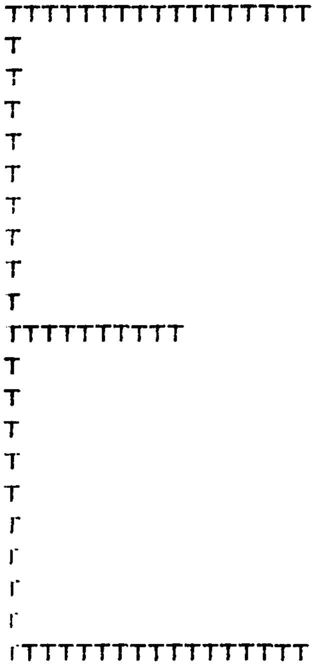


Figure 1. Stroop-type letter (Navon, 1977).

Keuss, 1979; Martin, 1979) have also used the Stroop-type letter task to investigate hemispheric differences in the order of visual processing. In general, visual information has been found to be processed in a "top-down" sequence in the left visual field (LVF) and in a "bottom-up" sequence in the right visual field (RVF). While the above results are important in distinquishing the processing advantages of the left and right hemispheres, they are by no means conclusive for all stimuli. Letter stimuli represent a finite set of visual patterns that are overlearned and appear in high contrast to their visual surround. It is possible that different results for hemispheric processing advantages would be obtained if other stimuli were used.

The first purpose of this thesis was to determine the order of visual processing using nonlettered stimuli. This was achieved by presenting a set of nonlettered stimuli under task demands that foster either global or local processing. The second purpose of this thesis was to clarify the issue of cerebral hemispheric differences in visual processing. This was achieved by presenting the same nonlettered stimuli to the right or left visual fields under conditions that varied task demands. In order to facilitate an understanding of this study and the findings obtained, the following report was organized so that the introduction, method, results, and discussion sections are divided into two parts. The first part deals simply with the issue of the order of visual processing. The second part deals with the issue of hemispheric differences in visual processing.

The Order of Visual Processing

Aristotle stated that the physical world consisted of a hierarchy of form and matter (in this case, constituent parts). A form was constituted from the forms of the lower levels (parts) and in turn, the parts were made up of even lower level parts. Most of the natural sciences, such as chemistry, biology, and physics all take this principle as a given. Recently, it has been used to characterize the visual world (Martindale, 1981).

Figure 2 is an example of a visual scene composed of two hierachial levels. Focus particularly on the large form (the square) made up of the small dots. In the figure, the dots are the elements of the large form but they are not the features of the large form in the sense that the angles between lines forming the sides of an ordinary square would be. Features are usually defined as an attribute or relationship between elements that is useful in distinquishing the form from other forms (Ward, 1982). An element is simply a constituent; it may be a feature but need not be. Thus the features of the square created by the four small dots might be, for example, the equal distance between the dots located along the horizontal or vertical axes and the intersection of the dots on the horizontal and vertical axes at right angles. The above stated features are global features. The features of the dots themselves include their circular nature and their small size. These are local features. These are, of course, relative definitions. For example, the square itself is an element making up the features on the page.

The global-local distinction. What is meant by the global-

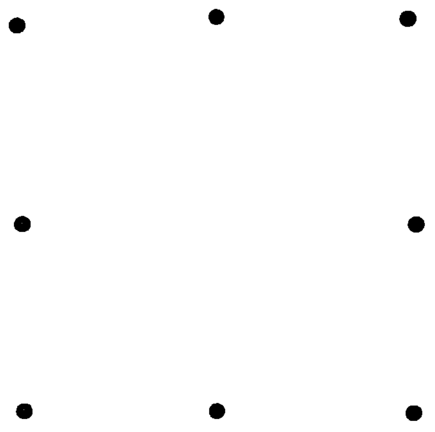


Figure 2. An 8-dot square.

local distinction is rather obvious in everyday language. The concept of spatial frequency can provide a more formal defintion. Campbell (1974) suggests that visual forms can be described as a mixture of different spatial frequencies. A way of eliminating high spatial frequencies is to defocus the image. For example, the image from a projector can be easily defocused. Local or detailed information contained in the high frequncies is lost, while gross, global shapes contained in the low spatial frequencies are perserved. If the image in Figure 2 was presented defocused by a slide projector on a screen, the observer would be able to make out the overall shape of the figure (square) but would have difficulty reporting whether the elements forming the square were dots, small square, triangles, and so on. Thus, the local features, such as the circular nature of the dot, would be lost to blurring before global features.

The order of visual processing. The various components of a pattern are probably not processed equally fast. Patterns that are closer to the fovea, familiar, simpler, more distinctive, or expected are probably recognized more rapidly than others. Speed or order of processing may also be related to hierarchial levels of global and local features. There are at least three possibilities for such an ordering: (1) a "bottom-up" sequence , (2) a "top-down" sequence, and (3) a "middle-out" sequence, in which processing of features is initiated at some sort of intermediate level first, followed by processing of both progressivley higher (global) and lower (local) levels.

The "bottom-up" sequence. Historically, the more common view has been the "bottom-up" sequence of processing. According to this theory, the visual system first extracts components of the display and subsequently integrates them into an overall pattern. This view was encourgaged both by similar constructive algorithms used in computer pattern recognition programs (Selfridge, 1959; Ward & Wexler, 1976) and by electrophysiological studies of visual receptive fields (Hubel & Weisel, 1963, 1965, 1968). However, the findings from visual perceptual experiments fail to support this viewpoint. For example, Weinstein and Harris (1974) and McCelland and Miller (1979) have demonstrated that a line is more easily recognized when it is part of a three-dimensional structure than when it is presented in a less coherent pattern. Moreover, Neisser (1963) and Jonides and Gleitman (1972) have shown that a subject can locate a target (letter) more rapidly if it differs in meaning from its background (digits). In both cases, the "bottom-up" processing model is unable to account for the effects of context on visual processing. In addition, the model does not explain adequately figure-ground separation, or faster processing of good figures (Cocoran, 1973).

The "top-down" sequence. Another view of visual information processing advocates the primacy of information about the overall global pattern or structure. This view is referred to as the "top-down" sequence or global advantage theory (Lockhead & King, 1977; Lockhead & Monohan, 1977; Palmer, 1977; Prinzmetal & Banks, 1977). According to this model, visual system processing begins with a crude analysis of the whole pattern and progressively extracts further information about smaller and smaller details of the pattern. Navon (1977, 1981) has been the leading proponent of this viewpoint. His principle evidence has come from his reaction time experiments involving stimuli similar to the one shown in Figure 1. In one condition, subjects were asked to respond at times on the basis of the large letter (global-instructions), and at other times on the basis of the smaller constituent letter, (local-instructions). Navon found that the subjects were able to ignore the small letters under the global instructions, but their response latencies were influenced by the large letter under the local instructions. This was most apparent when the global form indicated a different response from the local one. Navon has suggested that the finding of faster reponses to the global letter compared to the local letter is consistent with a global to local order of visual processing.

More recent research has indicated that the global advantage is not ubiquitous. Hoffman (1980), Miller (1982) and Pomerantz and Sager (1975) have shown both global and local interference effects (neither level could be completely ignored), as if both levels were processed at the same speed. For example, in the Pomerantz and Sager study, subjects were required to sort patterns into groups based on their global and local form. They found that neither global or local forms could be ignored, but that, contrary to Navon's findings, subjects were better at ignoring the global forms.

Boer and Keuss (1982) evaluated the concept of global advantage using a deadline procedure to assess speed/accuracy tradeoffs. The task was comparable to Navon's Stroop type letter task. Boer and Keuss found that even under task instructions to respond as fast as possible, the subjects were unable to ignore completely either level of the form.

The "middle-out" sequence. Kinchla and Wolfe (1979) have argued that processing is neither "bottom-up" or "top-down". Instead, forms at some intermediate level are recognized first with subsequent recognition of both higher (global) and lower (local) level forms. Using stimuli similar to Navon's, Kinchla and Wolfe presented the display in several sizes. Subjects were asked to respond "yes" or "no" with respect to the presence of the target letter. As long as the large letter was less than 8 degrees of visual angle, subjects responded faster if the target was a large letter. However, at sizes greater than 8 degrees, they responded faster to the smaller target. Kincla and Wolfe have indicated that there is some optimal size for forms (about 2 degrees) and that forms of this size would be processed first, with higher and lower levels processed subsequently as necessary (middle-out processing)

Martin (1979) obtained results similar to Kinchla and Wolfe (1981) and showed the additional requirement that the number of elements constituting the global shape should not be too few. She found a global advantage when the large letter was formed by small letters in a 5 X 7 matrix, but not when the matrix was 3 X 5. Her results suggest that if global features of the same size were made up of fewer and somewhat larger local elements, local judgements were faster and unaffected by the identity of the global forms, whereas global judgements were interfered with by an inconsistent local form. Thus the most well formed and salient features seem to have processing precedence regardless of their level in the form hierarchy.

Hoffman (1980) and Grice, Canhan, and Bouroughs (1980) have noted that the relative speed with which a subject reports targets defined at the global or local levels can be manipulated by degrading the forms at either level.

Overall, the above studies are consistent with the view that visual processing is not local to global or global to local but rather operates at some intermediary level first, with subsequent processing at both global and local levels. Hoffman (1980) suggests that the processing at different levels may occur both independently and simultaneously. However, once sufficient information is processed at one level, it may influence the processing of the other levels because of the redundancy between different levels of structure in most stimuli.

The attentional model. While there appears to be evidence to support the "middle-out" processing sequence, a current view suggested for the global or the local advantage, is the focus of the observer's attention (Harvey, 1984; Hoffman, 1975, 1980; Kinchla, Solis-Macias, & Hoffman, 1983; Miller, 1980; Pashler, 1984; Pomerantz, 1983; Treisman, 1982). For example, the global advantage obtained in the previous studies may not be due to the fact that global letters are identified first. Instead, it may be easier to attend to global features and ignore local ones, but not the reverse. According to a model with the concept of global advantage in the decision processes, information about both levels is availible at the same time, but it is simply easier to attend to and base decisions on information from the global level (Pomerantz, 1983).

Hoffman's (1980) experiment with th Stroop-type letter task appears to be relevant to this present discussion on attention. He had subjects view stimulus displays similar to Figure 1 to determine whether the relevant letter was a member of a memory set containing one, two, or four letters. The relevant letter was indicated by instructions. In the selective attention condition, subjects were to base their decisions on either the large or the small letter, whereas in the divided attention condition, subjects were to base their judgements on both the large and small letters. Hoffman found that in the selective attention condition, interference occurred between global and local levels of the visual form regardless of which level, small or large, the subject was instructed to attend to. In addition, he noted that in the divided attention condition, responses were made equally fast to targets located at either the global or local levels. However, in both cases, the responses in the divided attention condition were slower than in the corresponding selective attention condition. Based on the latency difference between the selective and divided attention conditions, Hoffman indicated that the speed of processing at a given level of a form is dependent upon the amount of processing attention allocated to that level.

In line with Hoffman's suggestion, more attention might be allocated to the level used most recently, and less to others not recently used. This is exactly what Ward (1982) found using the Stroop-type letter task. He noted that processing at a given level of detail biases the distribution of attention so that more is allocated to that level for future processing. Ward suggested that the conflict between the levels appears to depend on the imbalance of the conspicuity and the attentional allocations between levels, with the more conspicious or attended to features interfering more.

Arguments against the attentional model. Navon and Norman (1983) have challenged the research demonstrating the role of attention in determining a global advantage. They indicate that if the global letter attracts more attention, then the global advantage should be more pronounced in the divided attention condition than in the selective attention condition because the deployment of attention in the selective attention condition is dictated by the task demands. However, in the divided attention condition, the subjects have greater lattitude to manifest natural attentional strategies where the task demands are vague. To determine the role of attention in the global advantage, they performed an experiment in which the subject had to indicate the direction of an open C made up of circles or C's that were the elements of a circle. The two types of stimuli were presented randomly in blocks of trials during the divided attention condition but were presented separately during the selective attention condition. Their results revealed that subjects were faster to the global features in the selective attention condition compared to the divided attention condition. They suggest that the global advantage is not due to attentional factors directing the subjects attention to the most salient hierarchy level but to the sensory characteristics of the stimulus.

The question of whether the global advantage effects observed by Navon (1977) and a number of other researchers is due to sensory factors or attentional processes is still a matter of debate. Even the findings of Navon and Norman (1983) can be interpreted in light of an attentional model. For example, it is very difficult to conceive of the more pronounced global advantage that Navon and Norman obtained in the selective attention condition as being purely sensory. As in the Hoffman (1980) study, Navon and Norman's results suggest that the speed of processing is dependent on the amount of attention allocated to that level.

The problems with the Stroop-type letter task. One major problem with the use of the Stroop-type letter task to investigate the order of visual processing is the confounding of response inhibition with the local letter processing task. Many invesitigators (Bjork & Murray, 1977; Ericksen & Hoffman, 1972; Estes, 1972, 1974; McIntyre, Fox, & Neale, 1970; Shiffin & Gardner, 1972; Solman, 1975) have demonstrated that when two or more identical letters are presented simultaneously, subjects are slower at recognizing multiple and identical letters than at recognizing single letters. Inhibition occuring between the similar features of the multiple letters is believed to produce the slower performance. Estes (1972) has termed this effect 'response inhibition'. With respect to the Stroop-type letter task, the notion of response inhibition might be used to account for the slower and less accurate performance in the processing of the local letter compared to the global letter. One difference between the global and local letter tasks is the presence of response inhibition in the latter task. As noted previously, the local letter is presented in a group of multiple and identical letters whereas the global letter is presented individually.

In addition to the confounding of response inhibition with the local letter processing task, other sources of confounding can be identified in studies employing the Stroop-type letter task. For example, Martin (1977) demonstrated that both global and local advantages were dependent on the sparsity of the local letters. Her global letters were at a fixed size but defined either as a subset of a 5 X 7 matrix of small letters or a 3 X 5 matrix of slightly larger letters. Unfortunately, her sparsity manipulation was entirely confounded with variation in visual angle size of the local forms. Moreover, Kinchla and Wolfe (1979) found that a prominent determinant of whether or not the "top-down" sequence of visual processing was manifest appeared to be the visual angle subtended by the stimulus. In their experiment, they asked subjects to search for a designated target at the two levels of a compound letter. They noted that when the global pattern subtended more than 6-7 degrees of visual angle, it was responded to more slowly than the local letter. Although it seems indisputable that the global form should be seen from a certain distance to be perceived as a global form, there is a problem in relating that fact with the notion of global advantage. These problems stem from the confounding of visual angle size and eccentricity in many stimuli. As stimuli are increased in visual angle size, the possible bias introduced by this confounding is accentuated. In summary, it appears that the findings of Martin (1977) and Kinchla and Wolf (1979) must be interpreted cautiously in light of the sources of confounding inherent in the experimental design.

One final source of confounding that is intrinsic nature to the Stroop-type letter is the difference in the number of stimulus elements used to accomplish the global and local letter processing tasks. In order to detect correctly the large letter, the subject must base his judgement on the smaller letters forming the large one. The number of stimulus elements determining a large letter is equal to the number of smaller letters times the number of elements forming each smaller letter. However, in deciding upon the form of the small letter, the subject must attend to one letter. The number of elements determining his judgement in the latter task is equal to the number of elements in that specific letter. As a result, the recognition of the smaller letter is based on a considerably smaller number of stimulus elements compared to that of the larger letter. Given the experimental design, it appears that the number of elements forming each level is confounded with the task demands. Perhaps a better but untested design is one in which the local letter is formed from the same number of even smaller letters as found in the larger letter. In this design, the number of letters forming both the global and local letters would be equivalent.

Another way of dealing with the confounding of the number of elements with the task demands is to provide the subject with two tasks that make use of the entire stimulus pattern. For example, one task would involve determining the global form and the other would involve deteminine the the total number of elements. In this design, the number of elements used for each task would be equal.

Studies that control for confounding variables. Foster (1978) has employed a research design similar to the one described above. In his study, Foster utilized four classes of paired dot patterns: same form-same number, different form-same number, same form-different form, and different form-different number. The dot patterns consisted of 7 or 10 dots and were of random forms. Subjects made same-different judgements in a paired comparison task to determine whether the members of each pair were identical in shape or whether the number of dots in each pattern was the same. Foster found that there was slighlty greater accuracy for the form discrimination task than for the number discrimination task. His finding is consistent with Navon's concept of a global advantage and suggests a "top-down" sequence of visual processing.

While Foster's findings are important to this discussion on the hierarchial levels of processing, his study is lacking in several respects. First, he did not employ a reaction time measure. As a result, it is difficult to determine whether the form of the patterns was processed faster or slower in relation to the number of dots in the pattern. Moreover, there was no divided attention condition whereby form and number discrimination could be assessed simultaneously for priority in terms of both reaction time and accuracy. The mixed design is a important technique in controlling attentional set and can be useful in determining what type of processing occurs faster and more accurately.

Research that avoids the above stated difficulties was carried out recently in an unpublished study by this author (Mikitish, unpublished). Dots patterns consisting of 3-7 dots were utilized. The patterns formed one of four geometric figures: square, rectangle, rhombus, and parallelogram. As in the Foster study, subjects made same-different comparisons to pairs of patterns on the basis of the form or the number of dots. Unlike the Foster study, however, there was also a divided attention condition in which the subject was able to make a same-different comparison on the basis of either the form and number. The dependent variables in the study were manual accuracy and latency.

Table 1 presents the results of the Mikitish study. Mean percentage to and latency to correct responses for the four stimulus classes in blocked form, blocked number, and mixed form and number tasks are provided as well as the grand means for each condition. As shown in the table, the processing of dot form was found to be significantly faster than the processing of dot

Table 1

Percentage of and latency to correct responses for the four stimulus classes of the blocked number, blocked form, and mixed form and number tasks.

Blocked number task:

	Percentage of correct responses			Latency to correct responses (in seconds)		
	SF	DF	X	SF	DF	X
SN	76	71	73	1.42	1.45	1.44
DN	77	74	76	1.44	1.56	1.51
X	76	73	75	1.44	1.50	1.47

Blocked form task:

	Percentage of correct responses			Latency to correct responses (in seconds)		
	SF	DF	X	SF	DF	X
SN	70	78	74	1.38	1.37	1.37
DN	64	77	70	1.40	1.22	1.31
X	67	78	72	1.39	1.30	1.34

Mixed form and number task:

	Percentage of correct responses			Latency to correct responses (in seconds)		
	SF	DF	X	SF	DF	X
SN	60	80	70	1.68	1.40	1.54
DN	65	84	75	1.54	1.18	1.36
X	63	82	73	1.61	1.29	1.45

Key to the Table
SN: Same number pairs
DN: Different number pairs
SF: Same form pairs
DF: Different form pairs

Note. From Mikitish (unpublished).

number (1.34 versus 1.47 seconds) in the selective attention condition. Moreover, in the divided attention condition, the detection of a pair difference in the pattern form was noted to be significantly faster (1.40 versus 1.54 seconds) and significantly more accurate (80% versus 65%) than detection of a pair difference in the number of dots. The differences between form and number processing were found to be related to the number of dots in the second pattern of a pair in both the selective and divided attention conditions. When the number of dots in the second pattern was three or four, the difference between form and number processing for speed and accuracy were not significant. However, when the number of dots in the second pattern was five, six, or seven, the differences were significant and demonstrated that form processing was faster than number processing. Overall, the results of the Mikitish study suggest that there is a "top-down" sequence of visual processing. However, this order was found to depend upon the number of dots in the stimulus.

The results of the Mikitish study also revealed interference effects between dot form and dot number in the both the blocked form and number tasks. As shown in Table 1, more accurate responses were noted in the blocked form task with the equivalent dot number stimulus pairs compared to the nonequivalent dot number stimulus pairs. Moreover, in the blocked number task, more accurate and faster responses were found with the equivalent form stimulus pairs compared to the nonequivalent form stimulus pairs. Overall, the findings suggests that information regarding dot form and number might be availible within a similar time course, thus producing the interference.

In conclusion, the concept of a "top-down" order of visual processing has been demonstrated in a number of studies. These investigations have also found that the order of visual processing is dependent upon a number of factors which include the sparsity of elements, the visual angle of the stimulus, and the conspicuity of the stimulus.

Hemispheric Differences in Visual Processing

During the last 25 years, considerable evidence has been obtained from humans on the difference in function of the two cerebral hemispheres. In right handed subjects, the left hemisphere has been associated with verbal processing and the right hemisphere has been asociated with visuospatial processing. Using tachistoscopic presentations, many investigators have documented right visual field-left hemisphere (RVF) performance advantages for such tasks as digit and letter naming (Kimura, 1961, 1966) and word report (Dimond, 1971; Ellis & Sheppard, 1974; Levine & Banich, 1984; McKeever & Huling, 1970; Young, Ellis, & Bion, 1984). Other studies have demonstrated left visual field-right hemisphere (LVF) superiority in nonverbal processing tasks such as dot localization (Bryden, 1976; and Kimura, 1969), dot detection (Umilta, Salmaso, Bagnara, & Simion, 1979) face recognition (Geffen, Bradshaw, and Wallace, 1971; Umilta, Rizzolatti, Marzi, Zamboni, Franzini, Carmarda, & Berlucchi, 1974) and visual orientation matching (Atkinson & Egeth, 1973).

Two interpretations have been proposed to describe these visual field differences: the temporal-spatial hypothesis (Semmes, 1968) and the analytic-synthetic (analytic-holistic) hypothesis (Bradshaw, Gates, & Patterson, 1976; and Paterson & Bradshaw, 1975).

The temporal-spatial hypothesis. Semmes (1968) has proposed that the left cerebral hemisphere is specialized for temporal analysis and the right for spatial analysis. The temporal and spatial dimensions have been related to cerebral asymmetry from several lines of research. For example, Efron (1963b) was the first to show experimentally that the left hemisphere mediated temporal analysis. He noted that injury of the left hemisphere in neurologically-impaired patients produced a larger deficit in order-discrimination of visual and auditory stimuli relative to injury of the right hemisphere. In another study, with normal subjects, he demonstrated that perception of simultaneity in visual and tactile stimuli was better on the right side. Efron (1963a, b) has suggested that the left cerebral hemisphere processes visual, auditory, and tactile stimuli over time. He has proposed that temporal analysis underlies speech comprehension in which the left hemipshere dominates. In addition, he has indicated that the left hemisphere processes certain nonverbal stimuli, when such stimuli are of a temporal-spatial nature.

The number of demonstrations showing left hemisphere dominance with neurologically-impaired patients on temporal sequence tasks has increased steadily since Efron's initial study (Carmon & Nachson, 1971; Horan, Ashton, & Minto, 1980; Milner &

Taylor, 1972; Swisher & Hirsh, 1972; Tallal, 1980; Tallal & Percy, 1973; Van Allen, Benton, & Gorden, 1966; Zaidel, 1973;). In addition, there are numerous studies documenting left hemisphere dominance for temporal processing in normal subjects. These studies have utlizized dichotic auditory procedures for the presentation of stimulus material (Emmerich, Pitchfold, Joyce, & Koppell, 1981; Mills & Rollman, 1979, 1980; Natale, 1977; Sherwin & Efron, 1980).

Advocates of the temporal-spatial hypothesis have also stated that the right hemisphere is specialized for the processing of spatial stimulus material, citing numerous studies demonstrating right hemisphere superiority with visuospatial processing in both brain damaged (Arrigoni & De Renzi,1964; Corkin, 1965; Carmen & Benton, 1970; Levy, 1969; Zangwill, 1960) and normal subjects (Kimura, 1964, 1966; Knox & Kimura, 1970; and Freedman, 1963) as support for their conclusion.

Problems with the temporal-spatial hypothesis. Despite its empirical support, the temporal-spatial hypothesis cannot account for all lateralized findings. The theory cannot explain the left hemisphere dominance in the perception of written material (Kimura, 1966; Geffen, Bradshaw, & Wallace, 1971) nor the relative superiority of the right hemisphere in the recognition of musical chords (Gorden, 1970) and melodies (McGlone & Davidson, 1973; Milner, 1962; Shankweiler, 1966). In addition, the fact that following extensive early damage to the left hemisphere, the right hemisphere is largely capable of sustaining linguistic development, especially in children (Brown & Hacaen, 1976; Dennis & Whitaker, 1976; Levine & Mohr, 1979; Smith, 1969; Smith & Burklund, 1966; Woods, 1980) cannot be accounted for by the dichotomy. Finally, the temporal-spatial dichotomy does not explain the results of many studies that did not find any differences between the activities of the two cerebral hemispheres using verbal, nonverbal, and spatial tasks with the visual, auditory, and somatosensory modalities (Benson & Barton, 1970; Broman, 1978; Bryden, 1967; Butters & Barton, 1970; De Renzi & Faglioni, 1967; De Renzi, Faglioni & Scotti, 1968; Gott & Boyarsky, 1972; Koff & Riederer, 1981; Ragot, Renault, & Remond, 1980; Shanon, 1979; Uyehara & Cooper, 1980)

The analytic-synthetic hypothesis. The analytic-synthetic approach (Ben-Dov & Carmon, 1976; Bogen, 1969; Cohen, 1973; Levy, 1979; Nebes, 1978; Paterson & Bradshaw, 1975; Polich, 1980; Polich, 1984) states that the left- right difference are due to preferred modes of processing for each of the hemispheres. These researchers suggest that the right hemisphere is specialized for Gestalt, holistic perception--being primarily a synthesizer in dealing with information input. The left hemisphere, in contrast, seems to operate in a more logical analytic computer-like fashion.

According to Bradshaw and Nettleton (1981), time and space are not the unique, objective characteristics of the physical stimuli, but rather correspond to the subjective operations of analysis and synthesis, respectively. This distinction is less concerned with the way events happen than with the possibility that time and space are perceived qualitatively as two different ways of organizing sensory information in the higher cortical centers. Subjective time and space are the a priori forms of perception. They occur prior to perception and enable the perceiver to organize his external world.

Bradshaw and Nettleton (1981) have indicated that temporal organization is a process of sequential abstracting (analysis) and temporal resolving of the sensory information. Their notion is compatible with previous biological, cybernetic, and philosophical viewpoints that perception is a discrete process which involves final integration of periods, "moments" or "time quanta".

Spatial organization, as an activity of synthesis, is compatible with the characterization of the Gestalt as a totality of relationships and as a completeness of information establishing spatial relationships from partial sensory information, and setting up perception in relation to the spatial complexity of patterns.

A related model is suggested by Galper and Costa (1980). These authors attempt to combine the analytic-synthetic dichotomy with the recent studies that report marked individual differences in the use of the analytic versus the synthetic strategies. Their model assumes that there are indeed hemispheric differences in aptitude for particular modes of cognitive processing: the left hemipshere is specialized for analytic, sequential strategies and the right hemipshere is specialized for synthetic, simultaneous strategies. In addition, they suggest that either hemisphere can at times process cognitive information by either a synthetic or an analytic strategy. The adoption of such strategies can act to change the pattern of hemipsheric response to the task because hemispheric specialization is meant to describe hypothetical tendencies in subject processing strategies, thought to depend more on one hemisphere than another.

Empirical support for the analytic-synthetic hypotheis of cerebral specialization is quite extensive based on studies using different stimuli and different procedural tasks (Bever & Chiarello, 1974; Gur & Reivich, 1980; Levy-Agresti & Sperry, 1968; Newman, 1981; Peretz & Morais, 1980; Polich, 1980; Ornstein, Johnstone, Herron, & Swencionis, 1980; Ross & Turkewitz, 1981; Sergent & Bindra, 1981). For example, Bever and Chiarello (1974) demonstrated that trained musicians exhibited a left hemisphere advantage in identifying musical patterns by using an analytic approach to the task. Individuals who were unsophisticated with respect to music exhibited a right-hemisphere advantage in performing the same task. The authors found that the untrained subjects approach the task using a holistic strategy. Sergent and Bindra (1981) examined the procedures and stimuli used in lateralized face recognition studies and noted that the superiority of the visual field depended upon, among other things, the task requirements. A left visual field advantage was obtained in conditions that required synthetic processing (like degraded facial imformation; highly discriminable faces, and unfamiliar faces). However, a right visual field advantage was obtained with conditions that required analytical judgements (detecting difference in parts of faces). They found that no hemisphere had an inherent or absolute advantage. Based on their findings, Sergent and Bindra conclude that both hemispheres contribute to the processing of faces, but their contribution vary as a function of task demands.

Problems with the analytic-synthetic hypothesis. Despite the usefulness of the analytic-synthetic theory in the interpretation of many lateralized findings, there are experimental results that the theory cannot explain. For example, the dichotomy cannot account for the higher temporal resolution in the critical flicker fusion frequency threshold following damage to the left hemisphere (Goldman, Lodge, Hammer, Semmes, & Mishkin, 1968) or the left hemisphere's relative inefficiency in the recognition of letters in nonstandardized script (Bryden & Allard, 1976). Similarly, the holisitic processing suggested for the right hemisphere cannot easily explain its relative advantage in analytical tasks such as the detection of gaps in contours and the orientation of dots and lines in space (Kimura, 1969; Warrington & Rabin, 1970; Umilta, Rizzolatti, Marzi, Franzini, Camarda, & Berlucchi, 1974).

Despite these inconsistencies, most researchers (Bradshaw & Nettleton, 1981; Bryden, 1982; Moscovitch, 1979; and Nettleton & Bradshaw, 1983) agree that hemispheric specialization, although difficult to describe, does exist. The disabilities of commissurotomized patients and aphasic patients, who almost always suffer left hemisphere lesions, are difficult to interpret in any other way. Theorists reconcile the inconsistency between experimental findings and hemispheric specialization notions by assuming that the effects of individual differences, task demands, and situational factors are superimposed on the underlying functional specialization. For example, visual field asymmetries have been found not only to shift from one task to another (Geffen, Bradshaw, & Wallace, 1971; Robertshaw & Sheldon, 1976; Simion, Bagnara, Bisiacchi, Roncato, & Umilta, 1980) but also to differ from subject to subject (Kroll & Madden, 1978; Brandeis, 1983; Hatta & Dimond, 1980; Levy, Heller, Banich, & Burton, 1983), and even to differ from trial to trial in the same subject (Cohen, 1979). In addition, situational factors such as memory load (Hellige, Cox, & Litvac, 1979), memory duration (Hanny & Roger, 1979), practice (Hellige, 1976), task difficulty (Jonides, 1979), stimulus-set size (Kirsner, 1980; Miller & Butler, 1980), stimulus probability (Babkoff & Ben-Uriah, 1983) exposure duration (Sergent, 1982,1984), interstimulus interval (Moscovitch, Scullion, & Christie, 1976), subject strategy (Faber-Clark & Moore, 1983), and scanning biases (Heron, 1952) have been noted to exert a profound influence on visual asymmetries.

The attentional model. The idea that hemispheric superiority is dependent upon the requirements of the task has an increasing amount of evidence to support it(Bradshaw & Nettleton, 1981; Hellige & Cox, 1976; Kinsbourne, 1973; & Kirsner,1980). For example, Kinsbourne (1973) has suggested a third model of cerebral hemispheric specialization based on the task requirements. He has shown that the hemisphere that performs the processing in a particular situation can be determined by another task that is performed concurrently. In one experiment that required the subject to hold six words in memory during performance of a gap-detection task, a right visual-field advantage was noted. However, when there was no verbal memory requirement, no asymmetry in gap detection performance was obtained. Kinsbourne attributes the results to the priming effect that the memory task had on activating the left hemisphere for processing in the experiment. A similar kind of priming has been demonstrated by Hellige (1978) by comparing performance on a form recognition task under block presentations (only forms presented) or mixed presentations (forms and words presented). He found that the left visual field superiority obtained under the block presentations changed to a right visual field superiority when the forms were mixed with the words in the stimulus list. An interpretation of the results consistent with the Kinsbourne hypothesis is that the words primed the left hemisphere to dominate processing on the mixed presentation trials, and this hemisphere, once activated, dominated in the recogntion of forms as well.

Despite the strong experimental support in favor of an attentional model of hemispheric differences (Honda, 1978; Hellige, 1978; Kershner, 1977; Kinsbourne, 1973; Spellacy & Blumstein, 1970), there are a number of inherent difficulties in this model. In particular, there is the difficulty of distinquishing shifts in the allocation of attention from changes in strategy (Bryden, 1982). Moreover, the fact that the effects of imposing a concurrent memory load is uncertain, sometimes priming and sometimes depressing the performance of the loaded hemisphere, is seen as seriously limiting the predicting power of the model (Gardner & Branski, 1976; Geffen, Bradshaw, & Nettleton, 1973; Hellige & Cox, 1976). Finally, there are a number of studies that find concurrent verbal loads produce complex and variable changes in both the right and left hemispheres (Beaumont and Colley, 1980; Bradshaw & Nettleton, 1983; Cohen, 1973). For example, Beaumont and Colley presented subjects with a mixed list of shapes and words which appeared randomly in the left or right visual field. In a given set of trials either shapes or words were more common, and the subject was clearly informed about the frequency of occurrence for each type of stimuli. While subjects responded more rapidly to the more common type of stimulus in any set, the fact that a stimulus type was more common or less common did not affect the symmetry for the stimulus type as Kinbourne's attentional models would predict.

Sergent (1982) has suggested that there exists a continuum along which hemispheric advantages may emerge as a function of task demands. She states that the superiority of the left hemisphere over the right hemisphere is more likely to emerge when the task requires fine feature detection, provided that the viewing conditions make these components availible. In three experiments she investigated the involvements of the two cerebral hemispheres in the processing of faces. Perceptual discrimination of pairs of faces was equally fast overall. regardless of whether the faces were presented to the right or the left visual fields. However, for faces differing in one or two features, a qualitatively different pattern of results emerged. A RVF advantage was obtained when the difference between the two faces was in the upper part of the face. Sergent concluded that different strategies might be used to process faces according to which viusal field they were presented. There are a number of other studies using faces (Marzi & Berlucchi, 1977; Patterson & Bradshaw, 1975; Sergent, 1984) and other stimuli (Cohen, 1976; Pollich, 1980, 1984) that lend support for the notion of a left hemisphere advantage in detecting minor changes within complex stimuli.

Of course, in order for factors such as priming, overload, or instructions to be effective, there must be some capacity for both hemispheres to perform a variety of tasks, including some for which the opposite hemisphere is specialized. In support of this possibility, Gazzaniga (1970) and Nebes (1974) have noted that the nonlanguage hemisphere is capable of some language functions, although not many. Moreover, Levy, Trevarthen, and Sperry (1972) and Levy and Trevarthen (1976) report that in split brain patients, visual pattern recognition data with nonsense forms can be performed by both hemispheres, thus suggesting that processing capacity and dominance are separable from one another.

Nebes (1978) has indicated that the full range of abilities has not been explored in these studies, and the right and left hemipshere may proved equally competent on some tasks, though perhaps differing in the strategies they use to process them. He has suggested that it is not just the type of perceptual stimulus or mode of readout used that determined which hemisphere was dominant, but the type of information processing necessary to solve the problem at hand. When only visual recognition was called for, even if the material were verbal, the right hemisphere was dominant. If however, a verbal transformation was required, even if the material was nonverbal, it was handled by the left hemisphere. Thus, the dichotomy of the two hemispheres appears to be in accordance to the functions they perform rather than by their preferred input or output.

The unconfounding of task demands and test stimuli. The confounding of stimulus characteristics with the cognitive demands of the tasks used to test them has been a fundamental problem with tests of cerebral specialization (Brandeis, 1983; Cohen, 1975; Klatzky & Atkinson, 1971; Wolff, 1980; Wittelson & Rabinovich, 1971). Rarely has the same stimulus set been used in two tasks to differentiate the processing advantages of the hemispheres. Generally, left hemisphere advantages have been found on verbal tasks using language-related stimuli, whether visual or auditory (Levine & Banich, 1984; Young, Ellis & Bion, 1984), and right hemisphere advantages have been found on visual spatial tasks using nonverbal stimuli (Bryden, 1976; Umilta, Salmaso, Bagnara, & Simion, 1979).

Obtaining a suitable set of stimuli to study the different typesof processing has been an obstacle to the investigation of the effects of task demands and the role they play in cerebral hemispheric specialization. By their very nature, most stimuli are conducive to one type of processing. For example, words are analyzed efficiently with verbal processing tasks but inefficiently with visuospatial processing tasks.

The issue of task demands and cerebral asymmetry has been made most evident by the lack of consistency between different studies employing the same type of stimuli (dot, letters, or geoemtric forms) but under different task demands. The results of these investigations have suggested that visual field advantages are to some extent dependent on procedural task demands.

Dot patterns. One example of stimuli that have been noted to produce different lateralized findings under varying procedural task demands is the dot pattern. Dot patterns have been investigated in terms of the form and the number of dots in the pattern. In a study assessing form perception with dot patterns, McKeever and Hulving (1970) presented dot patterns that formed different geometric figures to the right and left visual fields. After each presentation, they asked the subjects to reproduce the pattern on paper. Geometric figures were found to be more accurately reproduced when the dot pattern was presented to the left visual field. Other studies employing simple but non-dot geometric figures have obtained similar findings (Bryden, 1973; Fontenot, 1973; Dee & Hannay, 1976; Hellige & Cox, 1976).

Studies employing enumeration tasks with dot patterns have found either no visual field advantages (Adams, 1971; Kimura, 1966; McGlone & Davidson, 1973; White,1971) or both left and right visual-field advantages relative to the shape of the dot pattern. For example, Granek and Stern (1982) presented dot patterns randomly to the left or right of the center of fixation. The patterns were constructed to form random and commom geometric figures. The authors noted that dot enumeration was more accurate in the left visual field when the dot formed a common geometric figure. A right visual field advantage was obtained for dot enumeration when they formed the more difficult random pattern.

The results of the studies using dot patterns are important to this present discussion because they have demonstrated how changes in task demands and task difficulty (Granek & Stern, 1982) interact with hemispheric differences. Stronger arguments for the role of task demands in cerebral specialization would have been possible if the different task demands were used with the same set of stimuli in a simple experiment.

Letter matching. There are several researchers (Cohen, 1972; Davis & Schmit, 1973; Egeth & Epstein, 1972; Geffen, Bradshaw, & Nettleton, 1972; Hellige, 1976; Niederbuhl & Springer, 1979; Segalowitz & Steward, 1979) who have achieved a differentiation of task demands with the one set of stimuli in the same study by using upper-case and lower-case letters in a matching task. For example, Geffen, Bradshaw, and Nettleton (1972) have shown that when an upper-case letter is paired with its lower case equivalent, the right visual field presentation shows a significant advantage over the left visual field presentation. However, a left visual field advantage is obtained for the response to the same case pairing. Geffen et al contend that when the pairing involves different cases (name matching) the judgement was entirely linguistic because in that instance only letters that had minimal similarity between upper and lower cases were used. When the pairing involved identical letters (same case), the matching was persumed to be based on physical similarity, producing a left visual field advantage. Similar findings have been reported by other investigators employing upper and lower case letters. The significance of this research paradigm is evident: while controlling precisely for stimulus attributes (since the same letters are used), letter matching has provided a tool for measuring hemispheric asymmetry as a function of two different task demands (physical and name matching).

Problems with letter stimuli. While the above studies have been informative with respect to letters, they by no means provide a complete description of the manner in which the two hemispheres function. Letter stimuli represent a finite set of stimuli that are sharply focused, familiar, and overlearned. Nonverbal and visual spatial stimuli represent a potentially infinite set of shapes with different levels of structure.It is possible that the verbal or nonverbal stimuli may not achieve a similar quality of representation in the sensory areas of the brain during tachistoscopic presentation (Sergent, 1982). It is for this reason that future investigation of the role of task demands in cerebral specialization must also employ visuospatial stimuli. To date, there have been no investigations utilizing visuospatial stimuli to differentiate the effects of task demands on hemispheric functioning. Comparable findings with visuospatial stimuli would increase the generalizability of the role for task demands in lateralized findings.

Task demands. Assuming that the interpreted nature of any problem suggests a particular type of solution, we contend that the procedural task demands themselves can be described as existing along a continuum. There are those task demands which require a particular pattern of cognitive analysis and therefore a certain hemisphere superioirty. On the other end of the continuum are those tasks which require a less defined pattern of cognitive analysis. These tasks are extremely weak in specifying one strategy over another in cognitive processing and usually result in the absence of lateralized findings.

Depending upon the composition of the task, many levels of processing might be enacted as subjects attempt to solve the problem they face. If that task is sensitive to individual differences, then the existence of variation in processing strategies may account for the fact that some studies on laterality report inconsistent, weak, or even contradictory findings for the same task (Witelson & Rabnovich, 1971; Bradshaw, 1978; Kinsbourne, 1980; Wolff, 1980). The concept of task demands as playing a role in cerebral asymmetry cannot be fully appreciated unless the underlying subject strategies are uncovered. This is a key factor to understanding the hemispheric differences that occur in studies involving one or many task demands with the same set of stimuli. It is an important topic and needs further exploration.

Task difficulty. Closely related to the concept of subject strategies is the notion of task difficulty. Different subject strategies are liable to be employed depending upon the difficulty level for a specific task. The significance of task difficulty for hemispheric differences has been suggested in many studies. The majority of the studies investigating task difficulty have manipulated stimulus characteristics such as exposure time (Rizzolatti & Buchtel, 1977; Bradshaw, Hicks, & Rose, 1979; Pring, 1981; Marzi & Berlucchi, 1977; Sergent, 1982), degradation (Moscovitch, 1979; McKeever & Gill, 1972; McKeever & Suberi, 1974; Eriksen & Schultz, 1979; O'Boyle & Hellige, 1978), and brightness (Simion et al. , 1980; Sergent, 1982). The findings from these studies indicate that there is a right visual-field advantage with a decrease in stimulus qualities. Studies that have investigated task difficulty through manipulation of task demands but without changing the stimulus qualities are few (Davis & Schmidt, 1973; Geffen, Bradshaw, & Nettleton, 1972; Hellige, 1976, 1978). In the simplest procedure, two different types of stimuli are presented separately in blocks of trials in which task conditions are the same, i.e. a blocked condition. The results are compared to the more complex mixed condition in which the two types of stimuli are presented randomly and the subject does not know on any given trial what type of material is to be presented. Thus, the subject cannot develop a specific set for type of material and cannot "activate" one hemisphere for one type of material and the other for a different type of material. The task demands are similar for both the blocked and mixed conditions. The difference between them lies in the level of difficulty. For the blocked condition, the subject must attend to only one type of stimulus characteristics. In the mixed condition, the subject must attend to two types of stimulus characteristics.

Hellige (1978) has used this procedure to investigate the processing of complex polygons in the divided visual fields. He has found an overall left visual field advantage for nonverbal form recognition presented in blocked trials, but an overall right visual field advantage when the form trials were randomly intermixed with the word recognition trials. Geffen et al. (1972) have also employed this procedure with physical and name matching of letters. The results of their experiment have indicated that name matching is more strongly localized in the left hemisphere on the blocked trials but in the right hemisphere on mixed trials. Physical letter matching was found to be localized in the right hemisphere during both block and mixed presentations. Hellige has suggested that attention or level of arousal is an important factor in determining cerebral specialization and has indicated that Kinsbourne's notion of "priming" may account for the inconsistencies in the cerebral asymmetry data in going from blocked to mixed trial presentation.

Other reseachers such as Paterson and Bradshaw (1972) and Sergent (1982) suggest that, in general, with more complex task demands using equivalent stimuli, the left hemisphere is more efficient. Tomlinson-Keasey and Kelly (1979) have shown this to be true for tasks that involve both words and pictures of objects. Unfortunately, left hemisphere dominance on complex tasks is not universal. Jonides (1978) has reported a right visual field superiority for a simple letter classification task but a left visual field superiority for a complex classification task. The right visual field advantage for the easy task was reversed when it was intermixed with the difficult one. Jonides has suggested that subjects develop expectations about task characteristics which, in turn, prime one or the other hemisphere. The primed hemisphere becomes dominant, resulting in contralateral field advantage.

The results of the above investigations indicate the importance of task difficulty for the production of lateralized findings. The direction of the relationship is dependent upon a number of factors. It appears that manipulation of stimulus characteristics which increase task difficulty, is associatied with a right visual advantage. Moreover, the manipulation of task demands by making them more difficult while retaining the same stimulus characteristics is also associated with a right visual field advantage. The results are consistent with the view that lateral asymmetries are due to many factors, such as task demands, task difficulty, subject strategies, and so on.

While the task demands specify processing of a particular stimulus feature, several studies with both lateralized presentations (Alivisatos & Wilding,1982; Boer & Keuss, 1979; Martin, 1979) and nonlateralized presentations (Foster, 1978) have demonstrated that irrelevant stimulus information sometimes invades the processing of the relevant features. These results are consistent with the view that task demands exist on a continuum and subjects may employ more than one strategy in order to come about a solution.

The role of irrelevant information in differential hemispheric processing has only recently been investigated. Studies (Alivasatos & Wilding, 1982; Martin, 1978; Sergent, 1982) that have presented the Stroop-like letter task to one or the other visual fields are of importance to the present discussion since they have sought to determine the interaction between relevant and irrelevant factors in each cerebral hemisphere. They have used the Stroop-type letter to determine the ability of the subject to filter out irrelevant information (i.e. the small letters) by observing performance in identifying relevant information (i.e. the large letter). Alivisatos and Wilding (1982), employing the letter recognition task in a lateralized tachistoscopic presentation, have reported that subjects are more accurate in the left visual field when reporting the large letter composed of small that are different. On the other hand, they have noted that subjects are more accurate in the right visual field when reporting the small letters which form a different large letter. The finding of asymmetrical interference for the right and left visual fields is consistent with the view that each task demand requires the operation of several processing strategies and that the strategies employed can differ for the two cerebral hemispheres.

In conclusion, the importance of distinquishing the visual processing differences of the right and left cerebral hemisphere has become more apparent. However, the research results suggests that task demands do not represent a unitary concept. Instead, they can be viewed as a continuum that is composed of different levels of cognitive strategies. Each levels can be evaluated with respect to task difficulty and individual differences. In addition, there is empirical evidence to suggest that different congitive strategies employed in the execution of a task can interfere with one another asymmetrically in the two cerebral hemispheres. It is clear that further research concerning the role of task demands and related factors is necessary if we are to fully understand the nature of the functioning of the two halves of the human brain and their interrelationships.

Rationale of the Present Investigation

The order of visual processing.

Most of the previous studies investigating the "top-down" sequence have presented stimuli under conditions of spatial certainty. One major difficulty with this procedure has been the possibility that the subjects might limit their attention to a particular region on a stimulus pattern and as a result, produce findings consistent with either a "top-down" sequence or a "bottom-up" sequence of visual processing. Several studies have attempted to deal with this problem by presenting the stimulus under conditions of spatial uncertainty (Alivisatos & Wilding, 1983; Boer & Keuss, 1982; and Martin, 1979) or by presenting the stimuli briefly (Foster, 1978; Mikitish, unpublished). The general results from these investigations has supported the concept of the global to local sequence of processing.

A major design problem associated with the above studies assessing the order of visual processing under conditions of either spatial certainty or uncertainty has been the confounding of the number of elements in the different levels of stimulus structure with the task demands. This design problem is characteristic of many of the above studies employing the Stroop-type letter.

The problem of confounding by the number of stimulus elements was controlled in a recent investigation (Mikitish, unpublished) by presenting to the central visual field the same dot pattern stimuli under three different task demands. Each task demand required the use of all stimulus elements for making a judgement. In general, findings consistent with a "top-down" sequence of processing were obtained.

The purpose of the present study was to replicate the above findings but under conditions of spatial uncertainty, by presenting the stimuli randomly to the right or left visual fields. This approach handles the problem of controlling the subjects attention but provides a way of studying possible hemispheric differences in the use of global versus local processing strategies.

The stimuli used in this study were fixed dot patterns of 4-6 dots. The dots were arranged to form one of four geometric figures: square, rectangle, rhombus, and parallelogram. These four figures were selected because of the simplicity of generating geometric patterns from one basic form: the square. The dot patterns were presented sequentially by a tachistoscope in pairs to which the subject manually responded same or different depending upon the number of dots or the geometric form they made. The first pattern of the pair was always presented to the central visual field and the second pattern was presented randomly to the right or left visual field. There were three task demands: blocked form, blocked number, and mixed form and number. In the blocked form task, the subjects were instructed to respond only to the geometric figures that the two dot patterns formed for sameness or difference and to ignore the number of dots creating each pattern. In the blocked number task, the subjects were instructed to compare only the number of dots in the two patterns for sameness or difference while ignoring their geometric form. Finally, in the mixed form and number task, the subjects were instructed to use both the number and the form of dots in the two patterns to determine their same or difference judgement.

The dependent variables in this study were response latency, manual accuracy, verbal report accuracy, and confidence ratings. Manual response latency was chosen as a dependent variable to provide a time course for each of the three task demands (Pachella, 1974). Manual and verbal report accuracy were chosen to determine the accuracy levels for the three tasks. Finally, confidence ratings were employed because they offerred an economical and reliable way to gain information about the subjects' judgements of task difficulty.

The manual accuracy data was also examined within the framework of signal detection. The purpose of the signal detection analysis was to investigate decision making processes for each of the three task demands. Both sensitivity and decision bias were evaluated.

Based on the preceeding discussion, the following hypotheses were made. One, the processing of the dot form would be faster and more accurate than dot number in the periphery for both the blocked and mixed presentations. This hypothesis was based on research by this author and others previously cited, showing that the global features of a stimulus are perceived faster and more accurately than the local features. Two, the nonequivalence of the number of dots within the two patterns of a pair would interfere with the speed and accuracy of form processing in the blocked form task. And three, the nonequivalence of the dot form within the two patterns of a pair would interfere with the speed and accuracy of dot number processing in the blocked number task. Both the second and third hypotheses were founded on previous research findings with both the Stroop-type letter and dot patterns, demonstrating that irrelevant features interfere with relevant one.

Hemispheric differences in visual processing. As stated earlier in the general introduction, the second purpose of this thesis was to investigate cerebral hemispheric differences in visual processing. This goal was achieved by presenting a single set of stimulus dot patterns to the right or left visual fields under different task demands. The task demands required the subject to discriminate pairs of successively presented patterns for sameness or difference on the basis of the geometric dot form or the number of dots. The task demands were of upmost importance to this study because they determined the type of visual processing the subjects employed.

Dot patterns were chosen as stimuli because of both their simplicity and their suitability for processing under different task demands (i.e., form and number). To date, there has been no study differentiating form perception from dot enumeration in the left and right visual fields using a single set of stimulus dot patterns (see pages 32-33). The advantage of the present design was that it permited a determination of hemispheric specialization under different task demands.

In addition to the study of task demands, this investigation was undertaken to determine the importance of task complexity in the production of lateralized findings. As stated earlier in the introduction (pages 35-38), previous research regarding the role of task complexity in cerebral hemispheric differences is conflicting. In this study, different levels of task complexity were achieved by presenting the task demands of both form and number discrimination in two different presentations (blocked and mixed). In the blocked presentation, the task demands consisted of discriminating either form or number. However, in the mixed condition, discriminating both form and number was required. The mixed condition was considered to be more difficult because it was necessary for the subject to process two diemensions, form and number, in order to complete the task.

The last issue addressed in this thesis was the interaction between form features and number features in the blocked presentations of the form and the number task. Each stimulus pair contained information about both the form and number of the dots. The issue under investigation was whether hemispheric differences would be found in the interaction between irrelevant information (for example, form) with the processing of relevant information (for example, number).

As noted in the introduction, most research investigating the interaction of different levels of features in a lateralized presentation have used the Stroop-like letter task (Boer 6 Keuss, 1981; Martin, 1979; Navon, 1977; Alivisatos & Wilding, 1981). The results of the above studies demonstrating asymmetrical interference in the right and left visual field are interesting with respect to different hypothetical models of cerebral specialization. However, the conclusions from those studies employing the Stoop-like letter task must be accepted cautiously in light of the failure of the researchers to control such variables as the level of task difficulty and the difference in the quality of the large and small letters

In general, hemispheric differences have been measured by a variety of paradigms. Of the many different types of dependent variables, it has been suggested that response latency is the most sensitive to detecting hemispheric differences (Babkoff et al, 1980; Bradshaw & Gates, 1978; Day, 1977). Bowers and Heilman (1980) demonstrated that asymmetrical activation is more likely when the stimuli convey discriminative information about the type of response to be made. This is consistent with the research of Murphy and Venables (1970) who have shown that asymmetries are too small to be detected when using a simple RT paradigm. The general concensus has been that a choice RT paradigm with stimuli that convey discriminative information is preferable, in order to take advantage of the larger predicted hemispheric asymmetry. This type of design has been used quite frequently in differentiating the two hemispheres for lexical or grammatical decision time tasks (Babkoff et al, 1980; Bradshaw & Gates, 1978; Day, 1977) and verbal (words or letters) versus face recognition tasks (Bowers & Heilman, 1980; Broman. 1978).

The present experiment was designed to assess a number of dependent variables for the production of lateralized findings with the same set of stimuli. The variables included manual response latency and accuracy, signal detection analysis of manual accuracy, verbal report accuracy, and confidence rating. The role of the dependent variable in the investigation of cerebral asymmetry has only been given scant attention (Beaumont, 1982; Bryden, 1982; White, 1966). This investigation sought to determine the most useful dependent variables in obtaining lateralized findings for the specific procedural tasks.

On the basis of the preceeding discussion of the literature, it was hypothesized that: (1) faster and more accurate performance in the processing of the form (the blocked form task) would be obtained for stimulus patterns presented to the left visual-field (Hellige & Cox, 1976; McKeever & Hulving, 1970); (2) when the number of dots within a pair of patterns was different, slower and less accurate processing of dot form (the blocked form task) would be noted with the stimulus patterns presented to the right visual field (Alivisatos & Wilding, 1981); (3) faster and more accurate performance in the processing of number (the blocked number task) would be shown with the stimulus patterns presented to the right visual field (Granek & Stern, 1982; McGlone & Davidson, 1973); (4) when the form of dots within a pair of patterns was dissimilar, slower and less accurate processing of dot number (the blocked number task) would be indicated for stimulus patterns presented to the left visual field; and (5) faster and more accurate performance in the processing of both form and number (the mixed form and number task) would be obtained to the stimulus patterns presented to the right visual field (Sergent, 1982; Tomlinson-Keasey & Kelly, 1979).

CHAPTER 2

METHOD

Subjects

Ten male subjects between the ages of 18 and 30 years were tested. All subjects were right handed and had normal or corrected-to-normal vision. Handedness was determined by a questionnaire adapted from Annett (1979) (see Appendix A). The criterion for elimination of weak right handedness was set at a value of 90% or less right-handed responses to the questionaire. Visual acuity was evaluated for each eye separately with a standard Snellen Chart. Visual acuity poorer than 20/25 with corrected vision was the criterion for subject elimination.

Subjects were also screened prior to the experiment with the Vocabulary and Block Design Subtests of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) to ensure equal verbal and visuospatial abilities (Matarazzo, 1976; Filskov & Leli, 1981). Subjects whose standard score performance on the Vocabulary subtest differed by more than one standard deviation from their standard score performance on the Block Design subtest were eliminated from participation in the study.. All subjects were paid three dollars an hour for their participation.

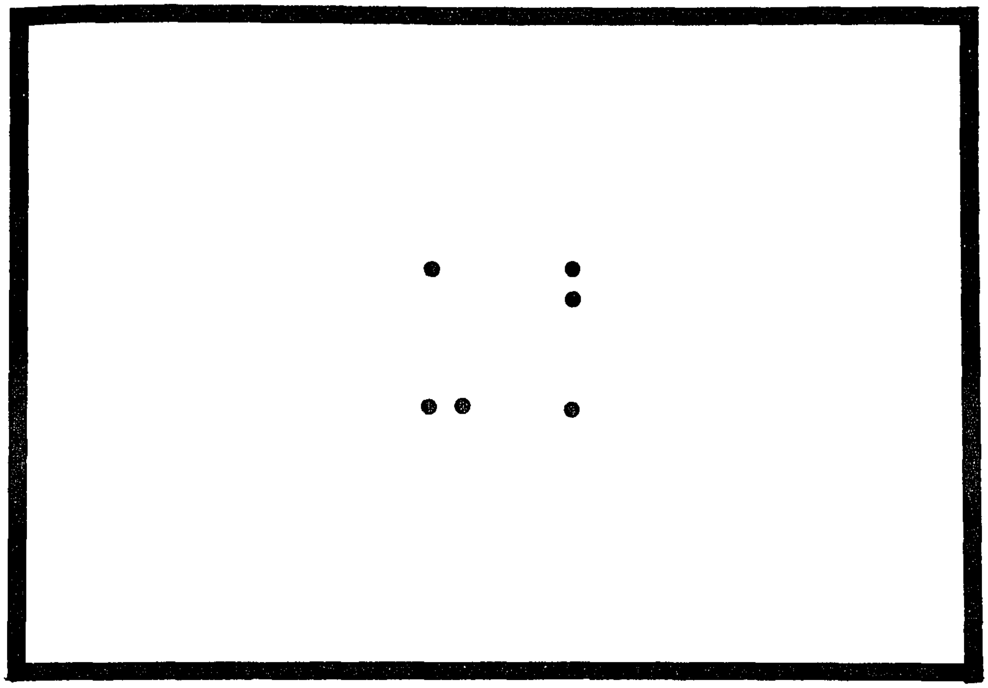
Stimuli

The stimuli consisted of gemoetric dot patterns drawn on 5 X 7 inch blank white cards. Each dot was a homogeneous blank circle of 1.5 mm in diameter. The dot patterns were arranged in pairs with the first member being presented symmetrically around the center of the card and with the vertical outer edge of the second member of the pair being presented 2.2 degrees to the right or left of the center of the card. (see Figure 3)

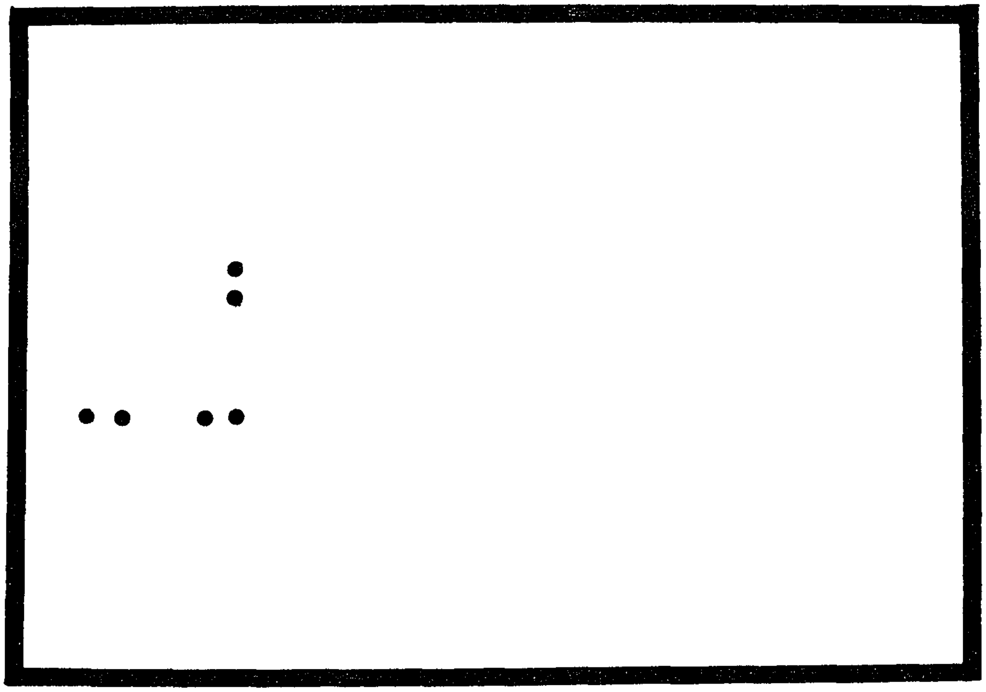
The coordinates for the placement of dots depended upon the following: (a) whether the dot pattern was the first or second member of a pair; (b) the number of dots in the pattern (4 to 6); and (c) the geometric figure that the dots formed (square, rectangle, rhombus, or parallelogram).

The stimulus pattern for the first member of a pair was constructed so that four dots were always placed at the four extreme corners to form one of the four geometric figures. The dots were located symmetrically around the fixation point in the center of the card. Any additional dots (1 or 2) were placed inside the figures at 38 or 76 degress of visual angles from one of the corners with the rule that each additional dot be placed on a different side. The overall size of the side of the figure varied with the geometric form, but the visual angle ranged from 1.52 to 1.90 degrees.

The first pattern was always drawn in the center of the card to permit adequate exposure in both visual fields. There was a visual angle of 3.10 degrees from the bottom of the card to the center of any of the four geometric figures. The square was constructed such that the difference between any two dots on adjacent corners was at a visual angle of 1.52 degrees. The other three figures represented a variation of the square. The rectangle dot pattern consisted of a base the same size as the square but with a longer vertical side extending 1.90 degrees.



First pattern of a pair



Second pattern of a pair

Figure 3. Pair of stimulus patterns.

The rhombus dot pattern had four sides (two of which were vertical) with a visual angle of 1.52 degrees between any two dots on adjacent corners but the acute angle between adjacent sides was 75 degrees. The parallelogram represented a composite of the rectangle and the rhombus. The longer side, which was always located on the vertical axis, had a visual angle of 1.90 degress while the slanted side had a visual angle of 1.52 degrees. The acute angle between adjacent sides was 75 degrees.

The second member of the stimulus pair was drawn at the same visual angle (3.10 degrees) from the bottom of the card to the center of each geometric figure as in the first pattern. However, the second dot pattern extended 2.2 degrees of visual angle to the right or left of the fixation point in the center of the card. In addition, only three dots were placed on the corners of the card with the upper or lower outer corners always missing. The use of three dots to define only three corners meant that a two-sided figure was formed (see Figure 3). The two sided dot pattern was used in order to elicit greater interpretation from the subject as to the nature of the figure. The subject was instructed that the second pattern was always a partial representation of one of the four geometric figures presented as a first pattern, and it was his task to complete the geometric figure. Previous pilot work demonstrated that a four cornered dot pattern was extremely easy for the subject to discern and resulted in excessively high accuracy scores.

Additional dots (1 to 3) in the second figure were placed at a distance of .38 or .76 degrees from one of the three corners of the figure with the rule that each dot be placed, if possible, on a different side. The description given for the construction of the four different geometric patterns from dots for the first member of a stimulus pair were the same for the second member with the exception that only three dots were used for the corners that defined the figure and the figure extended 2.20 degress to the right or left of fixation.

A blank white card with a small black dot (1.5mm in diameter) in the center was used as the fixation card. This card was presented prior to the first card and during the interval between the first and second cards of a stimulus pair.

Each pair of patterns were classified into one of the following four classes (see Figure 4):

(A) Same Form-Same Number (SFSN): The number of dots in the two patterns were the same (4 to 6) and the figures were the same.

(B) Different Form-Same Number (DFSN): The number of dots in the two patterns were the same but the geometric figure they formed were different.

(C) Same Form-Different Number (SFDN): While the geometric form of the two patterns were the same, the number of dots between them differed by one.

(D) Different Form-Different Number (DFDN): Both the number and the geomtetric form of the dots differed within the pair.

In addition to the above four categories, the stimulus patterns were also classified on the basis of pair form and pair number. The SFSN and SFDN class of stimulus pairs constituted the equivalent-form pairs and the DFSN and DFDN class of stimulus

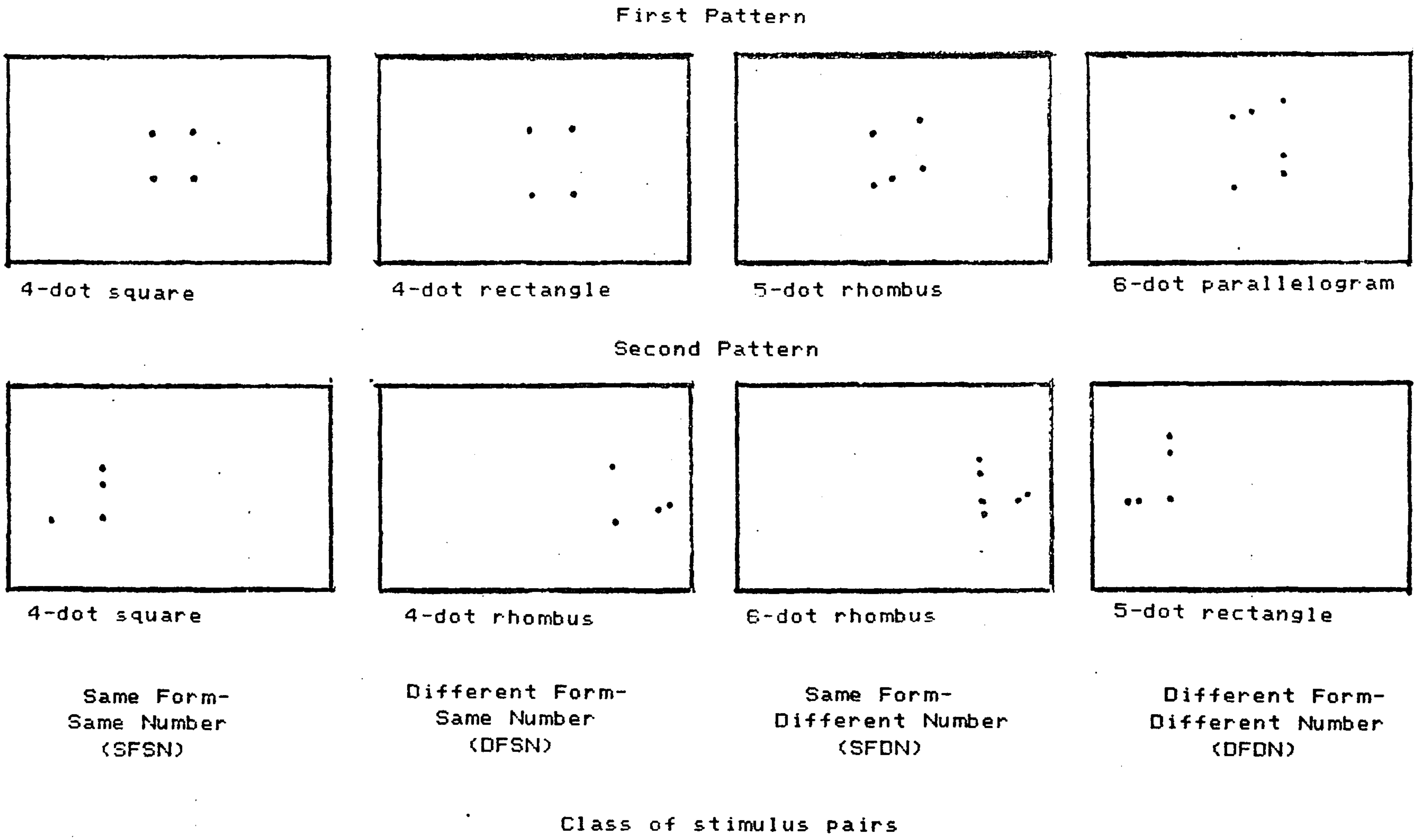


Figure 4. Four classes of stimulus pairs.

pairs constituted the nonequivalent-form pairs. Moreover, the SFSN and DFSN class of stimulus pairs accounted for the equivalent dot number pairs and the SFDN and DFDN class pf stimulus pairs accounted for the nonequivalent dot number pairs.

For each visual field, there were 144 pairs of patterns, with 36 pairs from each of the four classes. Within the group of patterns that made up the second member of the pair for each class, there was an equal number of the 12 different dot patterns that could be formed by any combination of number (4,5,6) and geometric form (square, rectangle, rhombus, or parallelogram). The 144 stimulus pairs generated for one visual field represented the same set presented to the other visual field but in mirror form. The instructions given to each subject for judgement of sameness or difference between the patterns will be discussed in detail later, but in brief, for judgements of dot number equality, the correct response to classes (A) and (B) was "same" and that to classes (C) and (D) was "different". For judgment of shape equality, the correct response to classes (A) and (C) was "same" and to classes (B) and (D) was "different".

Apparatus

The stimuli were presented with a Scientific Prototype Model GB three field tachistoscope equipped with Sylvania F475/CWX flourescent lamps. Luminance in the two main chambers was set at 11.0 mL and in the blank presentation field at 1.0mL. The experimenter indicated the onset of a trial by saying "ready" and then pressing a button which triggered the tachistoscope. The manner of presenting the paired stimulus patterns was identical throughout the experiment. The first pattern of a pair was presented for one second, followed by a three second blank interval of the white stimulus card with the fixation target (an X) in the center, and then by a 100msec presentation of the second stimulus pattern to the right or left visual field. The presentation of the second stimulus pattern triggered a Lafayette digital clock timer. The subject responded by means of a double-throw toggle switch for each hand where a forward push for both hands indicated a "same" response and a backwards pull indicated a "different" response. This procedure was reversed for half of the subjects. When the subjects moved the toggle switches, the reaction time clock stopped and a sets of light located next to the clock indiciated which response the subject had made. Both the subjects' manual response and the response latency (in milliseconds) were recorded. In addition, the subject's confidence rating of his response was collected after each trial.

Procedure

At the beginning of the experiment, all subjects were instructed about the nature of the visual recognition task they were to receive. They were told that the second stimulus pattern was was to be presented randomly to one of the visual fields and that their best fixation point was the X in the center of the viewing field. Subjects used both eyes in viewing the stimulus presentations.

Three conditions were run within each experimental session. The session consisted of discriminating pairs of patterns in a same-different paradigm on the basis of (a) the geometric figures formed by the dots (a blocked presentation), (b) the number of dots (a blocked presentation), or (c) the form and/or the number of dots (a mixed presentation). Six one and one-half hour experimental sessions were required for each subject. The order of presentation of the three conditions was counterbalanced for each subject and between all subjects. The stimuli used in each experimental session for all three conditions were the same. Each condition consisted of two trial blocks of 24 pairs of patterns preceeded by four warm up trials. The trial blocks were quasi-randomized to insure an equal number of both right and left presentations and the four classes of paired presentations described earlier. On the day of the first testing session, there was a practice session of three ten-trial blocks, one block for each of the three conditions. Results of these trial blocks were not included in the data analysis.

The three conditions in each experimental session were:

I) Blocked Form

In this condition, the subject was instructed to respond only to the geometric figure that the dot patterns formed and to ignore the number of dots. If the two patterns were not identical, he was to move the switches in each hand in the direction that indicated "difference", otherwise he was to move them in the direction that indicated "sameness". The subject was also required, following each manual response, (a) to indicate the confidence rating of his response on a scale of one to three, where a "one" represented maximun uncertainty, a "two" represented a neutral response, and a "three" represented maximun certainty and (b) to indicate verbally the geometric form of the second pattern that he saw.

II) Blocked Number

In this condition, the subject was instructed to respond only to the number of dots between the two patterns within a pair of stimuli and to ignore the global form of the patterns. If the number of dots was not the same, the subject was to respond by moving the levers of the switches in the direction that indicated difference. If the number was identical, he was to move the levers in the direction that indicated sameness. Again, the subject was required, following each manual response, (a) to indicate verbally the confidence rating of his response on a scale one to three and (b) to indicate the number of dots observed in the second pattern of each pair.

III) Mixed Form and Number

This condition involved having the subject make a judgement of different or same between patterns used previously. These judgements were to be based on the number of dots, the geometric figure of the dots formed, or on both the geometric figure and the number of dots. A pair of stimulus patterns was considered to be the same only if they consisted of both the same number of dots and the same geometric form. A confidence rating was required of the subject after each manual response. In addition, the subject was to indicate verbally, after each trial, the geometric form and the number of dots observed in the second pattern. The verbal reponse was used to determine whether the subject was responding to the appropriate dimensions of difference (form, number, or both).

The instructions given to the subject in each of the three conditions are presented in Appendix B.

Data Analysis

The scores were averaged separately for each of the four classes of stimulus pairs (i.e., Same Form-Same Number (SFSN)) in the blocked form, blocked number, and mixed form and number discrimination tasks. Since each of the four classes of stimulus pairs had two levels of visual field of presentation (LVF and RVF), three levels of number of dots (4, 5, and 6), and three types of procedural task demands, each subject contributed 72 mean scores to each dependent variable.

A 2x2x2x3x3 repeated measures ANOVA was used to analyze separately each of the four dependent variables. The factors in the ANOVA were: the pair form, the pair number, the visual field of presentation, the number of dots in the second pattern of a pair, and the procedural task demands. The first two factors, the pair form and the pair number were represented by the four different classes of stimulus pairs (Figure 4). As stated previously in the Stimuli section, the SFSN amd SFDN class of stimulus pairs constituted the equivalent form pairs and the DFSN and DFDN class of stimulus pairs constituted the nonequivalent form pairs. For the pair number factor, the SFSN and DFSN class of stimulus pairs accounted for the equivalent dot number pairs and the SFDN and DFDN class of stimulus pairs accounted for the nonequivalent dot number pairs.

In addition to the main ANOVA for each of the dependent variables, the dependent variables were further analyzed with a 2x2x2x3 repeated measures ANOVA for each task demand. The factors in the ANOVA were the pair form, the pair number, the number of dots in the second pattern of a pair, and the visual field of presentatation. Simple main effects testing was also used to evaluate the interaction between the visual field of presentation and the number of dots in the second pattern for all dependent variables of the three procedural task demands.

The ANOVA were performed using the Biomedical Computer Program BMDP2V (Dixon, 1979). Ajustment of the repeated measures ANOVA was achieved with the epsilon correction procedure (Jennings & Wood, 1976). Multiple comparison testing of the significant F ratios with three or more means was accomplished by the Shaffer-Welsch procedure. Sample mean differences with a probability of chance occurence at 5% or less were considered to be significant.

An F max test for the homogeneity of population variance was performed for each ANOVA (Kirk, 1968). Table 1 indicates that the assumption of homogeniety of variance was found acceptable in every ANOVA.

Signal detection was used to determine sensitivity and decision bias for the number of correct manual responses in the blocked presentations of the form and the number discrimination tasks, and the mixed presentation of the form and number discrimination task. Since a small number of trials were run in each condition, a nonparametric signal detection analysis (Grier, 1971) was used to prevent a violation of the assumptions of the

Table 2

Hartley F max test for homogeneity of population-error variances.

	K	n	F max
I) 2x2x2x3x3 repeated measures ANOVA:			
Number of correct manual responses	72	10	13.17 n.s.
Latency to correct responses	72	10	3.47 n.s.
Number of correct verbal responses	72	10	17.25 n.s.
Confidence ratings	72	10	12.59 n.s.
II) 2x2x2x2x3 repeated measures ANOVA			
Blocked number	48	10	3.254 n.s.
Blocked form	48	10	3.910 n.s.
Mixed form and number	48	10	2.857 n.s.
III) 2x2x2x3 repeated measures ANOVA			
A) Blocked number task:			
Number of correct manual responses	24	10	6.68 n.s.
Latency to correct responses	24	10	2.93 n.s.
Number of correct verbal responses	24	10	9.31 n.s.
Confidence ratings	24	10	4.58 n.s.
B) Blocked form task:			
Number of correct manual responses	24	10	6.60 n.s.
Latency to correct responses	24	10	2.93 n.s.
Number of correct verbal responses	24	10	9.31 n.s.
Confidence ratings	24	10	4.58 n.s.
C) Mixed form and number task:			
Number of correct manual responses	24	10	7.88 n.s.
Latency to correct responses	24	10	4.98 n.s.
Number of correct verbal responses	24	10	3.60 n.s.
Confidence ratings	24	10	3.62 n.s.
IV) 2x2x3 repeated measures ANOVA			
A) Blocked number task:			
Sensitivity (P(I))	12	10	3.29 n.s.
Decision bias (B'')	12	10	4.78 n.s.

Key to the Table

*** : Significant

n.s. : Nonsignificant

Table 2 (continued)

Hartley F max test for homogeneity of population-error variances.

	K	n	F max
B) Blocked form task:			
Sensitivity (P(I))	12	10	5.94 n.s.
Decision bias (B'')	12	10	6.13 n.s.
V)2x3x3 repeated measures ANOVA			
Mixed form and number task:			
Sensitivity (P(I))	18	10	4.91 n.s.
Decision bias (B'')	18	10	8.74 n.s.

Key to the Table

*** : Significant
n.s. : Nonsignificant

parametric analysis. Sensitivity (P(I) and decision bias (B'') measures were calculated separately for the number of dots in the second pattern (4,5, or 6) and for the visual field of presentation (LVF and RVF) in all three tasks.

In the signal detection analysis for the blocked-form discrimination task, the signal trials were defined as nonequivalent form stimulus pairs (DFSN and DFDN) and the nonsignal or noise trials were defined as the equivalent form pairs (SFSN and SFDN). For the number discrimination task, the signal trials were the nonequivalent number pairs (SFDN and DFDN) and the noise trials were the equivalent number pairs (SFSN and DFSN). Finally, in the mixed form and number discrimination task, the signal trials were the nonequivalent number pairs (SFDN), the different form pairs (DFSN), and the different form and number pairs (DFDN). The noise trials in all three class of stimulus pairs were the equivalent form and number pairs (SFSN). Following the determination of the sensitivity and decision bias measures, the data were analyzed by means of a 2x2x3 repeated measures ANOVA for the blocked form and blocked number discrimination tasks. A 2x3x3 repeated measures ANOVA was used to analyze the two measures for the mixed form and number discrimination task.

The results of all the ANOVA were divided according to laterality and nonlaterality conditions (summary tables for the ANOVA are found in Appendix C). This distinction was made possible by the presence of the 'visual field of presentation' factor in the ANOVA. In the Results, the nonlateralized findings are reported under the heading of, The Order of Visual Processing, and the lateralized findings are reported under the heading of, Hemispheric Differences in Visual Processing.

CHAPTER 3

RESULTS

As stated previously, the Results section has been divided into two parts: 1) the order of visual processing and 2) hemispheric differences in visual processing. Under each major heading, the results have been further divided on the basis of the five dependent variables: 1) manual accuracy; 2) response latency; 3) verbal accuracy; 4) confidence rating; and 5) sensitivity and decision bias parameters from the signal detection analysis. An introduction describing the major dependent variable findings is presented at the beginning of each major section.

The Order of Visual Processing

Three hypotheses were formulated in the Introduction section (page 43) with respect to the order of visual processing. An analysis of the data revealed that all three hypotheses were at least partially confirmed.

The first hypothesis stated that the processing of dot form would be faster and more accurate than the processing of dot number for both the blocked and mixed presentations. For blocked presentations, the hypothesis was confirmed in the analysis of both the manual accuracy and manual latency measures. Faster and more accurate manual responses were noted in the blocked form task compared to the blocked number task. However, the relationship was found to depend on the number of dots in the second pattern of the stimulus pair. As shown in Figures 5 (page

70) and 12 (page 83), the difference between form and number processing was only significant for the five and six dot second patterns.

Findings contrary to the first hypothesis were obtained in the analysis of the verbal accuracy measure. In general, the blocked number task produced significantly more accurate verbal responses than the blocked form task (Figure 15, page 88), suggesting that the obtained relationship between the blocked form and the blocked number tasks is contingent upon the dependent variable chosen.

With respect to the mixed form and number task, the first hypothesis was confirmed with findings from both the manual accuracy and latency measures. Significantly faster and more accurate manual responses were noted to a difference in form compared to a difference in dot number. As in the blocked presentations, however, a different relationship was found in the analysis of the verbal accuracy measure. Significantly more accurate verbal responses were reported to a difference in number compared to a difference in form.

The second hypothesis stated that the nonequivalence of the number of dots within the two patterns of a pair would interfere with both the speed and accuracy of form processing in the blocked form task. This hypothesis was confirmed only in the analysis of the manual accuracy measure. Significantly more accurate manual performance was obtained for the equivalent-number pairs compared to the nonequivalent-number pairs.

The third hypothesis stated that nonequivalence of dot form within the two patterns of a pair would interfere with both the speed and accuracy of dot number processing in the blocked number task. This hypothesis was confirmed for both accuracy measures. As shown in Figures 6 (page 72) and 13 (page 85), greater accuracy was noted in the blocked number task with the equivalent-form pairs compared to the nonequivalent-form pairs.

In addition to the findings related to the three hypotheses, a number of other findings were uncovered for the three task demands.

Blocked number. The 4-way ANOVA of each of the four dependent variables for the blocked number task revealed two additional findings: (1) with an increase in the number of dots in the second pattern of a pair from four to six, there was a corresponding significant decrease in manual accuracy (Figure 5, page 70), response speed (Figure 12, page 83), verbal accuracy (Figure 15, page 88), and confidence ratings (Figure 18, page 94); and (2) for the verbal report measure, significantly greater accuracy was found with the equivalent-number pairs compared to the nonequivalent-number pairs (Figure 13, page 85).

Blocked form. The 4-way ANOVA of each of the four dependent variables for the blocked form task produced three major findings: (1) for the manual accuracy, verbal accuracy, and confidence rating measures, significantly more accurate and confident performance was obtained as the number of dots in the second pattern of a pair increased from four to six (Figure 5, page 70, Figure 15, page 88, & Figure 18, page 94); (2) for the manual accuracy and latency measures, significantly faster and more accurate performance was found with the nonequivalent-form pairs compared to the equivalent-form pairs (Figures 6, page 72 & Figure 11, page 81); and (3) for the verbal report, significantly greater verbal accuracy was obtained with the nonequivalent-form pairs compared to the equivalent-form pairs when the number of dots in the two patterns of a pair was the same. The difference between the equivalent and nonequivalent-form pairs was not significant when the number of dots was different (Figure 16, page 89).

Mixed form and number. The four-way ANOVA of the four dependent variables for the mixed task produced four major findings: (1) for the manual accuracy and response latency measures, significantly faster and more accurate performance was obtained with the nonequivalent-form pairs compared to the equivalent-form pairs (Figures 6, page 72 & Figure 11, page 81); (2) for the verbal report variable, a different relationship was obtained: the equivalent-form pairs produced greater accuracy compared to the nonequivalent-form pairs (Figure 14, page 86); (3) for manual accuracy, verbal report accuracy and confidence rating measures, the equivalent-number pairs produced significantly greater accuracy and confidence than the nonequivalent-number (Figure 10, page 79, Figure 13, page 85, Figure 19, page 95); and (4) for the verbal accuacy measure, significantly greater accuracy was found with the equivalent-form pairs when the number of dots within the two patterns of a pair was the same. The difference between the two types of form pairs was not significant when the number of dots was different (Figure 16, page 89).

Manual accuracy

Table 3 presents the results of the 5-way repeated measures ANOVA of the manual accuracy, response latency, verbal accuracy, and confidence rating dependent variables. The factors in the ANOVA were the task demands, the pair number, the pair form, the number of dots in the second pattern of a pair, and the visual field of presentation. As shown in Table 3, the analysis of the number of correct manual responses revealed a siginificant main effect for the task demands factor. Signficantly greater accuracy was obtained in the blocked form (X=71%) and the mixed form and number (X=73%) tasks compared to the blocked number task (X=66%) (Shaffer-Welsch multiple comparison test). The difference between the blocked form and mixed form and number tasks was not significant.

In addition, the interaction between task demands and the number of dots in the second pattern was significant (Figure 5). Significantly greater accuracy was found in the blocked number and the mixed form and number tasks when the number of dots in the second pattern was four compared to when it was six. Testing with the Shaffer-Welsch test indicated that the difference between the four and six dot patterns was only significant for the blocked number task. In the blocked form task, the four and five dot second patterns produced the lowest levels of accuracy while the six dot pattern produced the highest. The difference between the four and six dot and the five and six dot second patterns was found to be significant with the Shaffer-Welsch multiple comparison test.

Table 3

F values from the 5-way ANOVA of the manual accuracy, response latency, verbal accuracy, and confidence rating dependent variables.

	Dependent Variable			
Source of Variance	MA	RL	VR	CR
T	13.07***	15.41***	127.88***	7.13***
N	.01	3.12	49.97***	18.75***
F	18.94***	8.82***	86.33***	.66
Q	10.07***	2.79	6.82***	11.56***
T X N	2.51	2.51	4.88***	11.48***
T X F	55.30***	18.31***	6.49***	1.35
T X Q	9.42***	6.51***	6.54***	28.19***
N X F	7.79***	.00	39.55***	3.85
N X Q	4.08***	8.94***	2.29	5.00***
F X Q	.94	.11	1.77	.61
T X N X F	.50	.26	4.58***	5.59***
T X N X Q	7.25***	6.39***	2.63***	13.58***
T X F X Q	8.79***	.88	1.62	.51
N X F X Q	4.34***	.29	1.02	1.96
T X N X F X Q	3.25***	.29	1.83	6.02***
VF	.09	3.78	.02	.86
VF X T	.18	.37	2.61	.95
VF X N	.04	1.09	.27	4.44
VF X F	.11	5.84***	3.12	5.52***
VF X Q	1.75	.35	2.36	1.31
VF X T X N	.06	.44	.39	.37
VF X T X F	2.26	.52	.16	.43
VF X T X Q	3.73***	.35	3.33***	1.09
VF X N X F	.70	.19	.67	.70
VF X N X Q	1.11	2.07	.29	.25
VF X F X Q	.30	.21	.81	1.42
VF X T X N X F	.75	.64	2.10	.18
VF X T X N X Q	.14	.63	.29	.82
VF X T X F X Q	1.55	1.31	2.80	.36
VF X N X F X Q	.76	.60	.87	.52
VF X T X N X F X Q	.99	1.76	1.99	.93

Key to the Table

T : Task demand

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

MA : Manual accuracy

RL : Response latency

VR : Verbal accuracy

CR : Confidence rating

*** : Significant

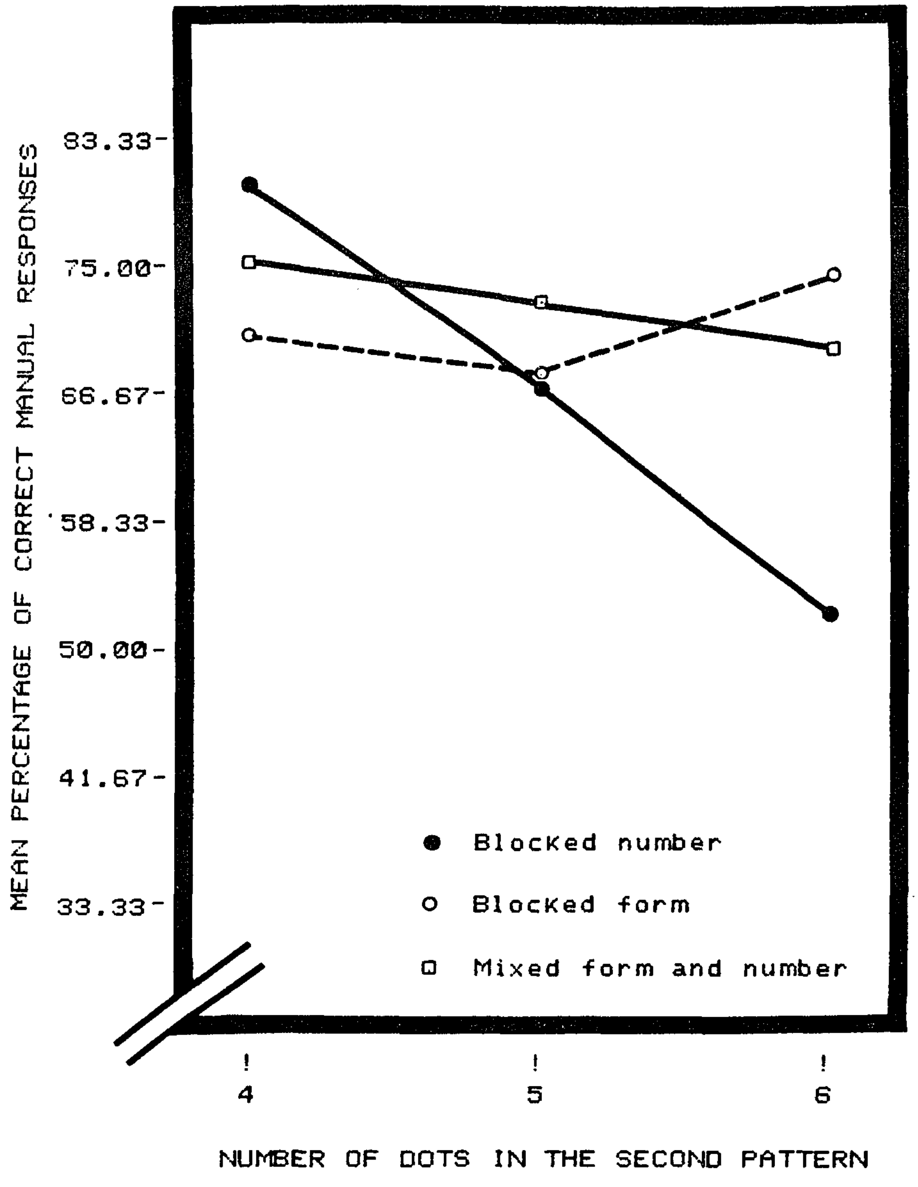


Figure 5. Mean percentage of correct manual responses for the interaction between the task demands and the number of dots in the second pattern of a pair.

Finally, the interaction between task demands and pair form was also significant in the 5-way ANOVA (Figure 6). Significantly higher accuracy was found in the blocked number task with equivalent-form pairs compared to nonequivalent-form pairs. In the blocked form and mixed form and number tasks, the reverse relationship was obtained in that significantly higher accuracy scores were noted with the nonequivalent-form pairs.

Each task was further analyzed in a 4-way repeated measures ANOVA for the four dependent variables. The results are summarized in Table 4. As can be seen, the 4-way ANOVA of the manual accuracy measure indicated several additional significant findings for the three tasks. For example, in the blocked number task, the interaction between pair number and pair form was found to be significant. The interaction is depicted in Figure 7. Significantly greater accuracy was obtained with the equivalent form pairs compared to the nonequivalent form pairs when the number of dots within the two patterns of the pair were the same. A smaller but nonsignificant difference between equivalent- and nonequivalent-form pairs was indicated when the number of dots within the two patterns of the pair was different.

In the blocked form task, the main effect for pair number was noted to be significant (Table 4). Significantly greater manual accuracy was demonstrated with equivalent-number pairs (73% versus 69%) compared to the nonequivalent-numbered pairs.

In addition to the above main effect, a significant interaction between the number of dots in the second pattern and pair form was also noted in the 4-way ANOVA of the blocked form

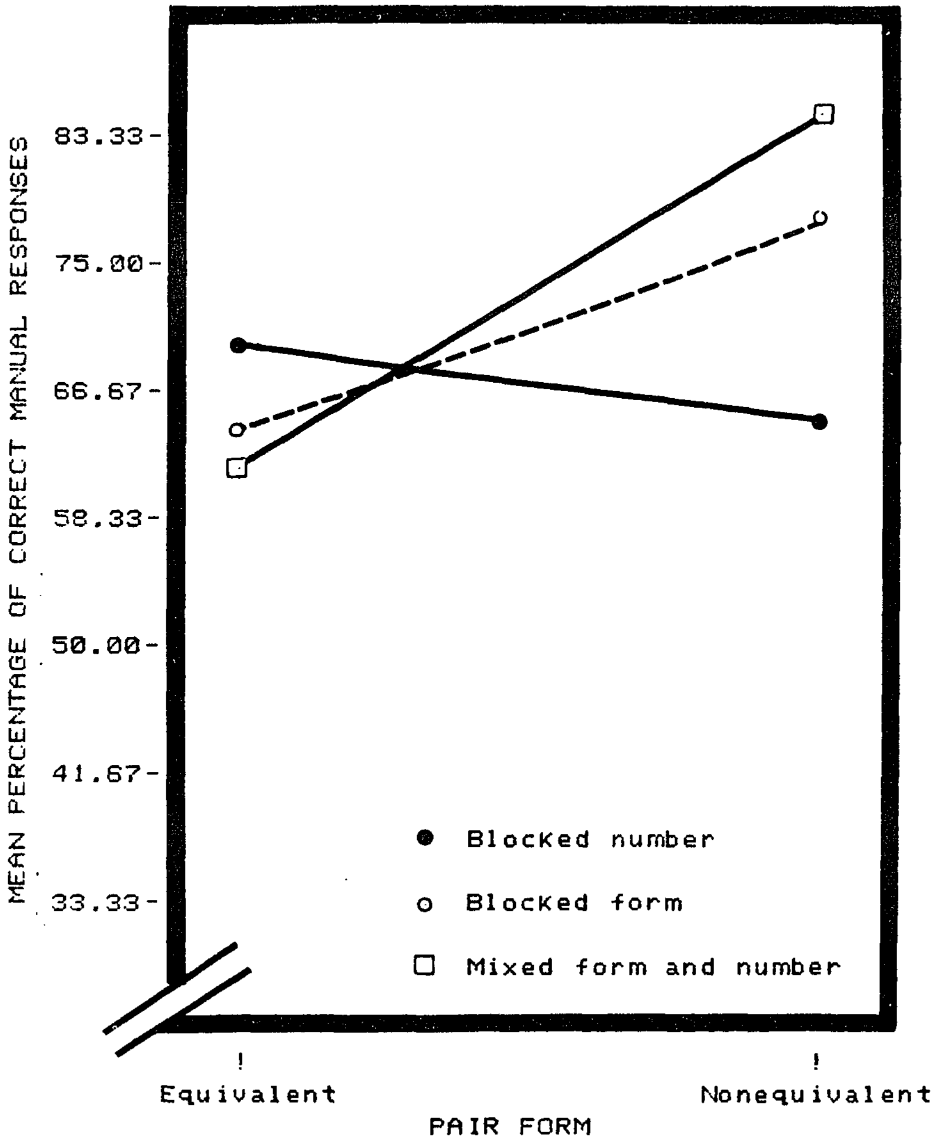


Figure 6. Mean percentage of correct manual responses for the interaction between the task demands and the pair form.

Table 4

F values from the 4-way ANOVA of the manual accuracy, response latency, verbal accuracy, and confidence rating dependent variables for the blocked number, blocked form, and mixed form and number tasks.

	Dependent Variable			
Source of Variance	MA	RL	VR	CR
Blocked number task:				
N	.27	1.05	12.62***	27.62***
F	10.38***	.45	17.08***	.06
Q	11.21***	7.17***	8.90***	35.43***
N X F	5.99***	.23	6.91***	1.71
N X Q	3.26	9.52***	2.04	18.98***
F X Q	3.11	.18	4.27***	.41
N X F X Q	1.17	1.21	2.19	2.63
VF	.32	1.03	.53	2.65
VF X N	.01	3.33	.30	.46
VF X F	2.26	.86	2.04	.27
VF X Q	2.73	.66	4.74***	1.52
VF X N X F	.06	.43	1.37	.12
VF X N X Q	.54	2.73	.49	.54
VF X F X Q	.48	.43	3.21	.47
VF X N X F X Q	.89	.92	2.36	.10
Blocked form task:				
N	5.26***	2.93	.96	6.55***
F	32.26***	5.40***	8.26***	.48
Q	8.34***	1.49	3.26	8.81***
N X F	.74	.75	6.55***	7.06***
N X Q	3.49***	.24	2.47	3.26
F X Q	5.26***	.52	1.38	.77
N X F X Q	.67	3.63***	.68	5.32***
VF	.00	.18	6.66***	.30
VF X N	.00	.37	.29	1.59
VF X F	1.59	1.86	.85	5.65***
VF X Q	2.51	.94	1.15	.51
VF X N X F	2.45	.61	1.90	.62
VF X N X Q	.84	1.78	.31	.41
VF X F X Q	.21	.46	.58	1.04
VF X N X F X Q	.21	.71	.37	1.41

Table 4 (continued)

F values from the 4-way ANOVA of the manual accuracy, response latency, verbal accuracy, and confidence rating dependent variables for the blocked number, blocked form, and mixed form and number tasks.

	Dependent Variable			
Source of Variance	MA	RL	VR	CR
Mixed form and number task:				
N	6.44***	.64	89.36***	6.78***
F	299.84***	30.07***	83.93***	1.37
Q	2.55	.68	2.34	5.23***
N X F	.14	1.13	58.60***	4.68***
N X Q	11.54***	.98	2.92	1.35
F X Q	7.90***	1.84	.52	.39
N X F X Q	9.21***	1.75	1.97	4.04***
VF	.03	.06	.80	.00
VF X N	.17	.53	.33	.18
VF X F	.01	1.95	2.81	1.22
VF X Q	4.93***	.66	1.89	2.18
VF X N X F	.03	.08	.66	1.05
VF X N X Q	.13	.24	.13	.02
VF X F X Q	2.23	.22	2.70	.42
VF X N X F X Q	2.82	1.49	2.01	.46

Key to the Table

N : Pair number
F : Pair form
Q : Number of dots in the second pattern of a pair
VF : Visual field of presentation
MA : Manual accuracy
RL : Response latency
VR : Verbal accuracy
CR : Confidence ratings
*** : Significant

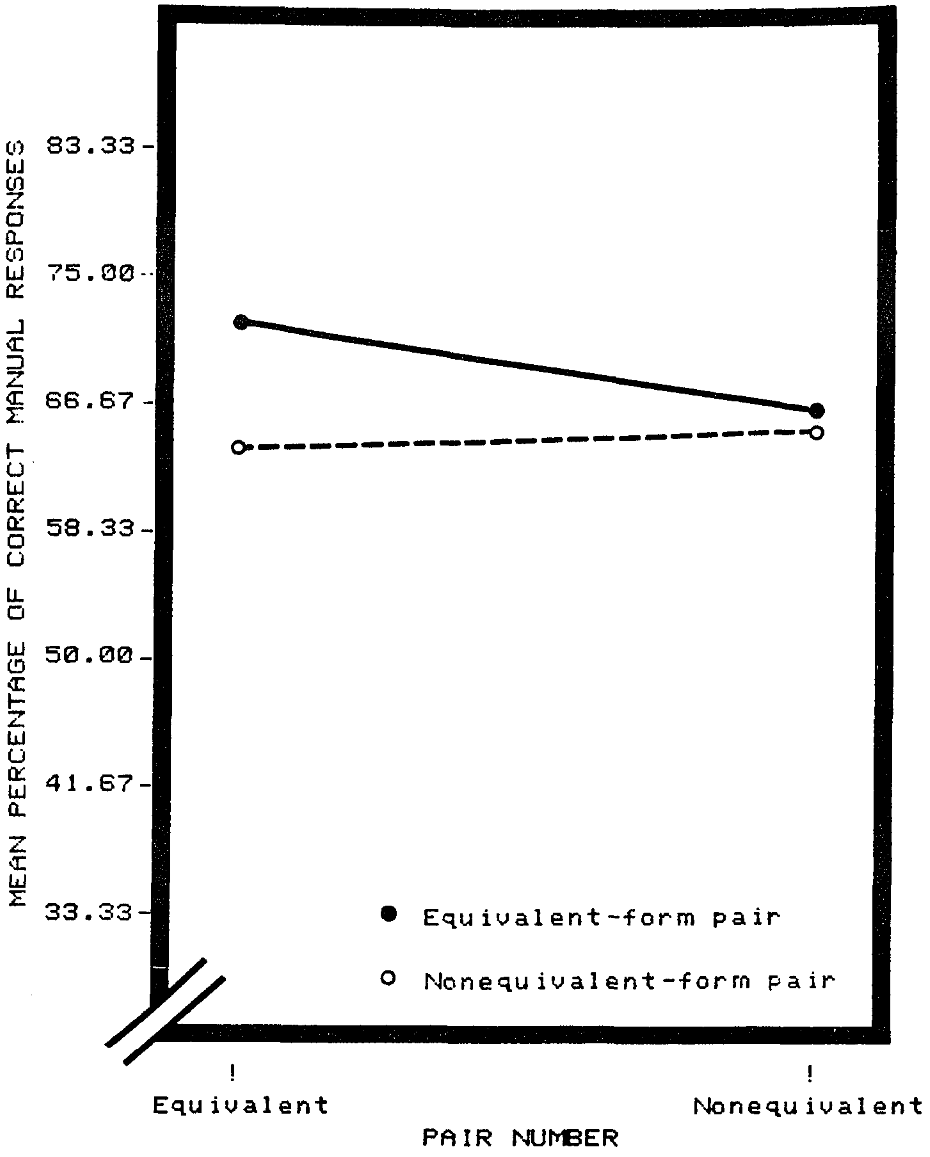


Figure 7. Mean percentage of correct manual responses from the blocked number task for the interaction between the pair form and the pair number.

task. Figure 8 illustrates the interaction. Significantly greater accuracy was found with nonequivalent-form pairs compared to equivalent-form pairs when the number of dots in the second pattern decreased from six to four (Shaffer-Welsch test).

Finally, the analysis of the mixed form and number task revealed that the main effect for the pair number factor was significant. Higher manual accuracy was noted with nonequivalent-number pairs (75% versus 70%) compared to equivalent-numbered pairs. In addition, the interaction between the pair form and the number of dots in the second pattern and the interaction between the pair number and the number of dots in the second pattern were significant. Figures 9 and 10, respectively describe the interactions. As shown in Figure 9, a significantly greater difference in the manual accuracy of the nonequivalent-form pairs over the equivalent-form pairs was observed when the number of dots in the second pattern increased from 4 to 6 (Shaffer-Welsch test). A different relationship was obtained in the analysis of the manual accuracy measure for the blocked form task in that significantly greater accuracy was found with nonequivalent-form pairs compared to equivalent-form pairs when the number of dots in the second pattern decreased from six to four.

Figure 10 illustrates the interaction between pair number and the number of dots in the second pattern. The difference in manual accuracy of the nonequivalent-number pairs over the equivalent-number pairs was significant when the number of dots in the second pattern was four or five but nonsignificant when the number of dots in the second pattern was six.

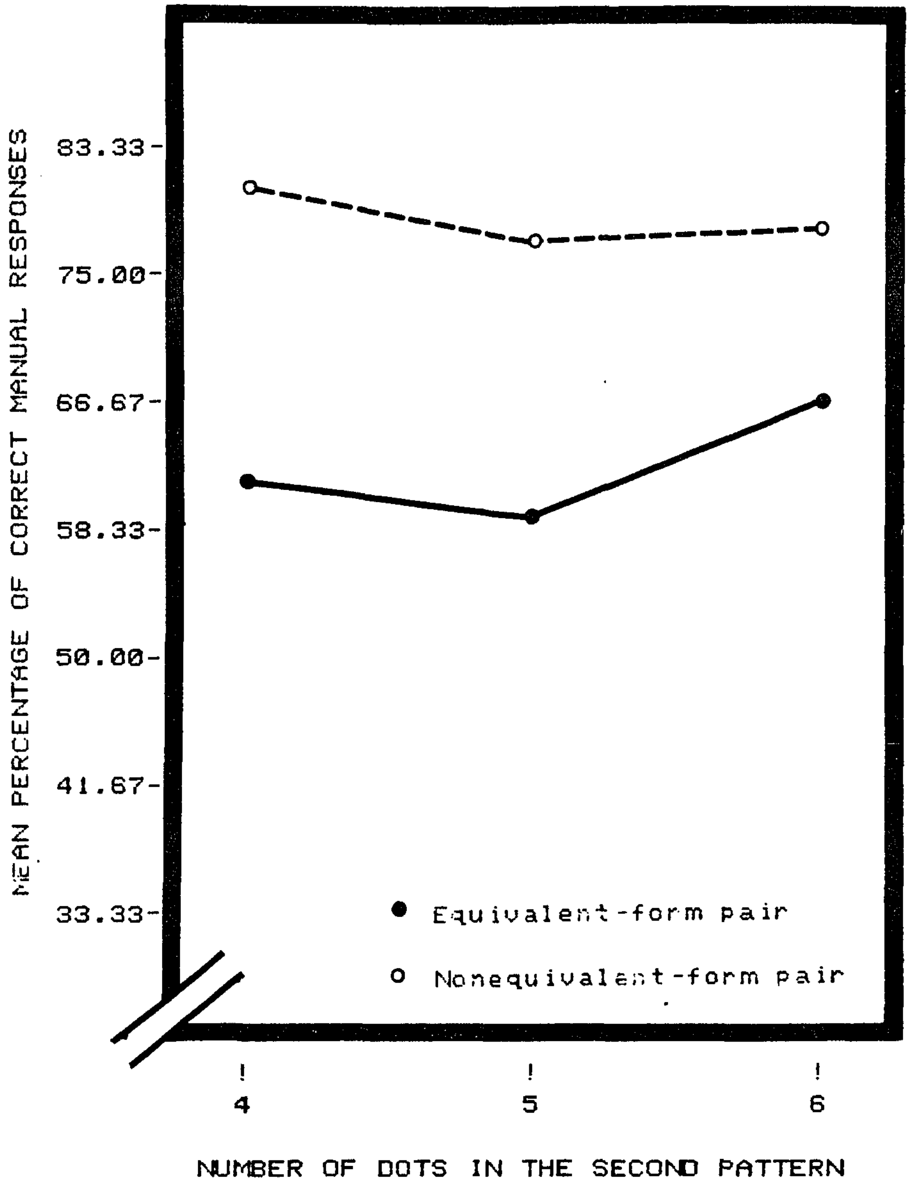


Figure 8. Mean percentage of correct manual responses from the blocked form task for the interaction between the pair form and the number of dots in the second pattern.

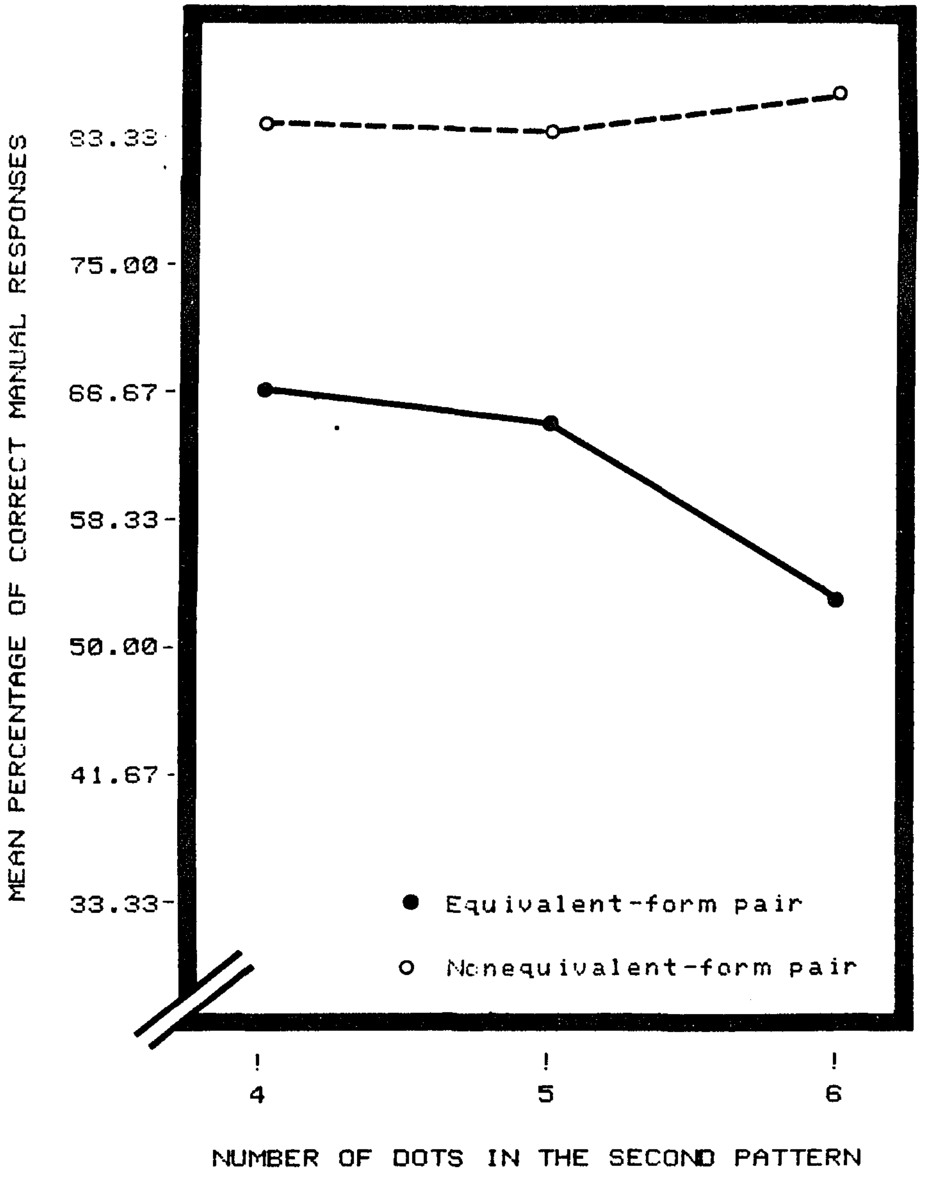


Figure 9. Mean percentage of correct manual responses from the mixed form and number task for the interaction between the pair form and the number of dots in the second pattern of a pair.

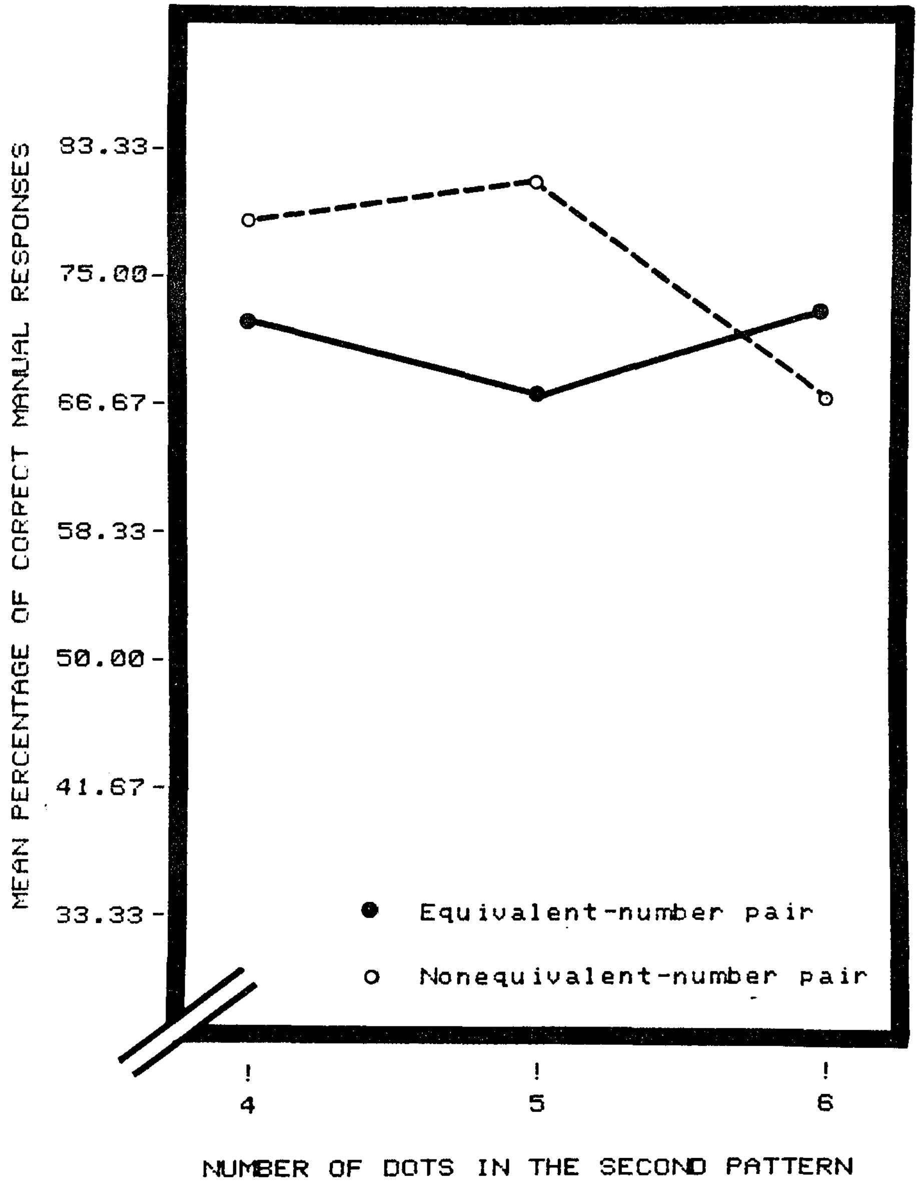


Figure 10. Mean percentage of correct manual responses from the mixed form and number task for the interaction between the pair number and the number of dots in the second pattern of a pair.

Response latency

Table 3 (page 69) presents the summary of the 5-way repeated measures ANOVA for the latency to correct responses. As in manual accuracy dependent variable, the main effect for task demands reached significance at the .05 level in the 5-way ANOVA of response latency. Significantly faster performance was demonstrated for the blocked form task (X=1.534) compared to both the blocked number (X=1.682) and the mixed form and number tasks (X=1.757). The difference between the blocked number and mixed form and number tasks was not significant on testing with the Shaffer-Welsch procedure. Overall, the results of the 5-way ANOVA of the manual accuracy and response latency suggest that the blocked form tasks produces significantly faster and more accurate manual responses.

Both the interaction between pair form and the task demands and the interaction between the number of dots in the second pattern of a pair and the task demands were also significant in the 5-way ANOVA of response latency. The interactions are depicted in Figures 11 and 12, respectively. As shown in Figure 11, nonequivalent-form pairs produced significantly faster responses compared to equivalent-form pairs in both the blocked form and the mixed form and number task. The difference between equivalent- and nonequivalent-form pairs was not significant for the blocked number task. The other interaction between the number of dots in the second pattern and task demands is presented in Figure 12. As shown, the response latency in the number task increased significantly as the number of dots in

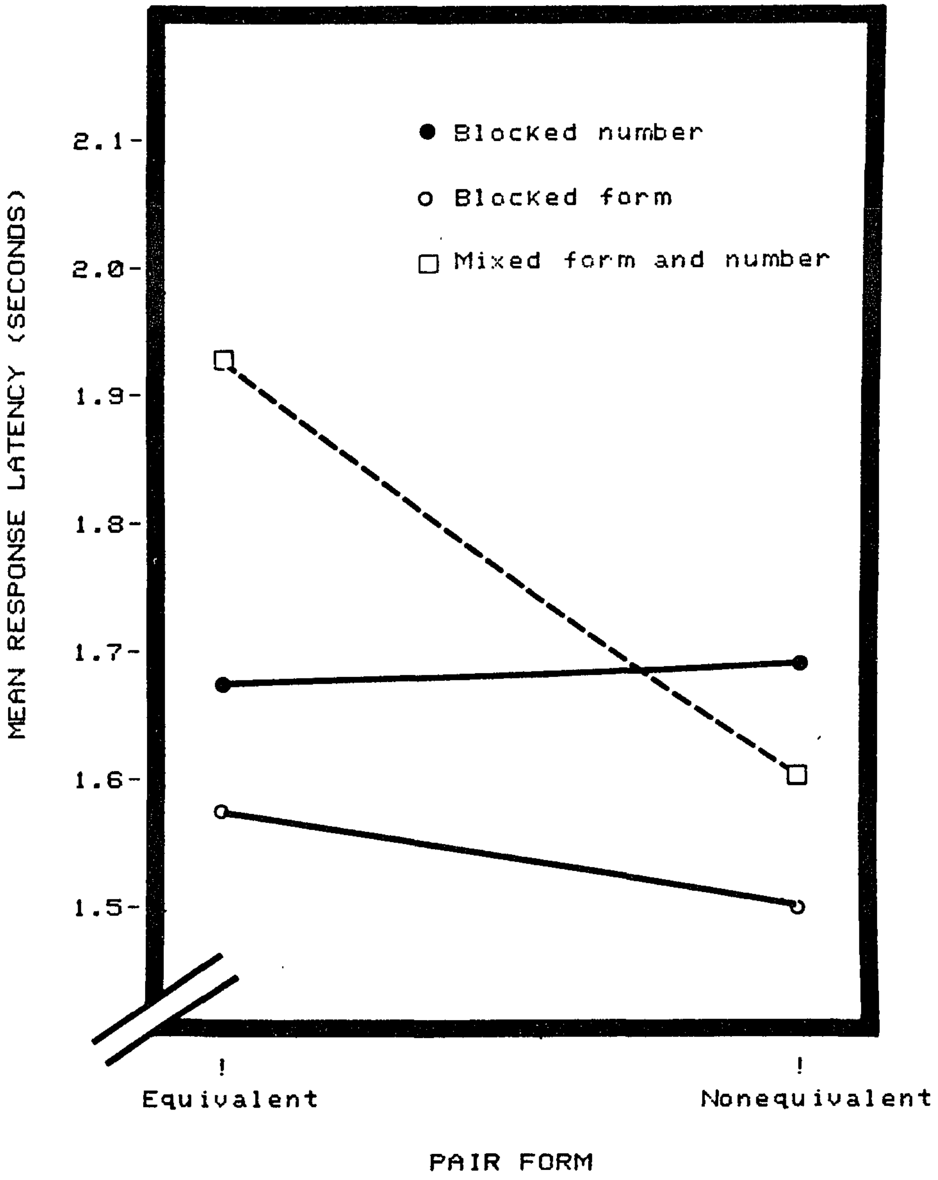


Figure 11. Mean response latency for the interaction the task demands and the pair form.

the second pattern increased from 4 to 6 (Shaffer-Welsch test). A similar finding was not obtained for the other two tasks. In both the blocked form and the mixed form and number tasks, response latency decreased significantly as the number of dots in the second pattern increased from four to six.

The summary of the 4-way ANOVA of the response latency for each of the task demands is presented in Table 4 (page 73). As can be seen in the table, the interaction between the pair number and the number of dots in the second pattern of a pair in the blocked number task was also found to be significant. Significantly faster responses were obtained with equivalent-number pairs (1.602 versus 1,752; 1.886 versus 2.025) compared to nonequivalent-number pairs when the number of dots in the second pattern was 4 or 6. The opposite relationship was obtained when the number of dots in the second pattern was five. Nonequivalent-number pairs were found to be significantly faster (1.802 versus 1.998) than equivalent-number pairs (Shaffer-Welsch test).

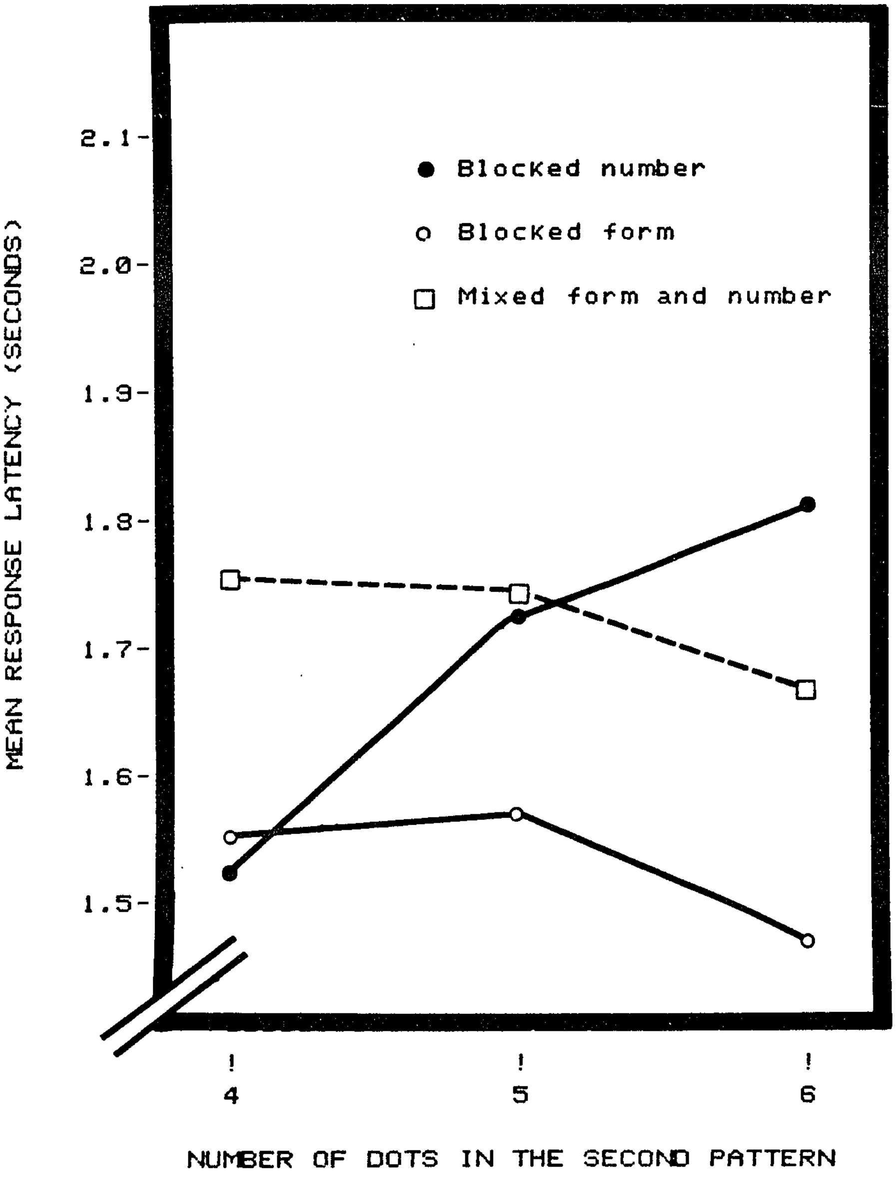


Figure 12. Mean response latency for the interaction between the task demands and the number of dots in the second pattern of a pair.

Verbal accuracy

Table 3 (page 69) presents the results of the 5-way ANOVA for the number of correct verbal responses. As shown in the table, the main effect for task demands was found to be significant. The blocked number task produced that highest verbal accuracy performance (X=65%). This was followed by the significantly less accurate performance on the blocked form task (X=58%). The poorest verbal accuracy performance was indicated with the mixed form and number task (X=36%) (Shaffer-Welsch test). Overall, the findings from the verbal accuracy measure were not consistent with those obtained from the manual accuracy measure where significantly greater accuracy was found in the blocked form task (71% versus 66%) compared to the blocked number task.

The interaction between the pair number and the task demands and the interaction between the pair form and task demands were also significant in the analysis of the verbal accuracy. Figure 13 and 14 illustrates the relationships. As shown in Figure 13, the equivalent-number pairs were associated with significantly higher verbal accuracy compared to the nonequivalent-number pairs in the blocked number, the blocked form, and the mixed form and number tasks (Shaffer-Welsch test). In addition, the equivalent-form pairs produced significantly higher verbal accuracy than the nonequivalent-form pairs in all three tasks (Figure 14). The latter finding was contrary to the one obtained in the analysis of the manual accuracy measure in that the nonequivalent forms were associated with a higher level of accuracy in the blocked

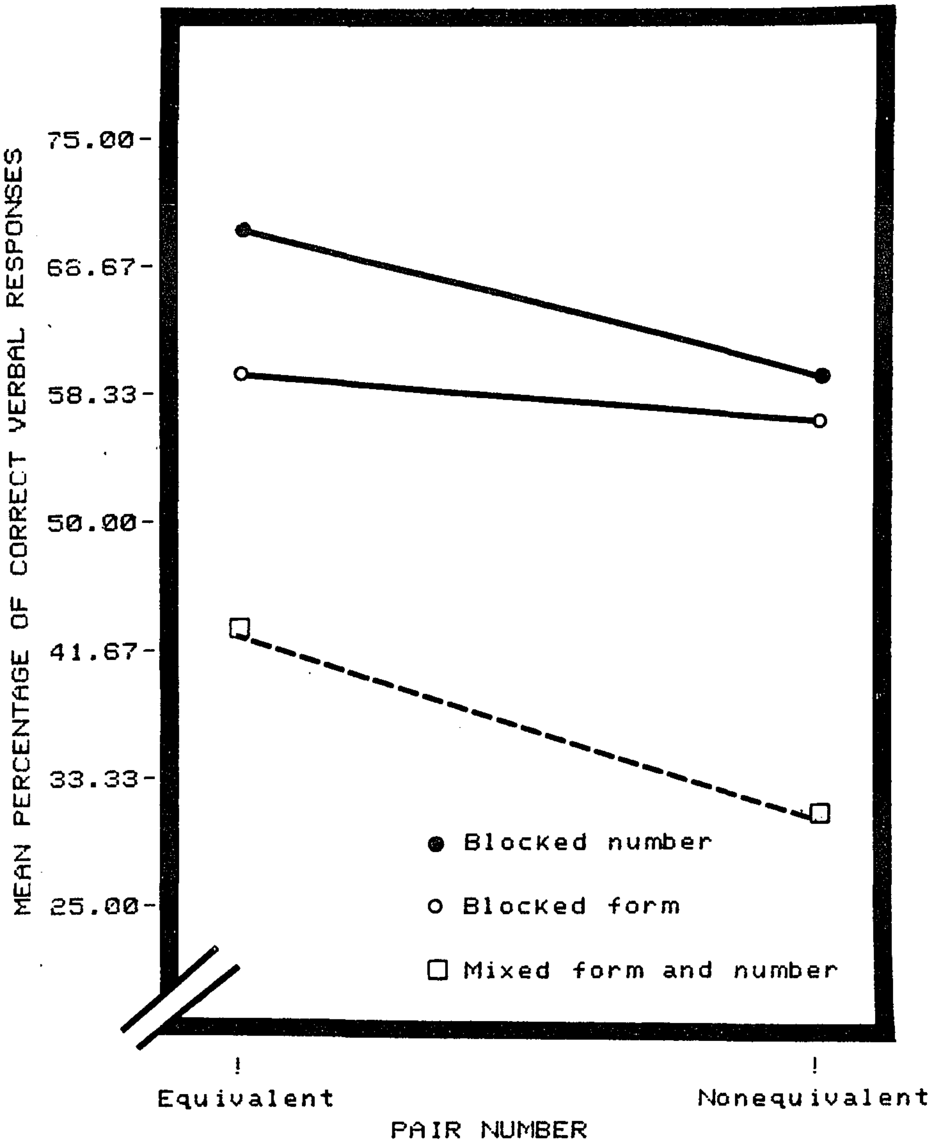


Figure 13. Mean percentage of correct verbal responses for the interaction between the task demands and the pair number.

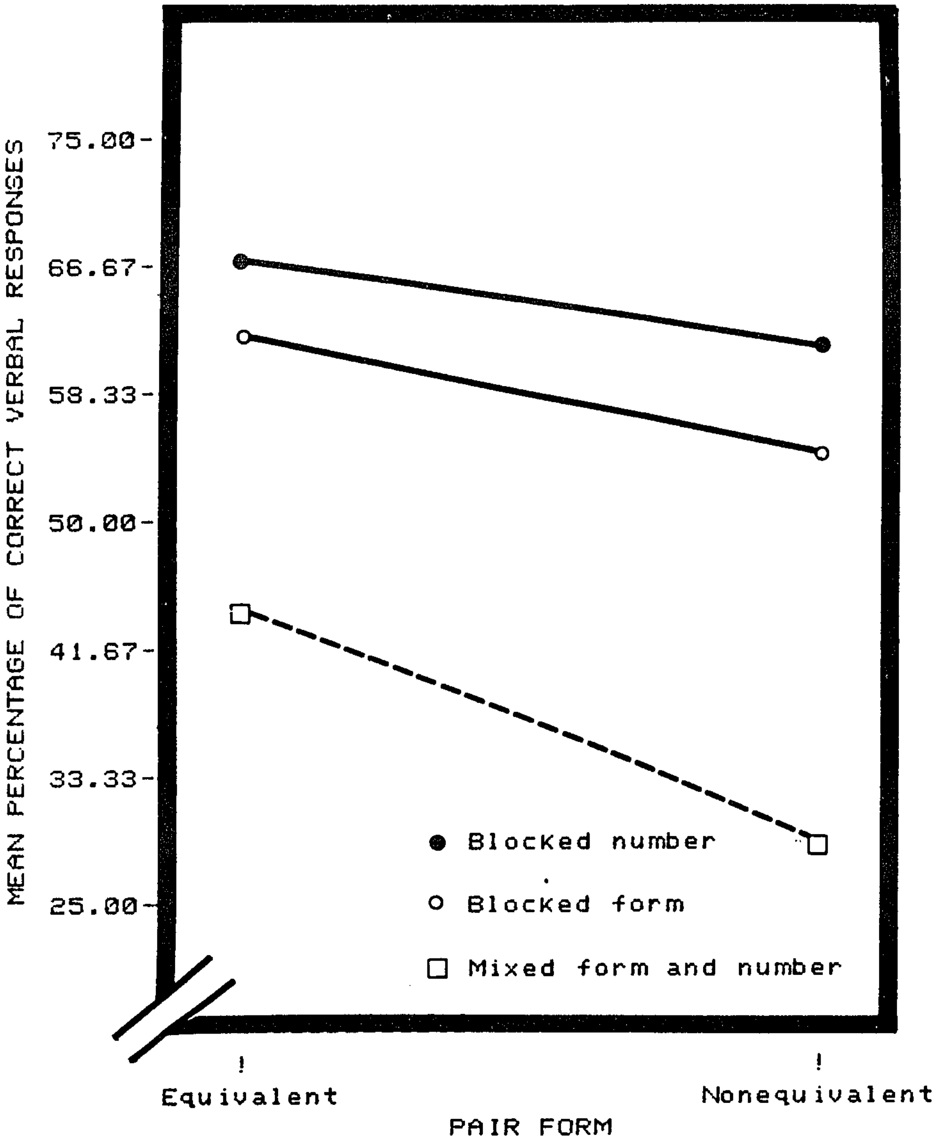


Figure 14. Mean percentage of correct verbal responses for the interaction between the task demands and the pair form.

form and mixed form and number tasks (page 72).

The interaction between the number of dots in the second pattern and the task demands was also significant (Figure 15). A significant decrease in verbal accuracy for both the blocked number and mixed form and number tasks was found with an increase in the number of dots of the second pattern of a pair from four to six. The opposite set of findings were noted for the blocked form task. An increase in the number of dots in the second pattern of a pair was associated with an significant increase in verbal accuracy (Shaffer-Welsch test).

Finally, a significant 3-way interaction was obtained in the 5-way ANOVA for the pair number, the pair form, and the task demand factors. The interaction is illustrated in Figure 16. Significantly more accurate verbal responses were found with equivalent-form pairs when the number of dots in the two patterns of a pair were the same. When the number of dots within the pair of stimulus patterns were different, nonsignificant findings were noted for the equivalent- and nonequivalent-form pairs. These findings are consistent with those described earlier for the analysis of the manual accuracy dependent variable in the blocked number and mixed form and number tasks.

Table 4 (page 73) describes the results from the 4-way ANOVA of the verbal accuracy for the three tasks. The 4-way ANOVA provided an additional finding not obtained in the 5-way ANOVA: the interaction between the number of dots in the second pattern and pair form in the blocked number task. Figure 17 illustrates the relationship. The difference in accuracy between

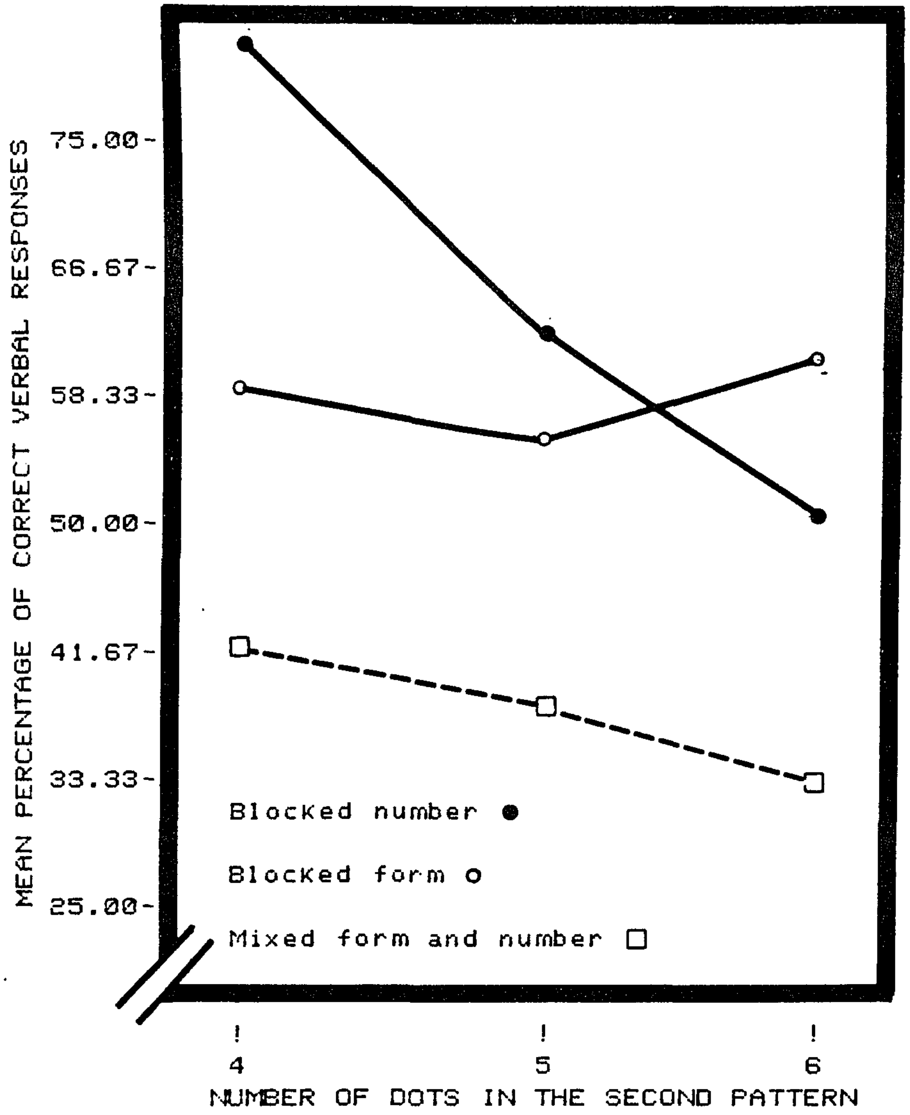


Figure 15. Mean percentage of correct verbal responses for the interaction between the task demands and the number of dots in the second pattern of a pair.

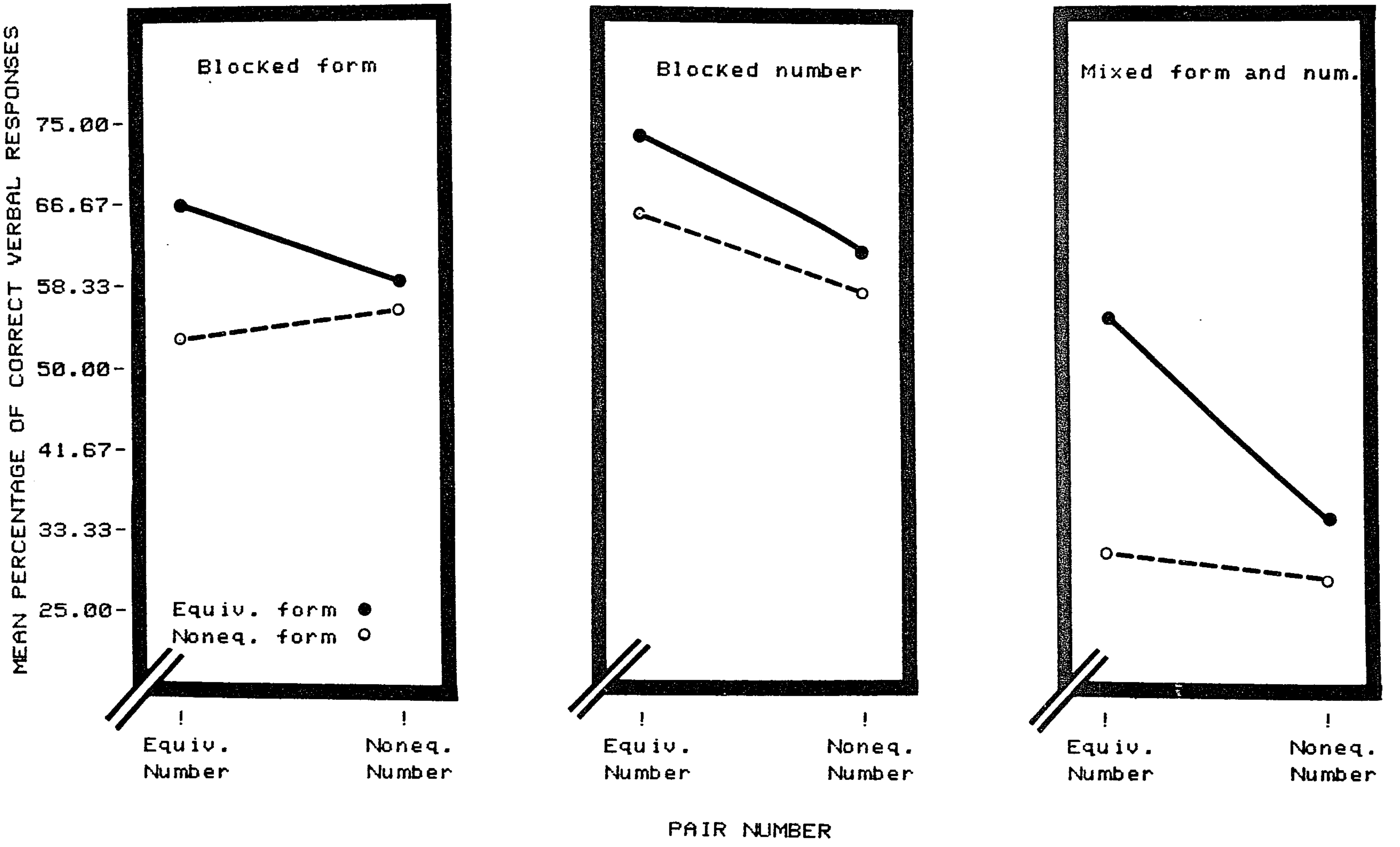


Figure 16. Mean percentage of correct verbal responses for interaction between the pair form, the pair number and the task demands.

the equivalent- and nonequivalent-form pairs was significant only when the number of dots in the second pattern was five or six (Shaffer-Welsch test).

Chance corrected accuracy

The findings from the 5-way repeated measures ANOVA of the chance corrected accuracy measures for the blocked number, blocked form, and the mixed form and number tasks are summarized in Table 5. The factors in the ANOVA were the same as in the 4-way ANOVA but with the addition of the chance corrected accuracy factor. The factors were composed of the chance corrected manual and verbal accuracy measures.

As shown in Table 5, the main effect for chance corrected accuracy was only significant in the 5-way ANOVA of both the blocked number and the mixed form and number tasks. In those two tasks, chance corrected verbal accuracy (47% vs 26% and 34% vs 19%) was found to be significantly higher than chance corrected manual accuracy. The difference between chance corrected verbal accuracy and chance corrected manual accuracy was observed to be nonsignificant for the blocked form task (40% vs 42%). Overall, the results suggest that for the blocked number and mixed form and number tasks, subjects were more accurate with a verbal response compared to a manual response.

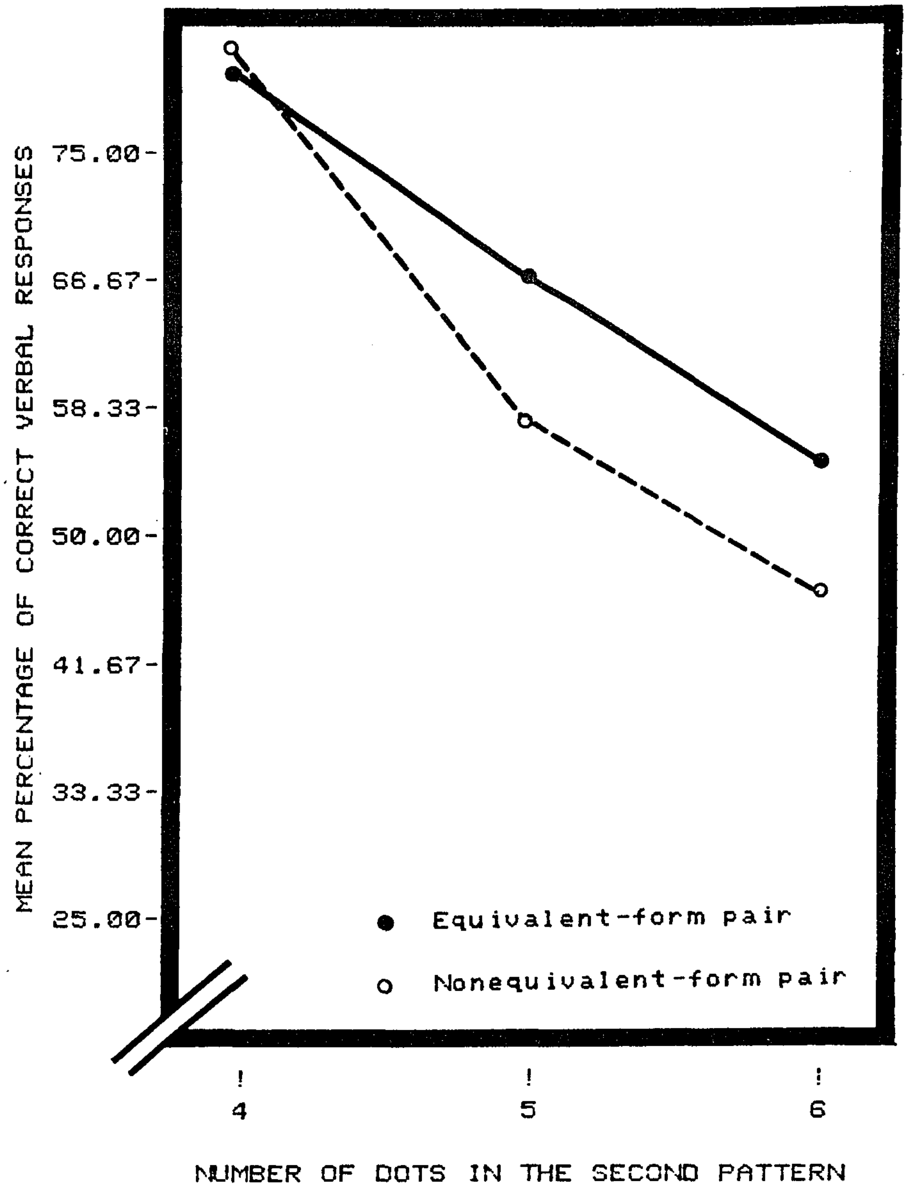


Figure 17. Mean percentage of correct verbal responses from the blocked number task for the interaction between the pair form and the number of dots in the second pattern.

Table 5

F values from the 5-way ANOVA of the chance corrected accuracy measures for the blocked number, blocked form, and mixed form and number tasks.

	Task		
Source of Variance	BN	BF	MFN
C	197.36***	1.46	50.60***
N	2.30	3.01	1.04
F	13.03***	6.72***	73.72***
Q	10.23***	8.62***	2.97
C X N	3.17	.97	47.25***
C X F	.45	56.04***	464.54***
C X Q	7.74***	2.13	.34
N X F	8.05***	4.47	6.10***
N X Q	2.90	4.29***	11.44***
F X Q	3.55***	3.83***	3.17
C X N X F	2.24	3.77	2.43
C X N X Q	4.37***	1.32	6.32***
C X F X Q	4.00***	5.17***	16.07***
N X F X Q	2.64	.98	9.53***
C X N X F X Q	1.64	.47	4.40***
VF	.72	1.21	.07
VF X C	.08	3.74	1.06
VF X N	3.17	.06	.41
VF X F	3.25	.10	1.55
VF X Q	3.22	2.79	4.72***
VF X C X N	3.06	.07	.00
VF X C X F	2.23	2.35	1.05
VF X C X Q	1.81	1.28	2.61
VF X N X F	.19	2.97	.00
VF X N X Q	.44	.12	.25
VF X F X Q	2.64	.14	3.77
VF X C X N X F	.03	.31	.41
VF X C X N X Q	.27	1.69	.05
VF X C X F X Q	.26	.97	.76
VF X N X F X Q	1.88	.47	4.49
VF X C X N X F X Q	.74	.77	1.15

Key to the Table
C : Chance corrected accuracy measures
N : Pair number
F : Pair form
Q : Number of dots in the second pattern of a pair
VF : Visual field of presentation
BN : Blocked number
BF : Blocked form
MFN : Mixed form and number
*** : Significant

Confidence rating

The results from the 5-way ANOVA of the confidence ratings are presented in Table 3 (page 69). As shown in the table, the main effect for task demands was found to be significant. Significantly greater confidence was associated with the blocked form (X=67%) and blocked number (X=69%) tasks compared to the mixed form and number task (X=63%). The difference between the blocked form and blocked number tasks was not significant when the Shaffer-Welsch procedure was applied.

The interaction between the number of dots in the second pattern and the task demands also reached significance in the analysis of the confidence ratings. The interaction is graphed in Figure 18. In the blocked number task, an increase in the number of dots in the second pattern from four to six was associated with a significant decrease in confidence ratings. The reverse relationship was obtained for the blocked form task in that an increase in the number of dots in the second pattern produced a significant increase in the confidence ratings (Shaffer-Welsch). Finally, in the mixed form and number task, the four and six dot second patterns were associated with a significantly higher level of accuracy than the five dot second patterns.

The interaction between pair number and task demands was also found to be significant. As shown in Figure 19, significantly greater confidence was associated with equivalent-number pairs compared to nonequivalent-number pairs for all three task demands. This is similar to the findings obtained with the verbal accuracy measure for the same interaction.

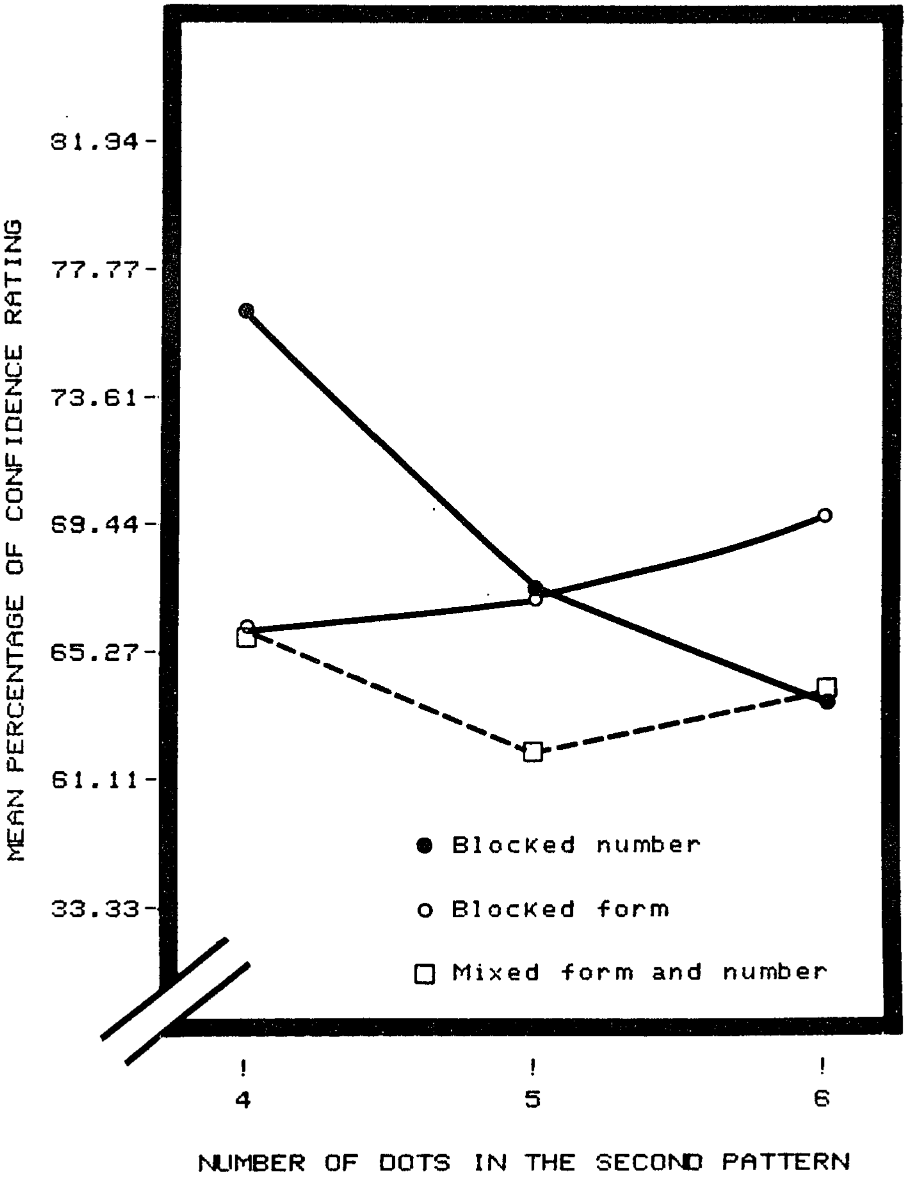


Figure 18. Mean percentage of confidence ratings for the interaction between the task demands and the number of dots in the second pattern of a pair.

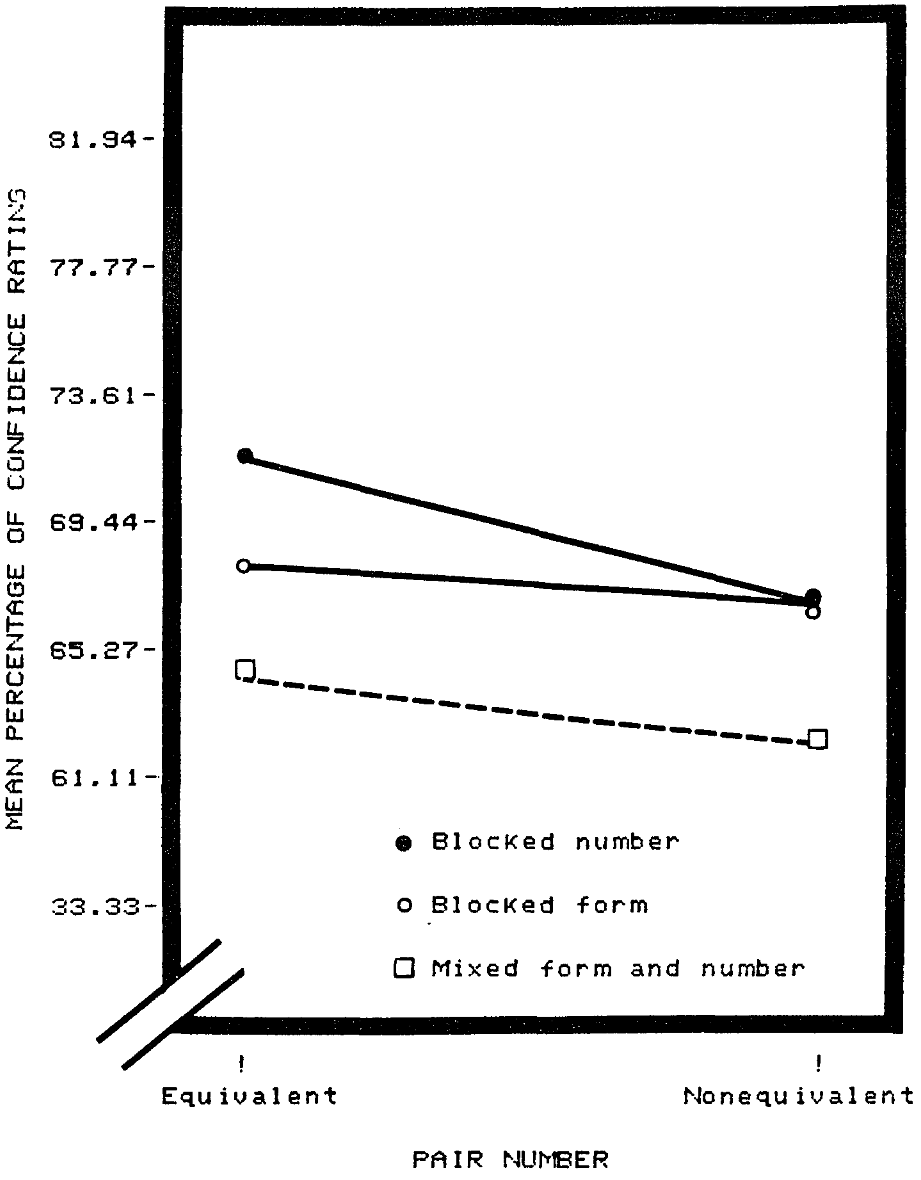


Figure 19. Mean percentage of confidence rating for the interaction between the task demands and the pair number.

As in the analysis of the preceeding three dependent variables, the 4-way ANOVA of the three tasks revealed additional significant findings (Table 4, page 73). For example, in the blocked number task, the interaction between pair number and the number of dots in the second pattern was significant. Significantly higher confidence scores were found with equivalent-number pairs compared to nonequivalent-number pairs when the number of dots in the second pattern was four (Figure 20). When the number of dots in the second pattern was five or six, the difference in confidence between the two types of number pairs was nonsignificant.

In the blocked form task, a significant interaction between pair number and pair form was also obtained. As shown in Figure 21, significantly greater confidence was demonstrated with nonequivalent-form pairs compared to equivalent-form pairs when the number of dots within the two patterns of the pair was the different. When the number of dots within the pair was the same, the difference between the equivalent- and nonequivalent-form pairs was not significant.

Finally, the interaction between the pair number and pair form was found to be significant in the analysis of the mixed form and number task. The interaction is depicted in Figure 22. Nonequivalent-form pairs produced significantly higher levels of confidence compared to equivalent-form pairs when the number of dots within the two patterns of a pair was different. Confidence ratings for both the equivalent and nonequivalent-form pairs were not significantly different when the number of dots was the same (Shaffer-Welsch test).

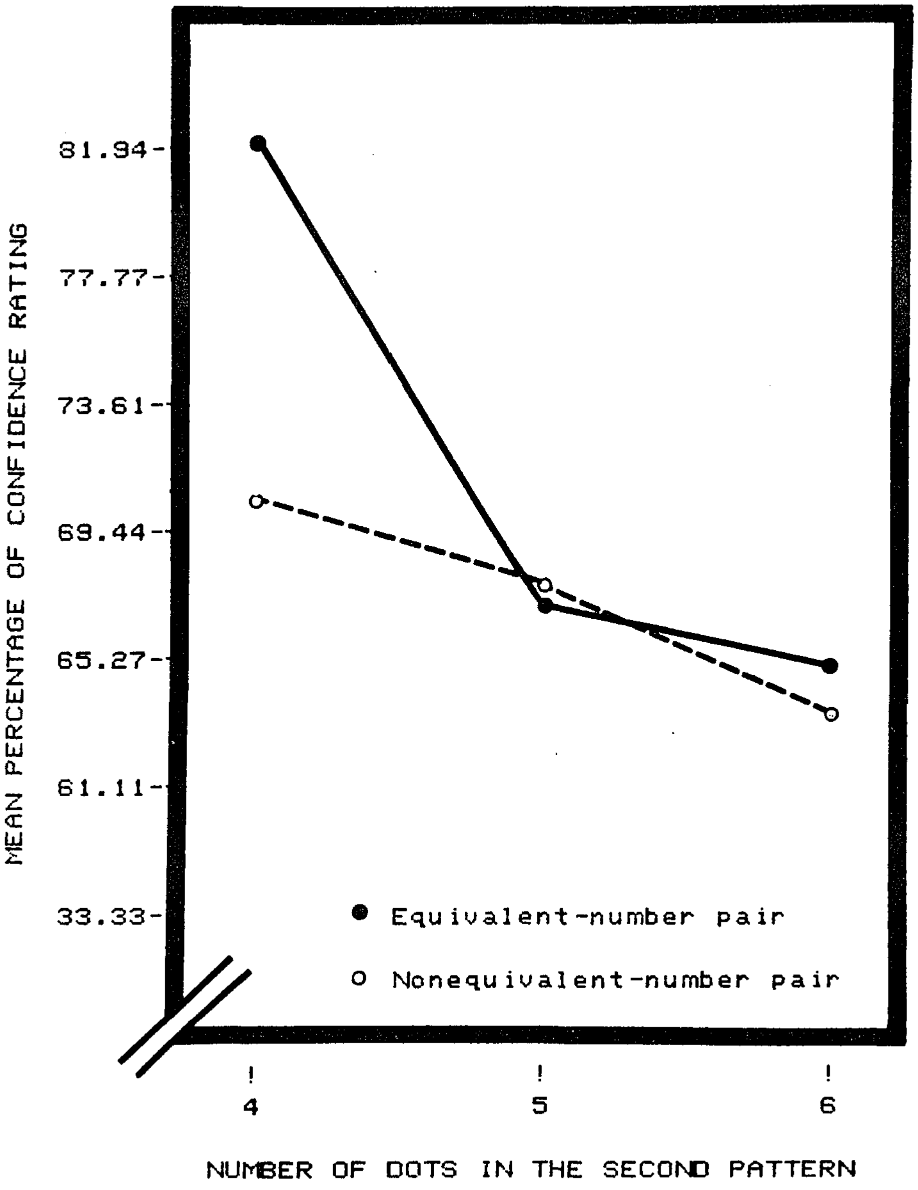


Figure 20. Mean percentage of confidence rating from the blocked number task for the interaction between the pair number and the number of dots in the second pattern of a pair.

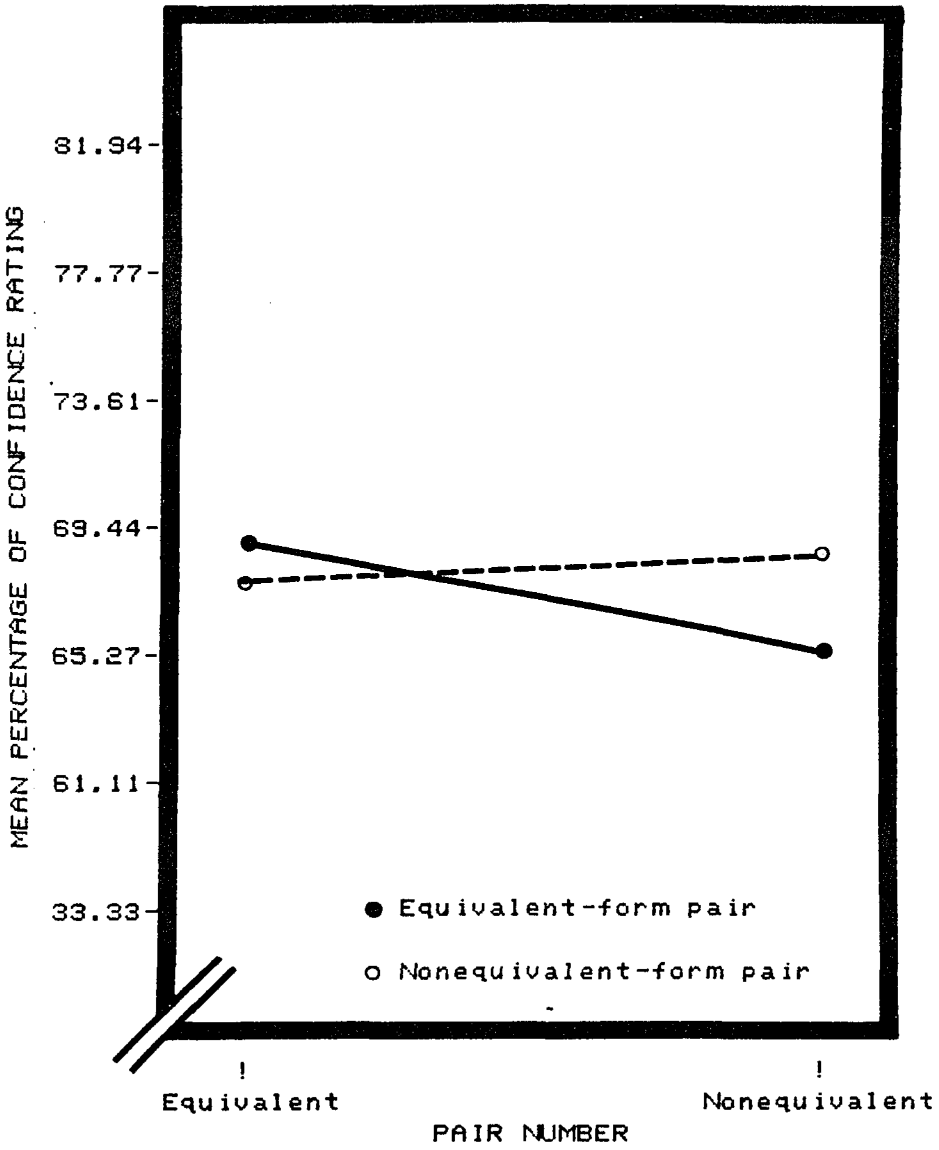


Figure 21. Mean percentage of confidence ratings from the blocked form task for the interaction between pair number and pair form.

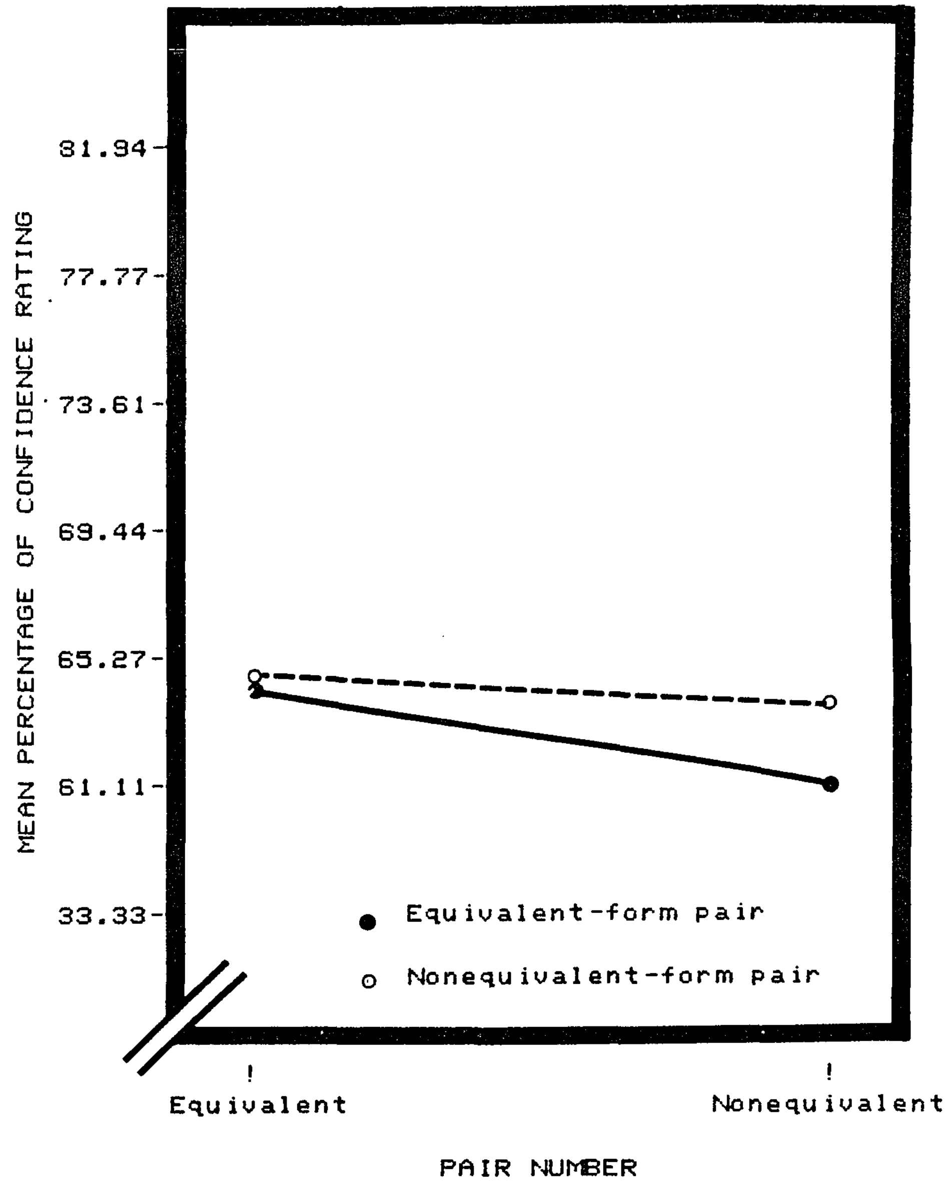


Figure 22. Mean percentage of confidence rating from the mixed form and number task for the interaction between the pair number and the pair form.

Signal Detection

The findings of the 3-way repeated measures ANOVA of the signal detection analysis of the number of correct manual responses are presented in Table 6. As can be seen, the results are divided into sensitivity and decision bias parameters for the three procedural tasks.

Blocked number. Significant main effects were found in the blocked number task for both the pair form and the number of dots in the second pattern of a pair factor. The main effects were consistent with those obtained in the 4-way ANOVA of the manual and verbal accuracy.

A significant interaction between pair form and the number of dots in the second pattern was also demonstrated in the analysis of the blocked number task. As depicted in Figure 23, significantly greater sensitivity was obtained with equivalent-form pairs compared to nonequivalent-form pairs when the number of dots in the second pattern was five. The difference between equivalent- and nonequivalent-form pairs was nonsignificant when the number of dots in the second pattern was four or six.

The ANOVA of the decision bias parameter (Table 6) revealed no significant findings.

Blocked form. In the 3-way ANOVA of the sensitivity parameter for the blocked form task, the main effects for both pair number and the number of dots in the second pattern of a pair were found to be significant. The main effects are consistent with the main effects obtained in the ANOVA of the number of correct manual responses. In addition, the interaction between pair number and

Table 6

F values from the 3-way ANOVA of the signal detection measures, sensitivity and decision bias, for the blocked number, blocked form, and mixed form and number tasks.

	Signal Detection Measure	
Source of Variance	P(I)	B''
Blocked number task:		
F	11.52***	2.51
Q	11.93***	3.22
F X Q	3.53***	1.07
VF	.09	.26
VF X F	1.76	.39
VF X Q	2.26	.78
VF X F X Q	.40	.05
Blocked form task:		
N	7.09***	2.38
Q	7.38***	2.53
N X Q	4.39***	.11
VF	.04	.03
VF X N	.11	1.37
VF X Q	3.19	.10
VF X F X Q	.76	.38
Mixed form and number task:		
TD	59.91***	12.48***
Q	2.28	.97
T X Q	15.78***	6.27
VF	.04	.05
VF X TD	.21	1.87
VF X Q	3.18	2.80
VF X Q X TD	3.08***	1.29

Key to the Table

N : Pair number
F : Pair form
Q : Number of dots in the second pattern of a pair
TD : Type of differnce between two patterns of a pair
VF : Visual field of presentation
P(I) : Sensitivity
B'' : Decision bias

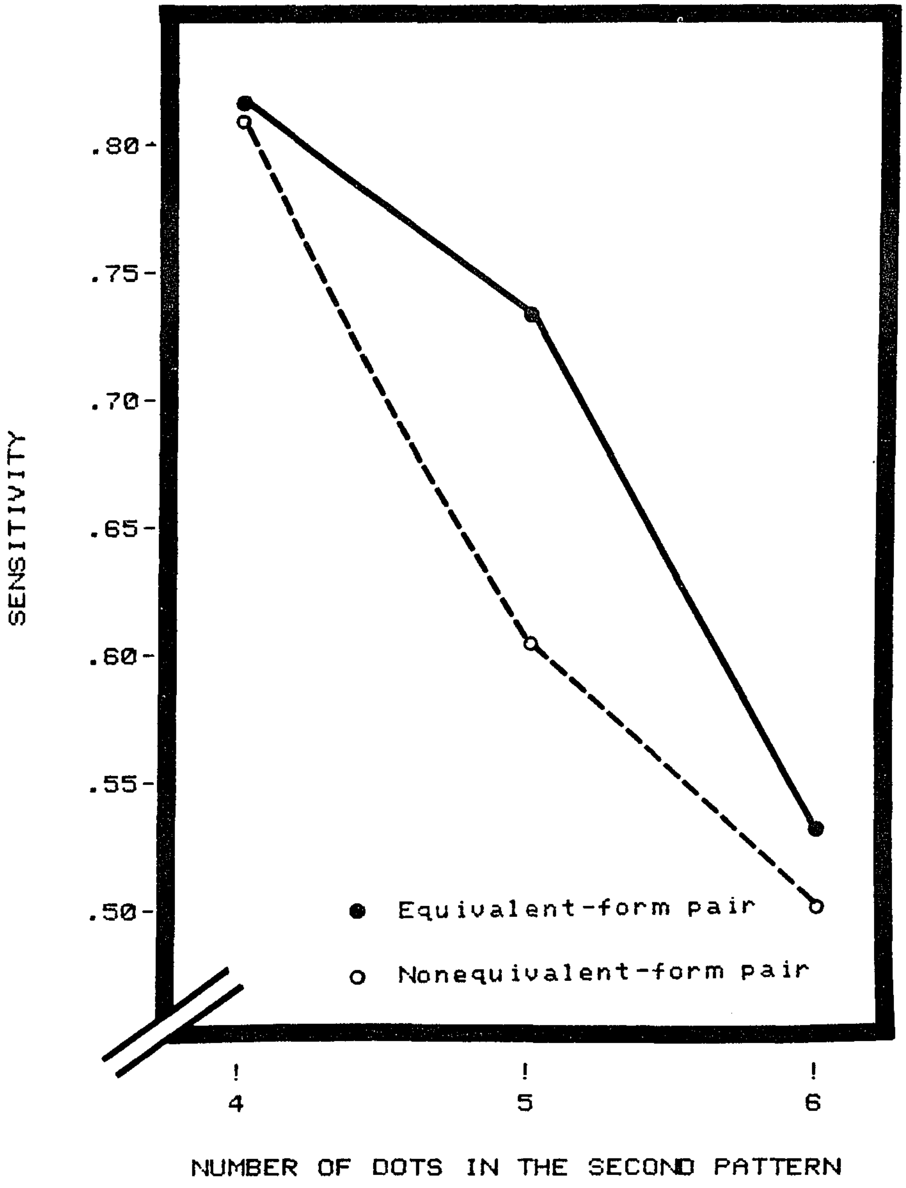


Figure 23. Mean sensitivity from the blocked number task for the interaction between the pair form and the number of dots in the second pattern of a pair.

the number of dots in the second pattern was also significant. As shown in Figure 24, significantly greater sensitivity was found in the blocked form task with the equivalent-number pairs compared to the nonequivalent-number pairs when the number of dots in the second pattern was four or five. The difference in sensitivity between the equivalent- and nonequivalent-number pairs was nonsignificant when the number of dots in the second pattern was six.

As in the blocked number task, the 4-way ANOVA of the decision bias parameter did not produce any significant findings for the blocked form tasks (Table 6)

Mixed form and number. Finally, the 3-way analysis of the sensitivity parameter for the mixed form and number task revealed a significant main effect for type of difference. Significantly greater sensitivity for detecting a difference in the form (X=.719) or both form and number of the dots (X=.746) was found compared to detecting a difference in number of dots (X=.618). However, the difference between the means for detecting a difference in form versus a difference in both form and number was nonsignificant (Shaffer-Welsch test). In addition, the interaction between the type of difference and the number of dots in the second pattern also reached significance in the mixed form and number task. As shown in Figure 25, sensitivity for detecting a difference in number decreased as the number of dots in the second pattern significantly increased from four to six. In detecting a difference in the form or both form and number, the opposite set of findings was obtained. There was a

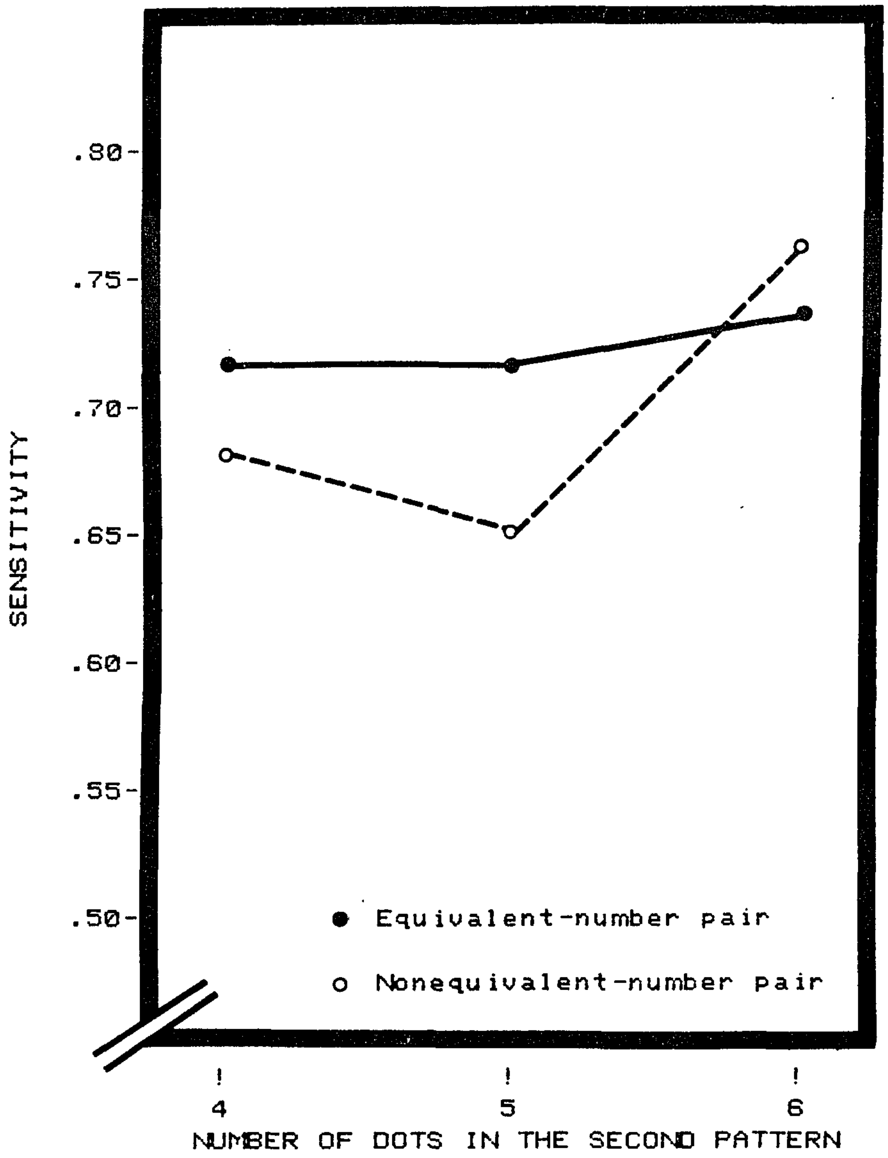


Figure 24. Mean sensitivity from the blocked form task for the interaction between the pair number and the number of dots in the second pattern of a pair.

significant decrease in sensitivity with a change in the number of dots in the second pattern of a pair from four to five, but a significant increase in sensitivity with a change in number of dots from five to six.

Unlike the blocked number and form tasks, the analysis of the decision bias parameter for the mixed form and number task (Table 3) produced significant findings for the main effect of the type of difference and the interaction between the type of difference and the number of dots in the second pattern of a pair. A significantly more conservative strategy was employed in detecting a difference in both the form (X=.280) and the form and number (X=.413) compared to detecting a difference in number (X=.077). The difference between detecting a difference in form versus detecting a difference in both form and number was nonsignificant (Shaffer-Welsch testing). Furthermore, the significant interaction between the type of difference and the number of dots in the second pattern of a pair (as shown in Figure 26) revealed that as the number of dots in the second pattern increased from 4 to 6, a significantly more conservative strategy was employed by the subject to detect a difference in the dot form. The opposite relationship was noted for detecting a difference in both the number and the form and number. As the number of dots increased from 4 to 6, there was a significant shift in the subjects strategy from a more conservative to a more liberal strategy. (Shaffer-Welsch tes[illegible]).

Summary of the Nonlaterality Results

The analysis of the four dependent variables revealed that

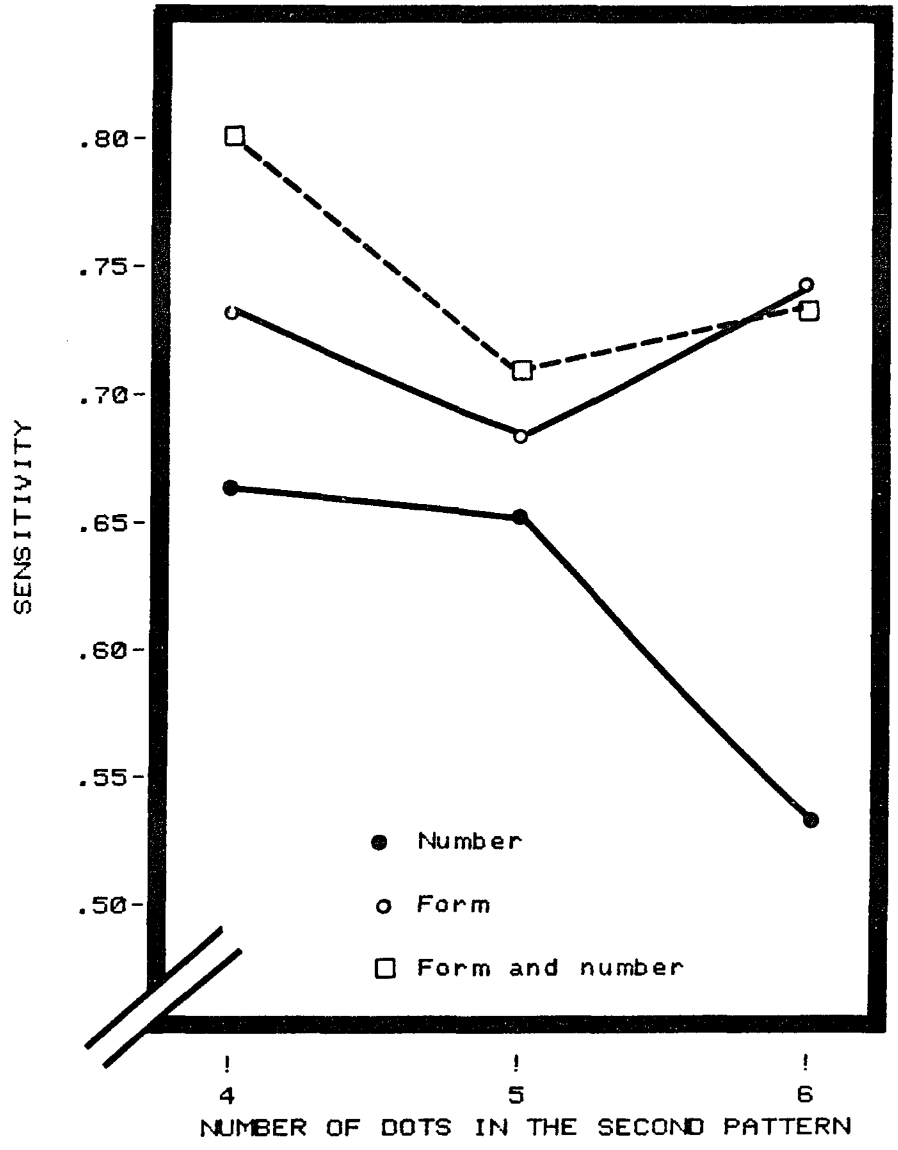


Figure 25. Mean sensitivity from the mixed form and number task for the interaction between the number of dots in the second pattern and the type of difference between two patterns.

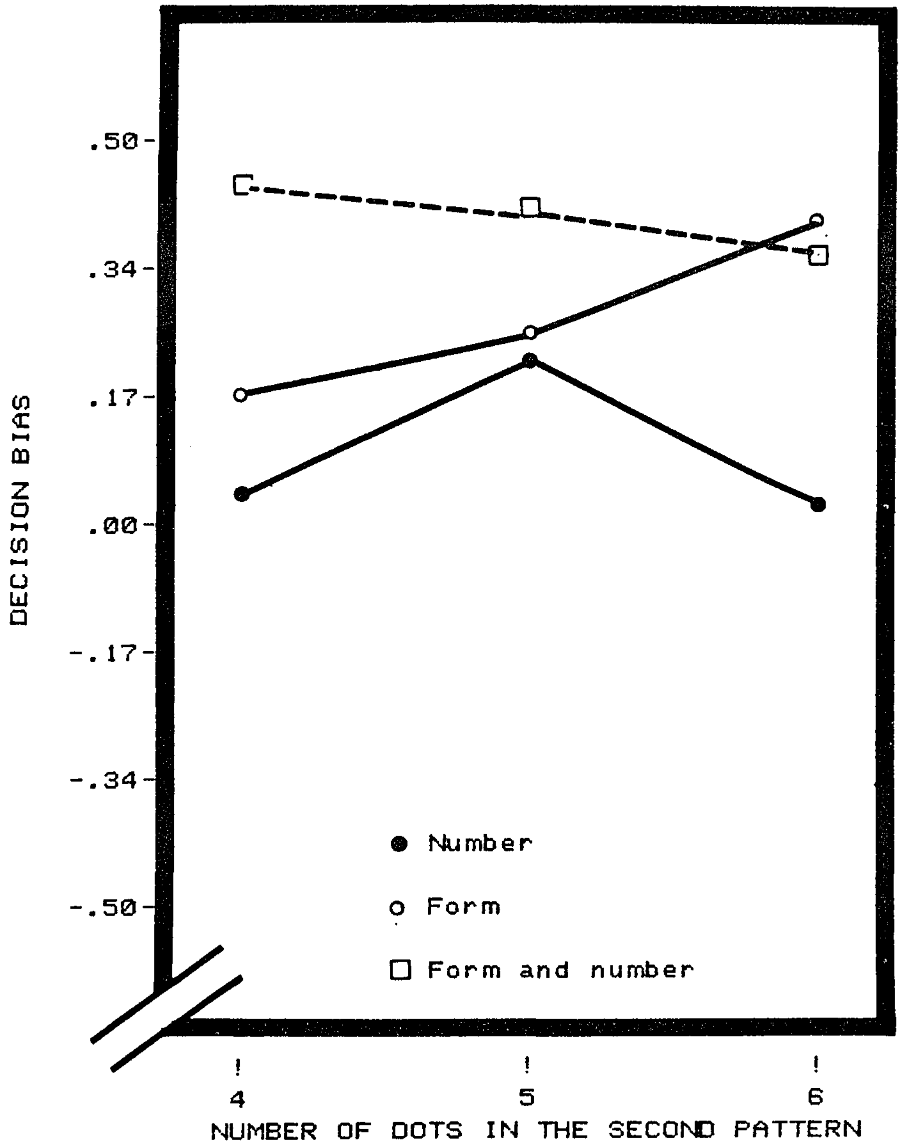


Figure 26. Mean decision bias from the mixed form and number task for the interaction between the number of dots in the second pattern and the type of difference between two patterns.

for the manual accuracy and response latency measures, the blocked form task was performed faster and more accurately than the blocked number or the mixed form and number tasks. However, for the verbal report accuracy and confidence ratings measures, significantly higher scores were found on the blocked number task compared to the other two tasks. In addition to the above findings, the analysis of the data revealed that for the blocked number task, significantly greater manual and verbal accuracy was associated with the equivalent-form pairs compared to the nonequivalent-form pairs. Moreover, for the blocked form task, the equivalent-number pairs produced significanlty greater manual accuracy than the noneqivalent-number pairs.

Hemispheric Differences in Visual Processing

Five hypotheses were generated in the Introduction (page 46) with respect to hemispheric differences in visual processing. None of the five hypotheses were clearly supported by the analysis of the data.

The first hypothesis stated that faster and more accurate performance in the processing of form (the blocked form task) would be obtained with stimulus patterns presented to the left visual field. The analysis of the dependent variables revealed findings both supportive and nonsupportive of the hypothesis. For example, visual field advantages were found to depend on the number of dots in the second pattern for the manual accuracy measure. In general, there was a shift in visual field field advantage from left to right as the number of dots in the second pattern increased from four to six (Figure 27, page 113). On the other hand, the analysis of the verbal accuracy measure revealed a right visual field advantage for form processing over the three levels of dot number (Figure 29, page 120). The verbal accuracy finding is contrary to the hypothesis, and suggests that form perception is better in the RVF with a verbal response. Finally, the ANOVA of the response latency measure failed to show significant visual field advantages. However, simple main effects testing demonstrated that subjects were significantly faster in the LVF with the five dot second pattern.

Closely related to the first hypothesis, was the second hypothesis. It was suggested that when the number of dots within a pair of patterns was different, slower and less accurate processing of dot form (the blocked form task) would be obtained with the stimulus pattern presented to the right visual field. The analysis of the data for the manual latency, manual accuracy, and verbal accuracy measures revealed no evidence to support this assertion. The interaction between the pair number and the visual field of presentation was not significant in the analysis of the four dependent variables in the blocked form task.

The third hypothesis stated that faster and more accurate performance in the processing of number (the blocked number task) would be shown with the stimulus patterns presented to the right visual field. The results demonstrated that this prediction was partially true only for the manual and verbal accuracy measures. As shown in Figures 27 (page 113) and 29 (page 120), a RVF advantage was found when the number of dots in the second pattern was six. However, when the number of dots was four, a LVF advantage for the blocked number task was found. In the ANOVA of the response latency measure, nonsignificant visual field differences were noted for number processing. However, the simple main effects testing of the blocked number task revealed that subjects were significantly faster in the LVF for the 4 and 5 dot second pattern.

The fourth hypothesis indicated that when the form of dots within a pair of patterns was dissimilar, slower and less accurate processing of dot number (the blocked number task) would be found with the stimulus pattern presented to the left visual field. Based on the analysis of the manaul accuracy and latency, and the verbal accuracy measures, the fourth hypothesis was not confirmed. The interaction between pair form and the visual field of presentation was not significant in the analysis of the four dependent variables in the blocked number task.

Finally, the fifth hypothesis stated that faster and more accurate performance in the processing of both form and number (the mixed form and number task) would be obtained to the stimulus pattern presented to the right visual field. As in the blocked number task, this hypothesis was true only for the six dot pattern with the manual and verbal accuracy measures. As shown in Figures 27 (page 113) and 29 (page 120), when the number of dots in the second pattern was six, a right visual field advantage was obtained. However, a significant left visual field advantage was obtained when the number of dots in the second pattern was four.

In addition to the above findings, a number of other significant results were obtained. For example, the interaction between the visual field of presentation and pair form was noted to be significant for response latency and confidence ratings. Significantly greater speed and confidence were found in the LVF compared to the RVF with equivalent-form pairs. Visual field differences for speed and confidence were not significant for nonequivalent-form pairs (Figures 28, page 118 & Figure 30, page 123).

Manual Accuracy

As shown in Table 3 (page 69), significance at p<.05 or better was obtained in the 5-way ANOVA of the number of correct manual responses for interaction between the visual field of presentation, the number of dots in the second pattern, and the procedural task demands (VF X Q X T). Figure 27 describes the relevant mean values. As can be seen, the highest accuracy levels in both the blocked number and mixed form and number tasks were associated with the LVF when the number of dots in the second pattern was four and in the RVF when the number of dots in the second pattern was six. Visual field differences were not significant between the two tasks when the number of dots in the second pattern was five. A different relationship was noted for the blocked form task. The six dot pattern was associated with a LVF advantage, and the four and five dot pattern was associated with a RVF advantage. On testing with the Shaffer-Welsch procedure, however, all mean differences between right and left visual fields were found to be nonsignificant.

The 4-way ANOVA (Table 4, page 73) for each of the three procedural tasks revealed significance of at least p<.05 only in the mixed form and number task. The significant finding was the interaction between the visual field of presentation and number of dots in the second pattern (VF X Q). In both the blocked form and the blocked number tasks, however, the interaction between the visual field and the number of dots was noted to approach significance (p<.15) . Shaffer-Welsch testing of the interaction between the visual field and the number of dots in the mixed form

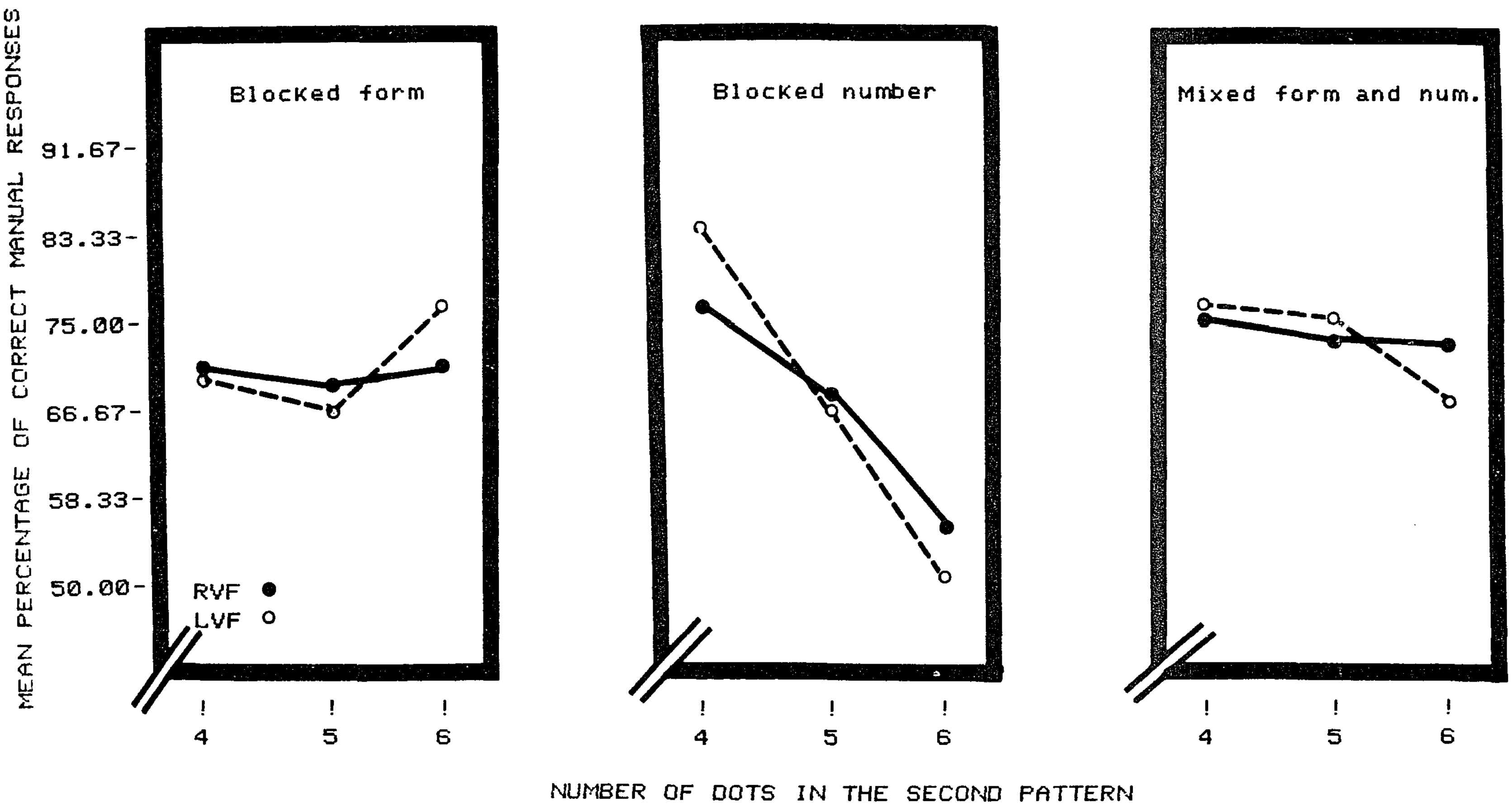


Figure 27. Mean percentage of correct manual responses for the interaction between the task demands, the visual field of presentation, and the number of dots in the second pattern of a pair.

and number task indicated a significant mean difference when the number of dots in the second pattern was six. Nonsignificant visual field mean differences were found when the number of dots in the second pattern was four or five.

Table 7 summarizes the results of simple main effects testing of the four dependent variables for visual field differences when the number of dots in the second pattern was four, five, and six. As indicated in the table, only one significant finding was obtained with the manual accuracy dependent variable. In the blocked number task, a significant LVF advantage was noted when the number of dots in the second pattern was four. However, a RVF advantage in the blocked form and a LVF advantage in the blocked number task was found to approach significance ($p<.10$) when the number of dots in the second pattern were six.

Table 7

Simple main effects testing of the visual field of presentation by number of dots in the second pattern of a pair for the manual accuracy, response latency, verbal accuracy, and confidence rating dependent variables of the blocked number, blocked form, and mixed form and number tasks.

			Task	
Number of dots in the second pattern	DV	BN	BF	MFN
Four	MA	LVF>RVF t=2.906***	RVF>LVF t=.004	LVF>RVF t=.532
	RL	LVF<RVF t=2.319***	LVF<RVF t=.752	LVF<RVF t=.296
	VR	LVF>RVF t=3.705***	RVF>LVF t=2.427***	LVF>RVF t=2.189*
	CR	LVF>RVF t=2.802***	LVF>RVF t=.102	LVF>RVF t=.564
Five	MA	RVF>LVF t=.475	RVF>LVF t=1.542	LVF>RVF t=1.127
	RL	LVF<RVF t=2.098***	LVF<RVF t=2.385***	RVF<LVF t=.352
	VR	LVF>RVF t=.623	RVF>LVF t=1.542	RVF>LVF t=.605
	CR	LVF>RVF t=.263	RVF>LVF t=.590	RVF>LVF t=.222

Table 7 (continued)

Simple main effects testing of the visual field of presentation by number of dots in the second pattern of a pair for the manual accuracy, response latency, verbal accuracy, and confidence rating dependent variables of the blocked number, blocked form, and mixed form and number tasks.

		Task		
Number of dots in the second pattern	DV	BN	BF	MFN
Six	MA	RVF>LVF t=1.048	LVF>RVF t=1.746	RVF>LVF t=1.894
	RL	RVF<LVF t=.309	RVF<LVF t=1.029	RVF<LVF t=.039
	VR	RVF>LVF t=2.011***	RVF>LVF t=.402	RVF>LVF t=.162
	CR	LVF>RVF t=.558	RVF>LVF t=.419	RVF>LVF t=.813

Key to the Table
BN : Blocked number
BF : Blocked form
MFN : Mixed form and number
MA : Manual accuracy
RL : Response latency
VR : Verbal accuracy
CR : Confidence rating
LVF : Left visual field
RVF : Right visual field
*** : Significant

Response Latency

The results of the 5-way ANOVA of the latency to correct responses revealed that only the interaction between the visual field of presentation and pair form was significant (Table 3, page 69). As shown in Figure 28, significantly faster correct responses were obtained in the left visual field compared to the right visual field with equivalent-form pairs (Shaffer-Welsch test). Nonsignificant differences were found between the right and left visual-fields with nonequivalent-form pairs. However, the nonequivalent-form pairs were noted to be significantly faster in both the right and left visual fields compared to the equivalent-form pairs.

Table 4 (page 73) presents the results of the 4-way ANOVA of the latency to correct responses for the three procedural tasks. As shown in the table, the main effects for visual field of presentation and the interactions between the visual field of presentation and other factors were found to be nonsignificant.

The results of the simple main effects testing of visual field differences as a function of the number of dots in the second pattern for the response latency dependent variable is presented in Table 7 (page 115) for each procedural task. As shown in the table, a LVF advantage was found in the blocked number task when the second pattern contained four and five dots, and in the blocked form task when the second pattern contained five dots.

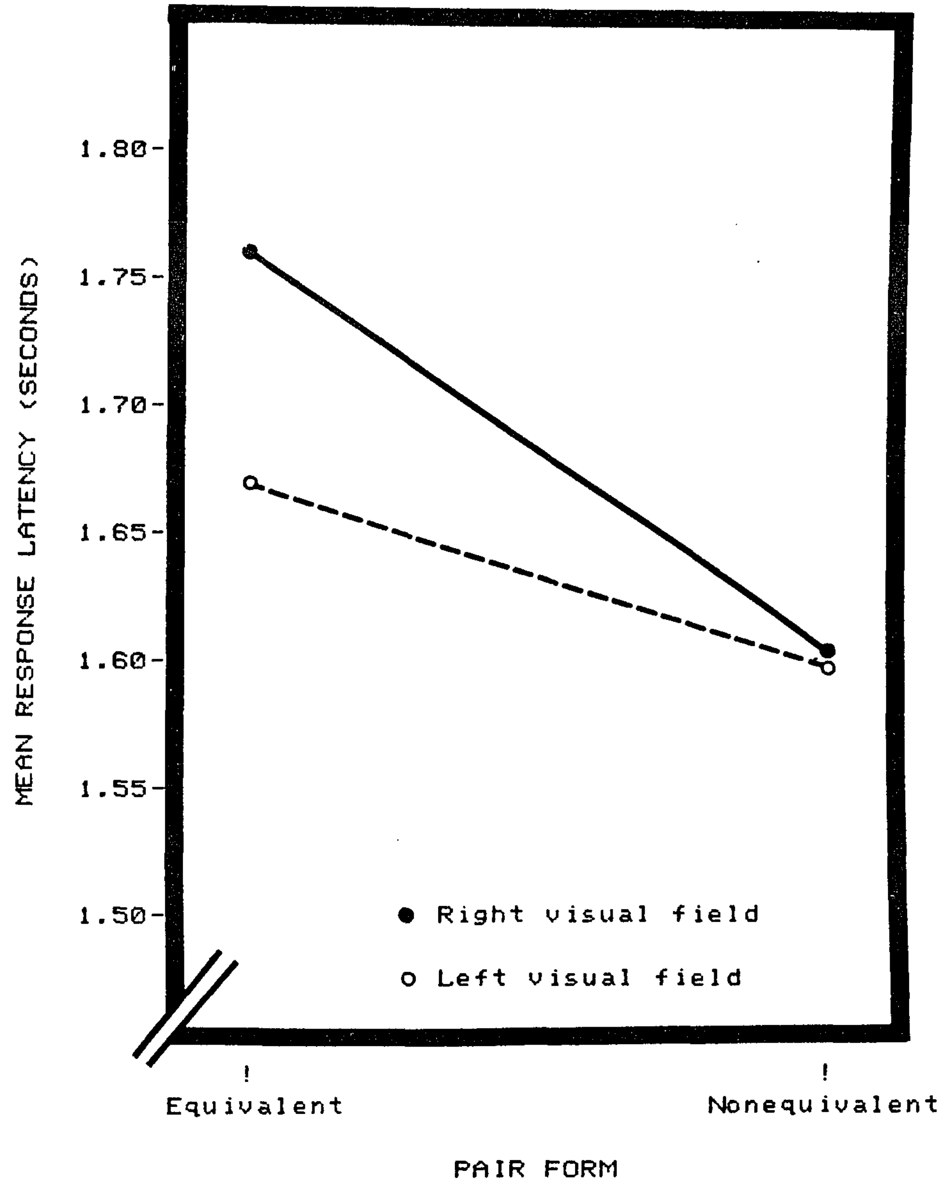


Figure 28. Mean response latency for the interaction between the pair form and the visual field of presentation.

Verbal Accuracy

As in analysis of correct manual responses, the 5-way ANOVA of the number of correct verbal responses revealed that the interaction between the visual field of presentation, the number of dots in the second pattern, and the procedural task was significant (Table 3, page 68). The interaction is illustrated in Figure 28. In the blocked number task, a LVF advantage was associated with the four dot stimulus pattern, no visual field advantage was associated with the five dot pattern, and a RVF advantage was associated with the six dot pattern. In the mixed form and number task, a LVF advantage was found with the four dot second pattern and no visual field advantages were found with the five and six dot second pattern. Finally, in the blocked form task, a RVF advantage was obtained regardless of the number of dots in the second pattern. As in the analysis of the manual accuracy, Shaffer-Welsch testing revealed that the visual field difference noted with the four dot second pattern was significant only in the blocked number task.

The 4-way ANOVA (Table 4, page 73) for each of the three procedural tasks demonstrated that in the blocked form task, the main effect for visual field was significant. As shown in Figure 28, significantly greater verbal accuracy was achieved with a RVF presentation (60% versus 56%) compared to a LVF presentation. This significant main effect for visual field of presentation was not found in analysis of the manual accuracy. In the blocked number task, only one factor was found to be significant. That was the interaction between the visual field of presentation and

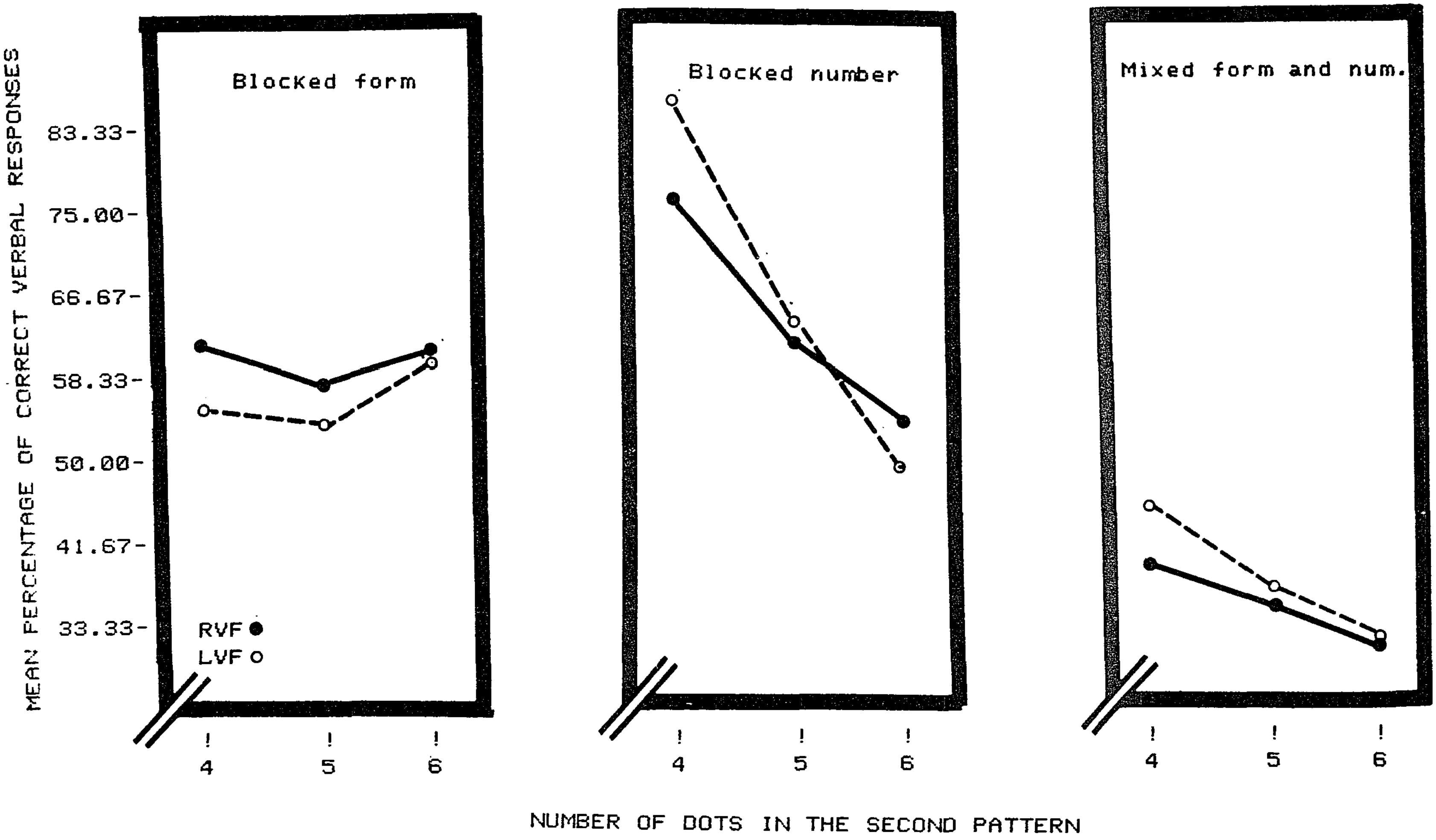


Figure 29. Mean percentage of correct verbal responses for the interaction between the task demands, the visual field of presentation, and the number of dots in the second pattern of a pair.

number of dots in the second pattern (VF X Q). The relationship is described in Figure 29. On testing with the Shaffer-Welsch procedure, the LVF advantage for the four dot pattern was found to be significant. In the 4-way ANOVA of the mixed-form and number discrimination task, no effects were significant.

Finally, the results of simple main effects testing of visual field differences as a function of the number of dots in the second pattern for the verbal accuracy dependent variable are summarized in Table 7 (page 115). As shown in the table, visual field differences for the blocked number, blocked form, and mixed form and number tasks were found when the number of dots in the second pattern was four. In the blocked number and mixed form and number task, a LVF advantage was obtained while in the blocked form task, a RVF advantage was obtained.

Chance Corrected Accuracy

Table 5 (page 92) presents the results of the 5-way ANOVA of the chance corrected accuracy measures. As in the ANOVA of the number of correct verbal responses, the interaction between the visual field of presentation and the number of dots in the second pattern of a pair was found to be significant in the blocked number task. The relationship between visual field and the number of dots was similar to that described previously for the verbal accuracy measure of the blocked number task. In addition, findings approaching significance ($p<.10$) were also obtained for the interaction of visual field by number of dots in both the blocked form and mixed form and number tasks.

Confidence Rating

As in the analysis of the latency to correct responses, the 5-way interaction of the confidence ratings revealed that the interaction between the visual field of presentation and pair form did achieved significance at the .05 level (Table 3, page 69). Figure 30 describes the interaction. Significantly greater confidence was obtained in the LVF compared to the RVF with equivalent-form pairs. The nonequivalent-form pairs were not associated with significant visual field differences (Shaffer-Welsch test). In general, the findings from both the confidence ratings and the response latency measure suggest that subjects are faster and more confident to equivalent form pairs in the LVF than in the RVF.

In the 4-way ANOVA of the confidence ratings (Table 4, page 73), the interaction between visual field and pair form was found to reach significance only in the blocked form task. The interaction is displayed in Figure 31. As shown, significantly greater confidence was indicated in the LVF with equivalent-form pairs. The visual field difference was not significant with the nonequivalent-form pairs (Shaffer-Welsch test).

Simple main effects testing of the visual field differences as a function of the number of dots in the second pattern for each procedural task, revealed significantly higher confident ratings in the LVF for the blocked number task when the number of dots in the second pattern of a pair was four (Table 7, page 115). This finding is consistent with the greater accuracy and

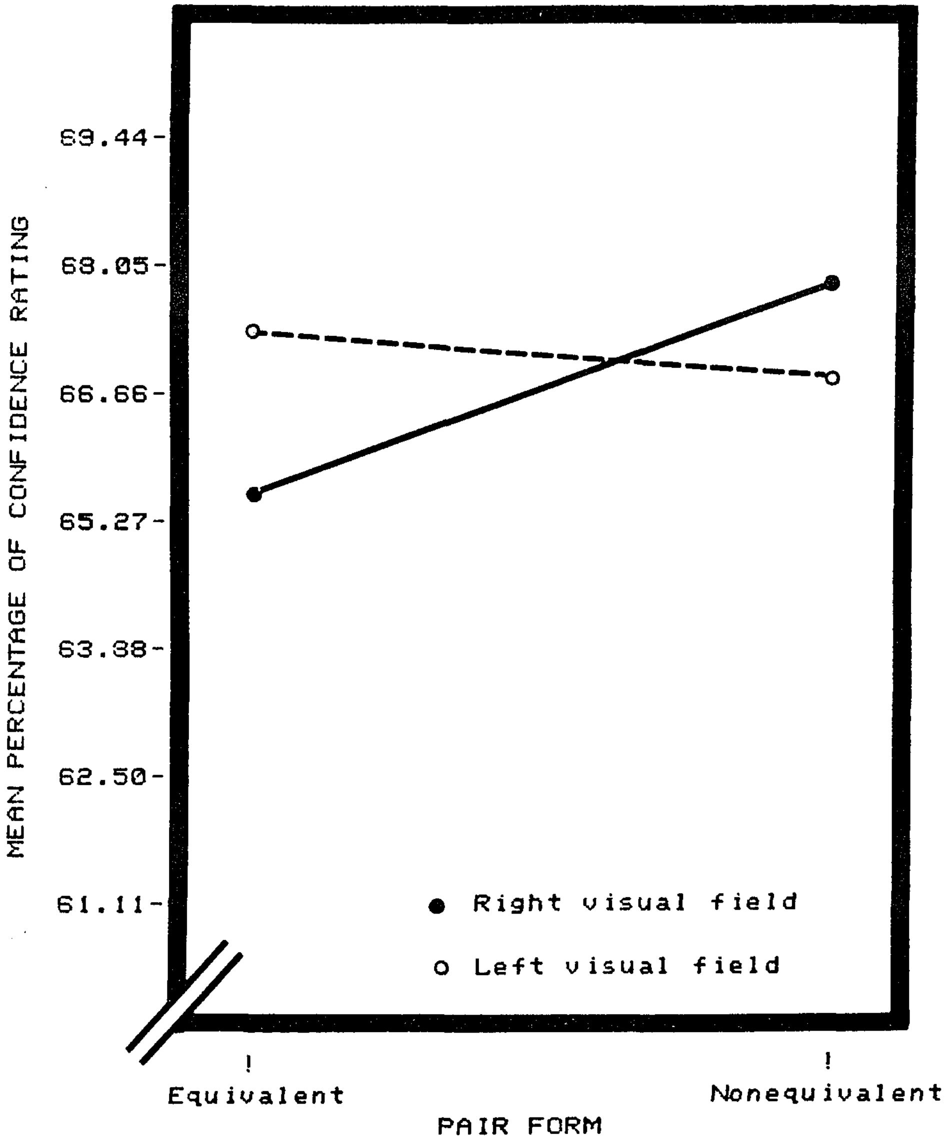


Figure 30. Mean percentage of confidence rating for the interaction between the pair form and the visual field of presentation.

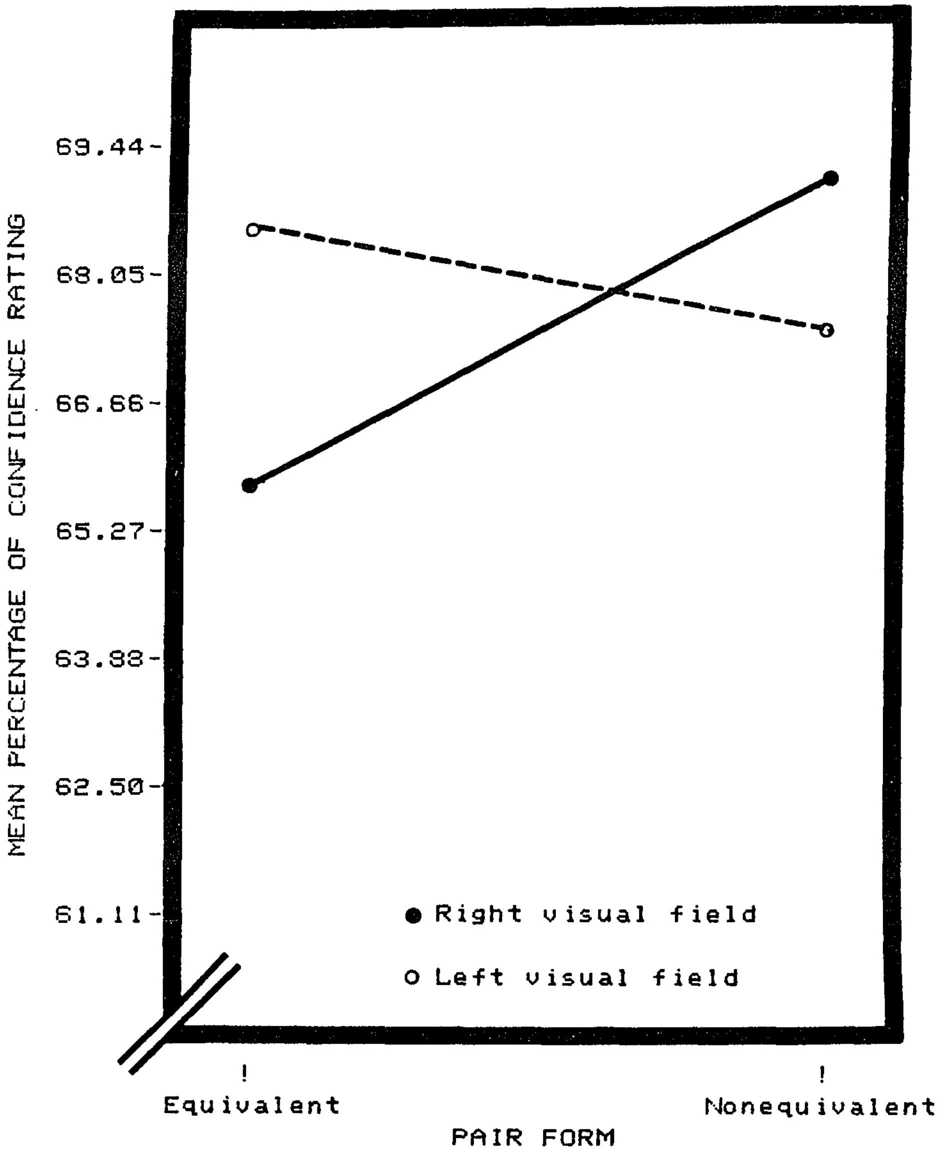


Figure 31. Mean percentage of confidence rating from the blocked form task for the interaction between the pair form and the visual field of presentation.

faster responses noted for the four dot pattern in the blocked number task. The remaining simple main effects did not achieve significance.

Signal Detection Analysis

Sensitivity. Table 6 (page 101) present the summary of the four-way ANOVA of sensitivity for each of the three procedural tasks. As shown in the table, only the mixed form and number task provided a significant finding. That finding was the interaction between visual fields of presentation, the type of difference between the two patterns of a pair, and the number of dots in the second pattern within pair (VF X TD X Q). The interaction is described in Figure 32. Significantly greater sensitivity for detecting a difference in the form between two patterns of a pair was noted in the LVF when the number of dots in the second pattern was six. In detecting a difference in the number of dots between two patterns of a pair, significantly greater sensitivity was noted in the LVF when the number of dots in the second pattern was four. Finally, in detecting a difference in both the form and number of dots between two patterns of a pair, significantly greater sensitivity was demonstrated in the LVF when the number of dots in the second pattern was four (Shaffer-Welsch test).

Findings approaching significance ($p<.15$) were found in all three procedural tasks (blocked form, blocked number, and mixed form and number) for the interaction between visual field and number of dots (VF X Q). The relationship for each task was consistent with the findings obtained in the ANOVA of the number of correct manual responses.

Decision Bias. Table 6 presents the partial summary of the four-way ANOVA of decision bias for each of the three procedural

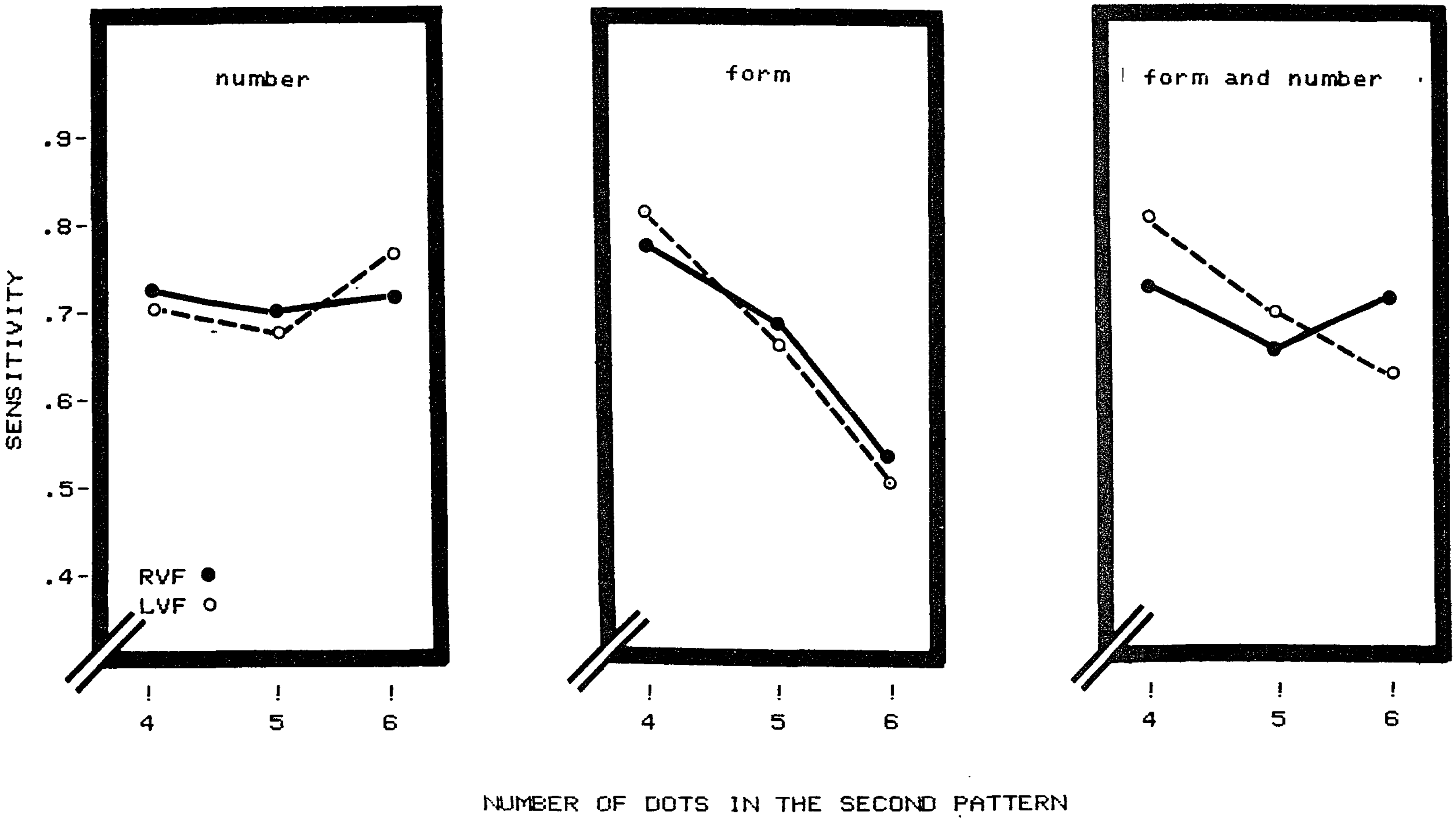


Figure 32. Mean sensitivity from the mixed form and number task for the interaction between the visual field of presentation, the number of dots in the second pattern of a pair, and the type of difference between two patterns of a pair.

tasks. As indicated in the table, there is no statistical support for a conclusion of visual field differences in decision bias.

Summary of the Laterality Results.

Two major findings were noted in the analysis of the four dependent variables for hemispheric differences. First, a significant interaction between visual field, number of dots in the second pattern, and the procedural task demands was demonstrated for both the manual and verbal report accuracy. In the blocked number and the mixed form and number tasks, a LVF advantage was associated with the four dot pattern, no visual field advantages were associated with the five dot pattern, and a RVF advantage was associated with the six dot pattern. A different relationship was obtained with the blocked form task. For the manual accuracy measure, a four dot pattern was associated with a RVF advantage, a five dot pattern was associated with no visual field advantages, and a six dot pattern was associated with a LVF advantage. For the verbal accuracy measure, a RVF advantage for all three levels of dot number.

Second, a significant interaction between the visual field of presentation and pair form was noted for response latency and confidence ratings. Significantly greater speed and confidence were found in the LVF compared to the RVF with equivalent-form pairs. Visual field differences for speed and confidence were not significant for nonequivalent-form pairs.

CHAPTER 4

DISCUSSION

The Order of Visual Processing

The results of analysis of the data confirm the predictions stated in the introduction: (1) in the blocked presentations, form processing was faster and more accurate than number processing with a manual response (pages 68 & 80); (2) in the mixed presentation, the processing of a form difference between two patterns of a pair was faster and more accurate than processing of a dot number difference (pages 76, 80 & 87); (3) the processing of form in the blocked form task was more accurate with equivalent-number pairs (Figure 14); and (4) the processing of dot number in the blocked number task was more accurate with equivalent-form pairs (Figures 6 & 13).

Overall, the results of this thesis can be interpreted as being consistent with a "top-down" sequence of visual processing. The finding of faster and more accurate form processing relative to number processing only serves to reaffirm a well known Gestalt principle of visual perception: "the whole is more than the sum of the parts" (Goldstein, 1980). However, a close examination of the obtained data reveals that the differences between form and number processing were contingent upon the number of dots in the second pattern of a stimulus pair. Significant differences between form and number processing were only obtained when the number of dots in the second pattern was five or six, suggesting that the characteristics of the stimuli were an important factor in the obtained order of visual processing. The order of visual processing might have been different if two and three dot patterns were used.

The importance of stimulus characteristics in the order of visual processing has not been fully appreciated. Differences in stimulus characteristics can account for the results of many investigators (Hoffman, 1980; Miller, 1982; Navon, 1977; Ward, 1982) who have employed the Stroop-type letter task to investigate the order of visual processing. In general, slower and less accurate performance has been found in the identification of the smaller letters. Navon (1977) contends that the slower and less accurate performance with the smaller letters is the result of a global to local order of visual processing. He believes that the visual system extracts global forms faster and more accurately than local forms. An alternative explanation based on differences in stimulus characteristics can also be made to account for the results. As noted in the Introduction, the slower and less accurate performance in the local letter processing task might be due to the presence of response inhibition from the presentation of multiple and identical local letters.

Navon (1977) has stated that stimulus characteristics are not a factor in the difference between the global and local processing test, but the notion of response inhibition makes this conclusion more likely. In fact, there is evidence from Navon's first study (1977) that is consistent with the above conclusion.

In a separate experiment, Navon demonstrated that equally fast responses were obtained with the small letter compared to the large letter when when the two letters were presented individually. However, when the same small letters were presented in a group of other small and identical letters, slower performance was noted. Overall Navon's 1977 results can be interpreted as evidence in support of a stimulus-task difficulty factor (in this case mediated by response inhibition) that is responsible for the order of visual processing.

Those studies demonstrating the role of sparsity (Martin, 1979), visual angle size (Kinchla & Wolfe, 1979), and conspicuousness (Hoffman, 1982) in the Stroop-type letter task are also relevant to this present discussion because they have indicated the importance of stimulus characteristics in the order of visual processing. In general, they have shown that the manipulation of task difficulty through changes in stimulus characteristics can determine whether a "top-down" or a "bottom-up" order is found.

In conclusion, the results of this thesis argue against Navon's general notion of a "top-down" order of visual processing. The results are consistent with other investigators who have shown that the order of visual processing is dependent upon the stimulus characteristics. However, further research is necessary if we are to understand the full implications of the stimulus factors in the order of visual processing.

The second major finding of this thesis concerns the processing of form and number in the mixed presentation condition. Stimulus pairs that differed in both form and number of dots (DFDN) were discriminated more accurately but equally fast as stimulus pairs that differed solely in form (DFSN). However, those pairs that differed solely in form were discriminated both faster and more accurately than stimulus pairs that differed solely in number (SFDN ; pages 80 & 87). Overall, these results suggest that both form and number may be processed within a similar time course. This conclusion is warranted by the results showing the additive effects of a difference in form and number on the accuracy but not processing speed. If form and number were processed over a different time course, then an increase in accuracy would have been associated with a decrease in processing speed when the stimulus pairs differed in both form and number.

The results from the mixed condition seem best explained in terms of an attentional model (Harvey, 1984; Hoffman, 1975; Krueger & Shapiro, 1980; Prinzmetal, 1981; Santee & Egeth, 1980). It is possible that a limited pool of attentional resources are divided across form and number processing, such that each type of processing can be monitored to enable discrimination of a difference. When a difference is recognized on one channel or another, the channel begins activating the approporiate decision. By virtue of a lower level of stimulus-task difficulty, the form channel may activate decisions faster than the number channel. When differences exist along two dimensions, both channels may mutually activate the appropriate decision. Since the decision is being activated by two sources simultaneously, a greater level of accuracy is achieved.

Miller (1980) has discussed the results of his study with the the Stroop-type letter task along similar lines. He found that a smaller letter exerted a significant effect on a larger letter. He contends that these findings imply that the smaller letter becomes availible to the decision processes with a time course similar to that of the large letter. He suggest that the effects previously attributed to the order in which different levels of structure are recognized, may be the result of differential ease of directing attention to those different levels and selecting responses based on them.

Additional evidence in support of a conclusion that both the form and the number of the dots are extracted over a similar time course has been provided from the results of the analysis of the interaction of irrelevant stimulus characteristics with the processing of relevant ones. As noted in the results section, the accuracy of form processing was found to be poorer but equally fast with nonequivalent-number pairs (Figures 7, 11, & 17). In addition, the accuracy of number processing was found to be poorer but equally fast with nonequivalent-form pairs (Figures 11 & 14). In general, the results suggest that the irrelevant variable of a stimulus can interfere with the accuracy of processing for a relevant variable. Since the interference of the irrelevant variable occurred only for accuracy and not response latency variables, these findings are consistent with the view that both the form and the number of dots are processed over a similar time course.

Dykes (1979) contends that relevant and irrelevant dimensions are processed by separate dimensional analyzers and interference results from misallocation of attention to the irrelevant dimensional analyzer. He notes that a difference in the irrrelevant dimensions should compete with the 'same' response such that the greater the amount of disparity between the irrelevant and relevant dimensions, the greater the competition. Dykes also predicts that the "different response" should also be graded in the opposite direction. That is, increases in irrelevant disparity should result in faster different responses. While Dykes' theoretical notions are consistent with the results of studies using an accuracy measure (Dykes, 1979; Egeth, 1966), those studies employing a reaction time measure (Dixon & Just, 1978) have not been able to validate his theory.

Some of the findings from the blocked number task of this experiment appear to be consistent with Dykes' theory. The analysis of the data for the blocked number task demonstrated that the 'same' responses were significantly less accurate when the form between two patterns was different (DFSN) compared to when it was the same (SFSN). However, the accuracy to equivalent- and nonequivalent-form pairs (SFDN & DFDN) was found to be similar when a 'different' response was required (Figure 7).

Other reseachers have also failed to obtain differential findings with the 'different' response (Kahn & Foster, 1981; Millspaugh, 1978; Santee and Egeth, 1980). This has led some researchers to assume that the selective effects of the irrelevant disparity on the 'same' judgement is consistent with a dual-process model in which it is assumed that 'same' and 'different' judgements are mediated by independent processes. Specifically, several investigators have proposed that 'same' judgements are determined by holisitic processes that are more sensitive to the configuration of a stimulus pair, whereas 'different' judgements are determined by a more analytic process that compares stimuli feature by feature.(Bamber, 1969, 1972; Bamber & Paine, 1973; Bamber, Herder, & Tidd, 1975; Donderi, 1983;; Egeth & Blecker, 1971; Eriksen, O'Hara, & Eriksen, 1982; Kreuger, 1973, 1978; Nickerson, 1969; Proctor & Rao, 1983).

The results of the present study for the blocked number tasks appear to be very consistent with respect to predictions of the dual-process model. The analysis of the data for the blocked number task suggest that in the 'same' judgment, the form of the dots played a role in the accuracy of the response. This was most clearly seen in the lower accuracy of the nonequivalent-form pairs (DFSN). However, the analysis of the 'different' response for the number processing revealed that a nonholisitic or analytic strategy was employed. This was clearly evident by the fact that the equivalent- and nonequivalent-form pairs (SFDN & DFDN) produced essentially equal levels of accuracy (Figure 7).

It is possible that 'different' judgements are not affected by the irrelevant disparity of the pair form if they are based on an ordered comparison. According to this position, either the relevant dimensions are examined prior to the irrelevant dimensions (Egeth's serial self terminating model) or both dimensions are processed in parallel but more capacity is allocated to the analysis of the relevant dimension such that it finishes first.

Treisman and Gellade (1980) have proposed a feature integration theory that describes some of the characteristic of this feature analysis. According to that theory, all of the features are extracted in parallel with exactly the same time course, and without the need for focal attention. Thus, the features become availible for further processing at roughly the same time. However, unless mediated by focal attention, the separately extracted features may or may not be conjoined into a perceptual object. Treisman and Gelade have proposed that features that fall within focal attention or that fall outside focal attention are likely to form conjunction, but that features within focal attention are not likely to form conjunctions with features from outside focal attention. This theory could explain the present results if allocation of attention is affected by some preattentive unit formation process, as proposed by Kahnemann and Henrik (1977).

Specifically, if attention is allocated to a particular perceptual unit or group, then features within that unit are likely to be integrated. For example, if in the number task, the 'same' judgement involved a holisitic approach in the processing of number, then the lack of equivalency of form within the pair of patterns would enter into focal attention and interfere with number processing. Moreover, if the 'different' judgement was directed to the number of dots without attention to form of the dots, then the nonequivalency of dot form would have no effect on number processing because it would not enter into focal attention.

To the extent that feature relations and feature number aspects of a stimulus are objects for perception, and to the extent that focal attention can be varied, the feature intergration theory can be applied to variety of findings. The theory suggests that preattentive processes operate on elements of a stimulus to present to the feature integration process groups of elements that can be easily and/or rapidly conjoined into perceptual objects for feature relation or feature number. In such a model, the more conspicuious features have a temporal precedence over the less conspicuious features. The precedence would be at the level of conjoining features into objects and not at the level of feature extraction. With respect to this present experiment, Treisman and Gelade 's prediction are consistent with many of the obtained findings. For example, the difference in accuracy between 'same' and 'different' responses in the blocked number task for equivalent- and nonequivalent-form pairs may be the result of a differential application of attention. In addition, the slower and less accurate performance with an increased number of dots in the second pattern of a pair noted in the blocked number task may be due to inefficent conjuncture of the dots into one total perception (Figure 5). Finally, the faster and more accurate performance in detecting a difference between two patterns of a pair when both form and number of dots differ in the mixed form and number task may be the consequence of a conjuncture of both form and number information.

In conclusion, the asymmetrical interference effects on accuracy in the blocked presentations suggest that feature information is combined in perceptual discrimination within the context of focal attention. More conspicuous features achieve a temporal precedence at the level of conjunction but not at the level of extraction.

An additional topic of this investigation was the differnce between the manual and verbal accuracy dependent variables. The results revealed that the verbal measure was more accurate than the manual measure when the scores were corrected for chance. The differences between the two accuracy measures was probably due to differences in processing time. Manual responses were provided within one to two seconds after the presentation of the second pattern. However, verbal responses were provided within four to six seconds after the manual response. The longer processing time in the verbal responses is believed to have produced the greater accuracy with the verbal measure.

Moreover, significant differences were noted between manual and verbal accuracy for the 'same' and 'different' responses. In general, the 'different' response was found to be faster and more accurate relative to the 'same' response for the manual accuracy and latency dependent variables in the blocked form, blocked number, and mixed form and number tasks (Figure 6, 7, & 11). However, higher accuracy levels were demonstrated to the 'same' stimulus pair with the verbal report (Figures 13 & 14). The obtained effects appear to be due to the stimulus qualities.

Unlike most studies (Bamber, 1969; Egeth & Blecker, 1971; Kreuger, 1973; Nickerson, 1969), the visuospatial stimuli employed in this present investigation lend themselves more readily to a 'different' judgement (Hock, 1973; Garner & Sutliff, 1974). For example, the dot form of the second pattern was always a partial representation of the first pattern such that when the two patterns within a pair were the same for geometric dot form (square, rectangle, etc.), they never looked alike. This fact may account for the greater manual accuracy for the 'different' judgement in the form task (Figure 6). However, the verbal report of form on those trials revealed that subjects were more accurate with the 'same' form pairs (Figure 17). This result is most likely due to the number of choices availible for a verbal report after having made a 'same' judgment versus a 'different' judgement. In the case of a 'same' judgment, there was only one choice to say , and that was the form of the first pattern seen. In the case of a 'different' judgment, there were three choices none of which represented the first pattern of the pair. It is believed that the differences in probability between the equivalent- and nonequivalent-form pairs for manual and verbal report accuracy account for the different findings. The same arguement is also offered to explain the findings of the blocked number and the mixed form and number tasks. In those tasks, manual accuracy was found to be better with stimulus patterns which required a 'different' response but verbal number accuracy was found to be more efficient with stimulus patterns which required a 'same' manual response.

The last major finding in this study concerns the nature of form perception. The post hoc analysis of the blocked form task revealed that the features of a visual form are not processed similarly. For example, the types of feature difference between two stimulus patterns were associated with different levels of speed and accuracy to correct manual responses. In general, the detection of an angle difference (square to a rhombus) between two patterns was discriminated faster (1.480 versus 1.790 seconds) and more accurately (89% versus 57%) than the detection of a length of side difference (square to rectangle). The post hoc results indicate that form perception is nonunitary. The results suggest that the features of a form might be processed by different channels, with more conspicuous features leading to faster and more accurate discriminations compared to less conspicuous features. These conclusions are consistent with the findings of other researchers who have also described the nonunitary nature of form perception (Hoffman, 1975; Norman, 1968; Treisman and Gelade, 1980). It is for future research to discern how conspicuous and nonconspicuous features are integrated to create the impression of form in the central nervous system.

In summary, the results of this experiment indicate that the order of visual processing of stimuli with multiple levels is determined by a number of factors, the most important of which is the stimulus characteristics. In addition, the findings show that the interaction of information about form and number of dots within a pattern does take place and can produce interference with the processing of form or number separately. The interaction appears to be related to the focus of attention. Finally, differences in probability were noted to produce dissimilar findings in the manual and verbal accuracy dependent variables for both the form and the number tasks. The results suggest that, in general, verbal responses were more accurate than manual responses.

Hemispheric Differences in Visual Processing

The major predictions of this thesis with respect to differential hemispheric processing were not supported by the results. General visual-field advantages for speed and accuracy were not found in the blocked form, the blocked number, or the mixed form and number tasks. In addition, visual-field advantages were not demonstrated for the pair number factor in the blocked form task or the pair form factor in the blocked number task. Instead, the results of the present study showed quite clearly that hemispheric differences in visual processing depend not only on stimulus characteristics but also on the task demands. For example, different lateralized findings were noted with changes in the stimulus characteristics for the three tasks.

The shift in visual field advantage with different stimulus characteristics was clearly seen in the interaction between the visual field of presentation and the number of dots in the second pattern of a pair for the blocked number, blocked form, and the mixed form and number tasks. This interaction was found to be significant or approaching significance ($p<.10$) more than any other laterality factor in the ANOVA and the testing of simple main effects. In both the blocked number and the mixed form and number tasks, a shift in visual field advantage from left to right for both manual and verbal accuracy was found as the number of dots in the second pattern increased from four to six (Figures 27 & 29). On the other hand, in the blocked form task, a shift in visual field advantage from right to left for manual accuracy was noted as the number of dots in the second pattern increased from four to six.

The results of the blocked form task appear to be in conflict with those obtained from the other two tasks. However there is one common thread connecting these divergent findings. The shift to a RVF advantage always occurred with the stimulus pattern that was the most difficult for the given task. Based on the accuracy, response latency, and confidence measures, the most difficult patterns for the number and the form and number tasks were those in which the second pattern of the pair contained six dots. For the form task, the most difficult patterns were the ones in which the second pattern of a pair contained four dots. This latter finding is expected based on previous research of form perception. Those forms that contain less relevant information are more difficult to identify than those with more information.

The analysis of the three different procedural tasks indicate that the level of task difficulty in the processing of a stimulus was an important variable in determining the direction of the lateralized findings. Simple patterns were more likely to be associated with a LVF advantage while complex patterns were more likely to be associated with a RVF advantage.

Support for the notion of a shift in visual field advantage with a change in stimulus-task difficulty is found throughout the literature. Several experiments have demonstrated this shift using stimuli that are traditionally considered to be processed by the right hemisphere (visuospatial forms, faces, etc...). One experiment was performed by Hellige (1976) in which he presented to the right and left visual field, 12 and 16 point Vanderplas and Garvin figures in a mixed visual recognition task of forms and words. He found a LVF advantage for the 12 point figures and a RVF advantage for the 16 point figures. Hellige suggested that the form complexity-visual field interaction may be the result of differences in the codability of the two types of forms. He noted that each complexity level could lead to use of a different preparatory set or to a different pattern of selective perceptual orientation.

Sergent (1984) and Paterson and Bradshaw (1975) have demonstrated in a same-different paired comparison task of faces that subjects are more accurate in the LVF when the faces differ by three features. However, if the faces differ by only one feature, the subjects are more accurate in the RVF. Different explanations have been offered by the respective researchers to account for the right visual-field advantage for the processing of faces at the higher level of difficulty. Paterson and Bradshaw have argued that the findings demonstrate the left hemisphere's superiority as an analytic processor. Sergent has suggested that the findings are consistent with her notion of the

the greater capacity of the left hemisphere in the processing of higher spatial frequencies. Regardless of theoretical models, the findings are strong evidence for a shift in visual field advantage from left to right with an increase in level of task difficulty.

Visual search tasks have also provided findings consistent with the current view. In one variation of such tasks, the subjects are tachistocopically presented a visual array of elements and and are asked to decide if all the elements are the same or if one is different. In general for such tasks,, a RVF advantage has been reported (Cohen, 1973, Polich, 1980; Polich, 1984). However, what is most interesting about the research has been the demonstration of an increase in the difference between the right and left visual fields in accuracy and response latency as the number of elements to be searched increases. Again, these findings are consistent with the view that an increase in the level of task difficuty (as represented by an increase in the number of elements) is associated with a left hemisphere advantage.

Finally, the strongest support for the notion of a left to a right visual field shift in superiority for the processing of complex or difficult stimuli has come from the electrophysiological recordings of brain waves. Galin, Johnstone, & Herron (1978) and McKee et al (1973) report that there is greater relative left hemisphere activation compared to right hemisphere activation in both linguistic and spatial tasks as task difficulty increases.

If the left hemisphere is specialized for processing stimulus complexity there must be some underlying factor accounting for this advantage. One possibility is the left hemisphere's capacity for language and the use of verbal processing to analyze the stimulus. All of the findings from this study and the others reported in this discussion section could be interpreted using the concept of a verbal processing strategy. There is some empirical support for such as conclusion. Faber-Clark and Moore (1983) have demonstrated in an electrophysiological study of brain activity, greater alpha supression for a recall task as compared to a word recognition task. Following the testing, they asked the subjects to describe the strategies they employed to remember the words. They noted that the subjects who employed a verbal strategy showed greater alpha suppression in the left hemisphere than those subjects who used a visual imagery strategy.

A right visual field advantage for the processing of complex or difficult stimuli is not universal. Numerous studies (Gorden and Carmen, 1979; Hellige, 1979; Miller & Butler, 1980) have shown that novel stimuli are processed better in the LVF initially. Following some experience with the stimuli, there is a shift towards a right visual field advantage. For example, Gordon and Carmen (1979) have demonstrated an initial LVF advantage for the verbal naming of unfamiliar visual symbols (taken from the digit symbol subtest of the WAIS and modified binary representation of digits). Following practice with the same symbols, a right visual field advantage was obtained. A similar left to right shift in visual field advantage in a same-different judgement task of letter pairs following practice has been reported by Hellige (1979). The results of the above studies employing novel stimuli suggest that a descriptive system is necessary for the development of a right visual-field advantage.

The importance of a descriptive system for hemispheric specialization is most apparent in those situations where a descriptive system cannot be applied effectively. One example of a situation where it cannot be effectievely applied is an evaluation of formal mathematical languages which represent a domain of nonverbal descriptive systems. Franco and Sperry (1977) have studied hemispheric asymmetries in performance on visuotactile tests involving apprehension of geometric relations in Euclidean, affine, projective, and topological spaces. They found a LVF superiority for all four sets of tasks. However, they noted that the the degree of the superiority in the LVF increased in the following order: Euclidean, affine, projective, and topological. The greatest LVF advantage was associated with the stimuli of the least structural input. This finding is consistent with the concept that the left hemisphere's performance is related to its capacity to encode the stimulus with some descriptive system. There exists a positive interaction between the degree of structure in the stimuli and left hemisphere performance. One possible explanation for the observed order of decremental performance is that it reflects the relevance of different classes of geometric objects to the preexisting descriptive systems. For the average subject, the descriptive system is most likely limited to Euclidean geometrics (square, circle, rectangle, etc...). If this is the case, the gradient of the LVF-RVF advantages that Franco and Sperry obtained, may reflect the gradient of descriptive systems that the subjects have developed for the tasks involved.

The Goldberg and Costa (1981) model of hemispheric differences is important to this discussion. They have argued that the left hemisphere superiority with many different stimuli and tasks is the result of its utilization of different descriptive systems which are fully formed in the individual's cognitive repetoire. The descriptive systems are relevant to specific classes of materials and tasks, but do not imply verbal encoding in every case. These authors have described the right hemisphere as crucial in the processing of material to which none of the descriptive systems exist (such as novel stimuli) or are needed. The right hemisphere is involved in the development of a new descriptive system in the individual's cognitive repertoire.

An evaluation of the results of the present study in terms of the Goldberg and Costa model suggests that the LVF advantage obtained with the simpler stimuli for each of the task demands was the result of the application of a nondescriptive processing mode in the right hemisphere. Moreover, the RVF advantage obtained to the more complex stimuli for the three task demands was the result of the application of a descriptive processing mode in the left hemisphere. Evidence in favor of such a conclusion exists in this study. The analysis of the subject's summary report of the strategies they employed to process form and number, obtained following completion of testing, revealed consistent findings. For simple stimuli, most subjects used a "sparsity of dots" strategy to process number and a "global" form strategy to process the geometric figure of the pattern. Both strategies involve minimal use of verbal encoding. However, for the processing of more complex stimuli, the subject relied more heavily on verbalization. In the processing of number, most subjects employed a "grouping strategy" whereby the dots were organized as groups and the number of dots within each group were then counted. In the processing of form, the majority of the subjects ultilized an "analytic" strategy where they assessed individual feature relations separately before combining them into a judgement of dot form.

The Goldberg-Costa model is also applicable to an explanation of the individual differences that occur in laterality studies. One finding that was noted throughout this investigation was the variance between subjects for processing strategies. While the majority of subjects adopted similar strategies, there were some who were quite divergent. The lack of consistency among subjects for the congitive strategies is an important factor in accounting for the some of the nonsignificant factors of the ANOVA. An interpretation of the obtained individual variance consistent with the Goldberg Costa Model is that subjects who were markedly different in the form and number processing task were dissimilar in their use of a descriptive processing mode. This might have been the result of individual differences in learning.

There is a long history of attempts to classify people according to a particular perceptual or cognitive styles (Hellige, 1975). Despite the wide variety of individual classification schemes, experimental tasks used, and explanations advanced, there appears to be consistent results that characterize all of these studies. All of the classification schemes involve one group that is hypothesized to be more efficient at some aspect of verbal processing or more likely to use a spontaneous verbal strategy relative to another group. If people vary systematically in the way they process particular stimuli using a verbal strategy, and if the manner of processing affects laterality, then individual differences become of critical import in studies of laterality. It is proposed that in future reasearch, greater attempts be made to determine the manner by which subjects arrive at a perceptual judgement. Minor attempts at this problem were carried out in this study using a debriefing session following the conclusion of the testing. However, the attempts at this level are not rigorous enough to provide answers to the questions regarding individual differences in lateralized findings.

The last major issue that this study raises concerns the dependent variable. Many investigators in lateralized research (Beaumont, 1982; Bryden, 1982) have reported the advantage of using one dependent variable over another. Reaction time relative to accuracy is sometimes suggested as the more sensitive measure (Beaumont, 1982). With respect to this study, the most effective dependent variable was the verbal accuracy measure. This measure produced more significant findings than any other measure in the ANOVA and the simple main effects testing. One possible explanation relates to the use of verbal processing to arrive at a judgement. Unfortunately, few studies have investigated lateralized findings with respect to the dependent variable used, thus making interpretation of the obtained findings difficult. Additional research concerning dependent measures in laterality research is necessary if we are to fully understand cerebral hemispheric differences.

In summary, the results of this investigation have demonstrated that hemsipheric differences in the visual processing of stimuli are dependent upon many factors. The most important are the stimulus characteristics and the task demands. The results also suggest that the differential application of a verbal descriptive system in the processing of visual stimuli may account for the shift in lateralized findings with changes in the level of stimulus-task difficulty. Two areas of future reseach that this study has revealed as necessary, are (1), an investigation of the role of individual differences in processing stratagies and their effects on the laterality outcome, and (2), an investigation of the role of the dependent variable in the production of cerebral specialization.

APPENDIX A: Handedness Questionaire

Name --------------------------------

Birthday ------------- Age ------------

Date -----------------

Score ----------------

Read to the subject:

This inventory is designed to determine which hand you use in the following manual activities.

1) Indicate 'left' if you perform the task with your left hand.

2) Indicate 'right' if you perform the task with your right hand.

3) Indicate 'both' if you perform the task equally well with both hands.

Assume that your hands are empty (except as indicated) before considering each task. If you have no experience with a given task, do not mark a preference.

A. Are you right handed or left handed?	R	L	B
B. With which hand or hands do you:			
1) write?	R	L	B
2) draw?	R	L	B
3) use a tennis raquet?	R	L	B
4) use a screwdriver?	R	L	B

5) throw a ball? R L B

6) use a hammer? R L B

7) light a match? R L B

8) use a toothbrush? R L B

9) hold a knife when carving meat? R L B

10) use a bottle opener? R L B

11) use scissors? R L B

12) stir a liquid? R L B

13) carry your books or book bags? R L B

14) pick up the salt or pepper shaker? R L B

15) hold a filled cup when drinking? R L B

16) with which foot do you kick a ball? R L B

C. Are there any one-handed actions for which you use the other hand?

If 'yes', what are they: ____

____

D. Is their anyone in your family who is left handed? _____________

Who? ____

APPENDIX B

Instructions read to subjects

Introduction

This is an experiment investigating form and number discrimination in the left and right visual field. You will see pairs of dot patterns of either 4, 5, or 6 dots that can make one of four geometric figures (square, rectangle, rhombus, or parallelogram). The first pattern of a pair will be presented for a second, followed by a three second blank interval, and then a very brief presentation of the second pattern in either the left or right visual field. Your task will be to determine if the geometric form or the number of dots presented is the same or different in the two patterns of a pair.

The first member of a pair always consists of a figure presented in the center of the card with dots in all four extreme corners. Observe the figures and their names on the cards in front of you. These cards are typical of the type of figures presented first in a paired presentation.

The second member of the pair always consists of a figure presented to the left or right of the center of fixation. Observe the figures and their names on the cards in front of you. The second figure is constructed with only three dots in the four possible extreme corners. There is always one dot missing from either the upper or lower outer corner of the figure. As a result, the second pattern is a partial representation of one of the four geometric figures (square, rectangle, rhombus, and parallelogram). You will be required to determine the overall geometric figure that the dots make from this partial representation. Study these figures in front of you carefully. Are there any questions?

The position of the dots within a figure will vary randomly. It will be your task to determine either the form that the dots make or the number that are presented for both patterns within a paired presentation. You will respond in one of two ways--same or different depending upon whether you are discriminating to the form or the number of dots presented within a pair.

Blocked Form

In this part of the experiment, your task is to compare the form or shape of the second pattern with that of the first, and decide whether it is same or different. When you have decided, move the levers on the two switches in front of you in either the forward or backward direction. If the second pattern forms the same geometric figure (square, rectangle, rhombus, or parallelogram), move the levers forward (backward) to indicate sameness. If the second pattern is different in geometric form from the first, move the levers backwards (forward) to indicate difference. Same or different trials will occur randomly and with equal probability. Your are only to make a comparison on the basis of the shape or form created by the dot configuration. Remember that the presentation of the second stimulus pattern will occur in either the right or left visual field. You are to fixate on the dot in the middle of the screen at all times during each paired presentation. In addition, respond as quickly as possible without error. Are there any questions?

After each response, please indicate your confidence on a scale of one to three, where a 'one' inidicates no confidence or guessing, a 'two' indicates neutral confidence, and a 'three' inidicates most confidence. Try to use an equal number of all three categories. Moreover, after each confidence rating please indicate the geometric figure of the second pattern within a pair. Indicate verbally: square, rectangle, rhombus, or parallelogram. Are there any questions?

Blocked Number

In this part of the experiment, your task is to compare the number of dots in the second pattern with that of the first pattern. You are to decide as quickly as possible if the number of dots presented in the second pattern is the same as that of the first pattern. If they are the same, move the levers on the console in front of you forward (backwards) to inidicate sameness. If they are different, move the levers backwards (forward) to indicate difference. Same or different trials will occur randomly with equal probability. Only respond to the number of dots within each pair. Remember that the presentation of the second stimulus will occur in either the left or right visual field. You are to fixate on the dot in the middle of the screen at all times during each paired presentation. In addition, respond as quickly as possible without error. Are there any questions?

After each response, please indicate your confidence rating on a scale of one to three, where a 'one' inidicates no confidence, a 'two' indicates nuetral confidence, and a 'three' indicates most confidence. Try to use an equal number of all three categories.

After each confidence rating, please indicate the number of dots presented in the second pattern. All that is required of you is to say: four, five, or six dots.

Mixed Form and Number

In this part of the experiment, you task is to compare the second pattern with that of the first and decide if it is same or different.The second pattern is the same only if it is of the same number of dots and the geometric form that it makes is identical with that of the first pattern. If it is the same, move the levers forward (backwards) to indicate sameness. If there is a difference in the second pattern, in either the number of dots or the form they make (square, rectangle, rhombus, or parallelogram) move the levers backward (forward) to indicate difference. Same or different trials will occur randomly with same trials occuring 25% of the time and different trials occuring 75% of the time. Again, the second pattern is presented to the left or right visual field randomly. Remember to fixate at all times on the dot in the middle of the screen in front of you.

After each response, please indicate your confidence rating on a scale of one to three where a 'one' represents uncertainty, a 'two' represents neutral confidence, and a 'three' represents most confidence. Try to use an equal number of all three categories.

After each confidence rating, please indicate verbally the number of dots and the geometric figure of the second pattern within a pair.

APPENDIX C: ANOVA tables

Table 8

5-way ANOVA of mean number of correct manual responses

Source of Variance	SS/ SSe	df/dfe	MS/MSe	F
T	70.71/ 48.70	2/18	35.35/2.70	13.07***
N	.07/ 77.89	1/9	.07/8.65	.01
F	287.53/ 21.75	1/9	287.53/2.41	18.94***
Q	170.37/152.21	2/18	85.18/8.45	10.07***
T X N	32.01/114.73	2/18	16.00/6.37	2.51
T X F	350.68/ 57.07	2/18	175.34/3.17	55.30***
T X Q	324.42/309.83	4/36	81.11/8.60	9.42***
N X F	10.03/ 11.59	1/9	10.03/1.28	7.79***
N X Q	19.67/ 43.41	2/18	9.83/2.41	4.08***
F X Q	7.72/ 74.03	2/18	3.86/4.11	.94
T X N X F	3.88/ 69.53	2/18	1.94/3.86	.50
T X N X Q	69.84/ 86.74	4/36	17.46/2.40	7.25***
T X F X Q	86.51/ 88.58	4/36	21.62/2.46	8.79***
N X F X Q	17.98/ 37.26	2/18	8.99/2.07	4.34***
T X N X F X Q	31.88/ 88.19	4/36	7.97/2.45	3.25***
VF	.17/ 15.96	1/9	.17/1.77	.09
VF X T	.81/ 39.60	2/18	.41/2.20	.18
VF X N	.03/ 8.86	1/9	.03/0.98	.04
VF X F	.11/ 9.23	1/9	.11/1.02	.11
VF X Q	7.53/ 38.71	2/18	3.77/2.15	1.75
VF X T X N	.34/ 48.96	2/18	.17/2.72	.06
VF X T X F	5.73/ 22.79	2/18	2.87/1.26	2.26
VF X T X Q	28.42/ 68.66	4/18	7.11/1.69	3.73***
VF X N X F	1.70/ 21.86	1/9	1.70/2.42	.70
VF X N X Q	3.94/ 32.03	2/18	1.96/1.77	1.11
VF X F X Q	1.01/ 30.51	2/18	.50/1.69	.30
VF X T X N X F	1.48/ 17.82	2/18	.74/0.99	.75
VF X T X N X Q	1.07/ 69.12	4/36	.27/1.92	.14
VF X T X F X Q	12.58/ 72.88	4/36	3.14/2.02	1.55
VF X N X F X Q	2.87/ 34.25	2/18	1.44/1.90	.76
VF X T X N X F X Q	.01/ 70.53	4/36	.00/1.95	.99

Key to the Table

T : Task demand

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

Table 9

5-way ANOVA of mean latency for correct responses

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
T	.38/.20	2/18	.19/.01	15.41***
N	.03/.07	1/9	.03/.01	3.12
F	.16/.14	1/9	.16/.02	8.82***
Q	.05/.15	2/18	.03/.01	2.79
T X N	.00/.03	2/18	.00/.00	2.51
T X F	.21/.09	2/18	.10/.01	18.31***
T X Q	.19/.23	4/36	.05/.01	6.51***
N X F	.00/.06	1/9	.00/.01	.00
N X Q	.07/.06	2/18	.03/.03	8.94***
F X Q	.00/.07	2/18	.00/.04	.11
T X N X F	.00/.03	2/18	.00/.00	.26
T X N X Q	.11/.14	4/36	.03/.00	6.39***
T X F X Q	.01/.11	4/36	.00/.00	.88
N X F X Q	.00/.05	2/18	.00/.00	.29
T X N X F X Q	.00/.12	4/36	.00/.00	.29
VF	.02/.04	1/9	.02/.00	3.78
VF X T	.00/.08	2/18	.00/.01	.37
VF X N	.01/.07	1/9	.01/.01	1.09
VF X F	.03/.04	1/9	.03/.00	5.84***
VF X Q	.00/.06	2/18	.00/.00	.35
VF X T X N	.00/.05	2/18	.00/.00	.44
VF X T X F	.00/.03	2/18	.00/.00	.52
VF X T X Q	.01/.12	4/36	.00/.00	.35
VF X N X F	.00/.02	1/9	.00/.00	.19
VF X N X Q	.01/.06	2/18	.01/.00	2.07
VF X F X Q	.00/.04	2/18	.00/.00	.21
VF X T X N X F	.00/.02	2/16	.00/.00	.64
VF X T X N X Q	.01/.12	4/36	.00/.00	.63
VF X T X F X Q	.02/.10	4/36	.00/.00	1.31
VF X N X F X Q	.00/.04	2/18	.00/.00	.60
VF X T X N X F X Q	.01/.09	4/36	.00/.00	.99

Key to the Table

T : Task demand

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

Table 10

5-way ANOVA of mean number of correct verbal responses

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
T	1529.07/107.62	2/18	764.54/ 5.98	127.88***
N	180.00/ 32.42	1/9	180.00/ 3.60	49.97***
F	228.94/ 23.87	1/9	228.94/ 2.65	86.33***
Q	313.85/414.17	2/18	156.93/23.00	6.82***
T X N	47.43/ 87.48	2/18	23.72/ 4.86	4.88***
T X F	44.84/ 62.18	2/18	22.42/ 3.45	6.49***
T X Q	323.01/444.22	4/36	80.75/12.36	6.54***
N X F	85.42/ 19.44	1/9	85.42/ 2.16	39.55***
N X Q	9.86/ 38.72	2/18	4.93/ 2.15	2.29
F X Q	22.37/113.66	2/18	11.18/ 6.31	1.77
T X N X F	17.91/ 35.23	2/18	8.96/ 1.95	4.58***
T X N X Q	25.23/ 86.95	4/36	6.34/ 2.41	2.63***
T X F X Q	16.72/ 93.17	4/36	4.18/ 2.59	1.62
N X F X Q	7.01/ 62.12	2/18	3.51/ 3.45	1.02
T X N X F X Q	16.22/ 79.89	4/36	4.06/ 2.22	1.83
VF	.05/ 27.81	1/9	.05/ 3.09	.02
VF X T	18.43/ 63.53	2/18	9.22/ 3.53	2.61
VF X N	.80/ 26.23	1/9	.80/ 2.91	.27
VF X F	8.45/ 24.41	1/9	8.45/ 2.71	3.12
VF X Q	16.86/ 64.28	2/18	8.43/ 3.57	2.36
VF X T X N	3.03/ 69.94	2/18	1.52/ 3.88	.39
VF X T X F	.43/ 24.20	2/18	.22/ 1.34	.16
VF X T X Q	35.58/ 96.19	4/36	8.90/ 2.67	3.33***
VF X N X F	8.97/ 14.60	1/9	1.09/ 1.62	.67
VF X N X Q	1.80/ 55.66	2/18	.90/ 3.09	.29
VF X F X Q	3.77/ 42.03	2/18	1.88/ 2.33	.81
VF X T X N X F	3.14/ 13.49	2/18	1.57/ 0.75	2.10
VF X T X N X Q	1.98/ 60.79	4/36	.50/ 1.69	.29
VF X T X F X Q	13.86/ 44.57	4/36	3.46/ 1.24	2.80
VF X N X F X Q	2.64/ 27.17	2/18	1.31/ 1.51	.87
VF X T X N X F XQ	13.06/ 59.06	4/36	3.26/ 1.64	1.99

Key to the Table

T	: Task demand
N	: Pair number
F	: Pair form
Q	: Number of dots in the second pattern of a pair
VF	: Visual field of presentation

Table 11

5-way ANOVA of mean confidence rating

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
T	562.59/710.58	2/18	281.29/39.47	7.13***
N	154.01/ 73.91	1/9	154.01/ 8.21	18.75***
F	13.07/178.47	1/9	13.07/19.83	.66
Q	283.20/220.46	2/18	141.60/12.24	11.56***
T X N	44.72/ 35.05	2/18	22.36/ 1.94	11.48***
T X F	11.80/ 78.53	2/18	5.90/ 4.36	1.35
T X Q	676.28/215.88	4/36	169.07/ 5.99	28.19***
N X F	16.50/ 38.59	1/9	16.50/ 4.28	3.85
N X Q	58.10/104.50	2/18	29.05/ 5.80	5.00***
F X Q	4.22/ 62.28	2/18	2.11/ 3.46	.61
T X N X F	37.28/ 59.99	2/18	18.64/ 3.33	5.59***
T X N X Q	167.84/111.21	4/36	41.96/ 3.09	13.58***
T X F X Q	9.59/169.40	4/36	2.40/ 4.70	.51
N X F X Q	22.77/104.67	2/18	11.38/ 5.81	1.96
T X N X F X Q	77.98/116.57	4/36	19.49/ 3.24	6.02***
VF	12.53/130.56	1/9	12.53/14.51	.86
VF X T	13.85/131.09	2/18	6.93/ 7.28	.95
VF X N	5.86/ 11.89	1/9	5.86/ 1.32	4.44
VF X F	22.40/142.84	1/9	22.40/ 7.94	5.52***
VF X Q	20.77/142.84	2/18	10.38/ 7.93	1.31
VF X T X N	2.60/ 64.17	2/18	1.30/ 3.56	.37
VF X T X F	4.60/ 95.84	2/18	2.30/ 5.32	.43
VF X T X Q	18.43/151.79	4/36	4.61/ 4.22	1.09
VF X N X F	.17/ 39.64	1/9	.17/ 4.40	.70
VF X N X Q	2.12/ 74.99	2/18	1.06/ 4.17	.25
VF X F X Q	12.72/ 80.73	2/18	6.36/ 4.49	1.42
VF X T X N X F	2.59/127.14	2/18	1.29/ 7.06	.18
VF X T X N X Q	19.65/214.57	4/36	4.92/ 5.96	.82
VF X T X F X Q	8.11/200.94	4/36	2.03/ 5.58	.36
VF X N X F X Q	4.33/ 75.05	2/18	2.17/ 4.17	.52
VF X T X N X F X Q	9.40/ 90.54	4/36	2.35/ 2.51	.93

Key to the Table

T : Task demand

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

Table 12

5-way ANOVA of chance corrected accuracy measures for the blocked number task.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
C	2.24/ .10	1/9	2.24/ .01	197.36***
N	.99/3.89	1/9	.99/ .43	2.30
F	.82/ .56	1/9	.82/ .06	13.03***
Q	20.59/18.11	2/18	10.29/1.00	10.23***
C X N	.31/ .87	2/18	.30/ .09	3.17
C X F	.01/ .11	1/9	.01/ .01	.45
C X Q	.25/ .29	2/18	.12/ .01	7.74***
N X F	.49/ .55	1/9	.49/ .06	8.05***
N X Q	.58/1.82	2/18	.29/ .10	2.90
F X Q	.80/2.04	2/18	.40/ .11	3.55***
C X N X F	.03/ .11	1/9	.03/ .01	2.24
C X N X Q	.14/ .29	2/18	.07/ .01	4.37***
C X F X Q	.13/ .28	2/18	.06/ .01	4.00***
N X F X Q	.12/ .28	2/18	.06/ .02	2.64
C X N X F X Q	.06/ .31	2/18	.03/ .02	1.64
VF	.12/1.55	1/9	.12/ .17	.72
VF X C	.00/ .16	1/9	.00/ .02	.08
VF X N	.31/ .87	1/9	.31/ .09	3.17
VF X F	.13/ .36	1/9	.13/ .04	3.25
VF X Q	1.04/2.80	2/18	.50/ .15	3.22
VF X C X N	.03/ .09	1/9	.03/ .01	3.06
VF X C X F	.03/ .12	1/9	.03/ .01	2.23
VF X C X Q	.06/ .29	2/18	.03/ .02	1.81
VF X N X F	.01/ .46	1/9	.01/ .05	.19
VF X N X Q	.06/1.17	2/18	.03/ .06	.44
VF X F X Q	.16/ .56	2/18	.08/ .03	2.64
VF X C X N X F	.00/ .13	1/9	.00/ .01	.03
VF X C X N X Q	.01/ .30	2/18	.00/ .02	.27
VF X C X F X Q	.01/ .31	2/18	.04/ .02	.26
VF X N X F X Q	.25/1.21	2/18	.13/ .07	1.88
VF X C X N X F X Q	.02/ .26	2/18	.01/ .01	.74

Key to the Table

C : Chance corrected accuracy measure

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

Table 13

5-way ANOVA of chance corrected accuracy measures for the blocked form task.

Source of Variance	SS/ SSe	df/dfe	MS/ MSe	F
C	.08/ .50	1/9	.08/ .06	1.46
N	.24/ .72	1/9	.24/ .08	3.01
F	.93/1.25	1/9	.93/ .14	6.72***
Q	.79/ .84	2/18	.39/ .05	8.62***
C X N	.03/ .23	1/9	.03/ .03	.97
C X F	4.16/ .66	1/9	4.16/ .07	56.04***
C X Q	.13/ .54	2/18	.06/ .03	2.13
N X F	.30/ .78	1/9	.30/ .09	4.47
N X Q	.33/ .67	2/18	.17/ .04	4.29***
F X Q	.87/2.04	2/18	.43/ .11	3.83***
C X N X F	.07/ .17	1/9	.07/ .02	3.77
C X N X Q	.10/ .66	2/18	.05/ .04	1.32
C X F X Q	.14/ .25	2/18	.07/ .01	5.17***
N X F X Q	.10/ .92	2/18	.05/ .05	.98
C X N X F X Q	.05/ .87	2/18	.02/ .05	.47
VF	.07/ .57	1/9	.07/ .06	1.21
VF X C	.07/ .17	1/9	.07/ .02	3.74
VF X N	.00/ .51	1/9	.00/ .06	.06
VF X F	.00/ .29	1/9	.00/ .03	.10
VF X Q	.20/ .65	2/18	.10/ .04	2.79
VF X C X N	.00/ .24	1/9	.00/ .03	.07
VF X C X F	.07/ .25	1/9	.07/ .03	2.35
VF X C X Q	.08/ .55	2/18	.04/ .03	1.28
VF X N X F	.10/ .29	1/9	.10/ .03	2.97
VF X N X Q	.01/ .76	2/18	.00/ .04	.12
VF X F X Q	.02/1.23	2/18	.01/ .07	.14
VF X C X N X F	.01/ .18	1/9	.01/ .02	.31
VF X C X N X Q	.08/ .41	2/18	.04/ .02	1.69
VF X C X F X Q	.04/ .37	2/18	.02/ .02	.97
VF X N X F X Q	.04/ .87	2/18	.02/. 05	.47
VF X C X N X F X Q	.04/ .45	2/18	.02/ .03	.77

Key to the Table
C : Chance corrected accuracy measure
N : Pair number
F : Pair form
Q : Number of dots in the second pattern of a pair
VF : Visual field of presentation

Table 14

5-way ANOVA of chance corrected accuracy measures for the mixed form and number task.

Source of Variance	SS/ SSe	df/dfe	MS/ MSe	F
C	2.83/ .50	1/9	2.83/ .06	50.60***
N	.06/ .52	1/9	.06/ .06	1.04
F	2.53/ .31	1/9	2.53/ .03	73.72***
Q	1.05/3.20	2/18	.53/ .18	2.97
C X N	1.63/ .31	1/9	1.63/ .03	47.25***
C X F	11.62/ .23	1/9	11.62/ .23	464.54***
C X Q	.04/ .97	2/18	.02/ .05	.34
N X F	.44/ .66	1/9	.44/ .07	6.10***
N X Q	1.20/ .94	2/18	.60/ .05	11.44***
F X Q	.59/1.67	2/18	.29/ .09	3.17
C X N X F	.20/ .74	1/9	.20/ .08	2.43
C X N X Q	.44/ .63	2/18	.22/ .04	6.32***
C X F X Q	.64/ .36	2/18	.32/ .02	16.07***
N X F X Q	.98/ .90	2/18	.48/ .05	9.53***
C X N X F X Q	.32/ .65	2/18	.16/ .04	4.40***
VF	.00/ .32	1/9	.00/ .04	.07
VF X C	.01/ .11	1/9	.01/ .01	1.06
VF X N	.02/ .39	1/9	.02/ .04	.41
VF X F	.02/ .14	1/9	.02/ .02	1.55
VF X Q	.22/ .43	2/18	.11/ .02	4.72***
VF X C X N	.00/ .39	1/9	.00/ .04	.00
VF X C X F	.02/ .14	1/9	.02/ .02	1.05
VF X C X Q	.13/ .44	2/18	.06/ .02	2.61
VF X N X F	.00/ .19	1/9	.00/ .02	.00
VF X N X Q	.03/ .99	2/18	.01/ .05	.25
VF X F X Q	.33/ .79	2/18	.17/ .04	3.77***
VF X C X N X F	.00/ .19	1/9	.00/ .02	.41
VF X C X N X Q	.00/ .60	2/18	.00/ .03	.05
VF X C X F X Q	.06/ .72	2/18	.03/ .04	.76
VF X N X F X Q	.30/ .61	2/18	.15/ .03	4.49***
VF X C X N X F X Q	.07/ .58	2/18	.03/ .03	1.15

Key to the Table

C : Chance corrected accuracy measure

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

Table 15

4-way ANOVA of mean number of correct manual responses.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Blocked number:				
N	4.54/151.75	1/9	4.54/16.86	.27
F	22.20/ 19.21	1/9	22.20/ 2.14	10.38***
Q	445.66/357.92	2/18	222.83/19.88	11.21***
N X F	11.70/ 17.58	1/9	11.70/ 1.95	5.99***
N X Q	19.42/ 53.65	2/18	9.71/ 2.98	3.26
F X Q	21.55/ 62.35	2/18	10.77/ 3.46	3.11
N X F X Q	6.36/ 48.72	2/18	3.18/ 2.70	1.17
VF	.94/ 26.35	1/9	.94/ 2.93	.32
VF X N	.04/ 23.72	1/9	.04/ 2.64	.01
VF X F	4.00/ 15.95	1/9	4.00/ 1.77	2.26
VF X Q	18.52/ 61.06	2/18	9.23/ 3.39	2.73
VF X N X F	.10/ 16.68	1/9	.10/ 1.85	.06
VF X N X Q	2.06/ 34.06	2/18	1.03/ 1.89	.54
VF X F X Q	.86/ 16.05	2/18	.43/ 0.89	.48
VF X N X F X Q	3.85/ 39.22	2/18	1.93/ 2.17	.89
Blocked form:				
N	7.70/ 13.17	1/9	7.70/1.46	5.26***
F	165.00/ 46.04	1/9	165.00/5.11	32.26***
Q	28.23/ 30.44	2/18	14.11/1.69	8.34***
N X F	1.50/ 18.20	1/9	1.50/2.02	.74
N X Q	12.16/ 31.34	2/9	6.08/1.74	3.49***
F X Q	30.56/ 52.27	2/18	15.27/2.90	5.26***
N X F X Q	2.76/ 36.90	2/18	1.38/2.05	.67
VF	.00/ 19.04	1/9	.00/2.11	.00
VF X N	.00/ 16.70	1/9	.00/1.85	.00
VF X F	1.84/ 10.35	1/9	1.84/1.15	1.59
VF X Q	8.25/ 29.57	2/18	4.13/1.64	2.51
VF X N X F	3.07/ 11.17	1/9	3.07/1.24	2.45
VF X N X Q	2.36/ 25.30	2/18	1.18/1.40	.84
VF X F X Q	.92/ 39.74	2/18	.47/2.20	.21
VF X N X F X Q	.62/ 26.54	2/18	.31/1.47	.21

Table 15 (continued)

4-way ANOVA of mean number of correct manual responses.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Mixed form and number:				
N	19.84/ 27.70	1/9	19.84/3.07	6.44***
F	451.00/ 13.53	1/9	451.00/1.50	299.84***
Q	20.91/ 73.67	2/18	10.45/4.08	2.55
N X F	.70/ 45.33	1/9	.70/5.03	.14
N X Q	57.95/ 45.16	2/18	28.96/2.50	11.54***
F X Q	42.11/ 47.97	2/18	21.05/2.66	7.90***
N X F X Q	40.75/ 39.82	2/18	20.38/2.21	9.21***
VF	.04/ 10.17	1/9	.04/1.13	.03
VF X N	.34/ 17.37	1/9	.34/1.93	.17
VF X F	.00/ 5.70	1/9	.00/0.63	.01
VF X Q	9.17/ 16.74	2/18	4.58/0.93	4.93***
VF X N X F	.04/ 11.88	1/9	.04/1.31	.03
VF X N X Q	.62/ 41.79	2/18	.31/2.32	.13
VF X F X Q	11.80/ 47.60	2/18	5.90/2.64	2.23
VF X N X F X Q	12.22/ 39.02	2/18	6.11/2.16	2.82

Key to the Table

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

Table 16

4-way ANOVA of mean latency for correct responses.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Blocked number:				
N	.17/1.47	1/9	.17/.17	1.05
F	.08/1.57	1/9	.08/.17	.45
Q	4.47/5.60	2/18	2.23/.31	7.17***
N X F	.02/ .66	1/9	.02/.07	.23
N X Q	1.95/1.83	2/18	.97/.10	9.52***
F X Q	.01/ .63	2/18	.01/.03	.18
N X F X Q	.14/1.05	2/18	.07/.06	1.21
VF	.15/1.26	1/9	.15/.14	1.03
VF X N	.33/ .89	1/9	.33/.09	3.33
VF X F	.09/ .90	1/9	.09/.10	.86
VF X Q	.18/2.40	2/18	.09/.13	.66
VF X N X F	.02/1.35	1/9	.02/.07	.43
VF X N X Q	.51/1.68	2/18	.26/.09	2.73
VF X F X Q	.07/1.35	2/18	.03/.07	.43
VF X N X F X Q	.13/1.23	2/18	.06/.07	.92
Blocked form:				
N	.15/ .47	1/9	.15/.15	2.93
F	.57/ .95	1/9	.57/.10	5.40***
Q	.30/1.83	2/18	.15/.10	1.49
N X F	.04/ .49	1/9	.04/.05	.75
N X Q	.03/1.11	2/18	.02/.06	.24
F X Q	.07/1.12	2/18	.03/.06	.52
N X F X Q	.24/ .06	2/18	.12/.03	3.63***
VF	.01/ .25	1/9	.01/.03	.18
VF X N	.01/ .36	1/9	.02/.04	.37
VF X F	.07/ .36	1/9	.07/.04	1.86
VF X Q	.08/ .73	2/18	.04/.04	.94
VF X N X F	.02/ .24	1/9	.02/.03	.61
VF X N X Q	.08/ .40	2/18	.04/.02	1.78
VF X F X Q	.03/ .67	2/18	.02/.04	.46
VF X N X F X Q	.04/ .51	2/18	.02/.03	.71

Table 16 (continued)

4-way ANOVA of mean latency for correct responses.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Mixed form and number:				
N	.05/ .65	1/9	.05/.07	.64
F	10.21/3.05	1/9	10.21/.34	30.07***
Q	.12/1.60	2/18	.06/.08	.68
N X F	.12/ .97	1/9	.12/.01	1.13
N X Q	.18/1.64	2/18	.09/.09	.98
F X Q	.19/ .92	2/18	.09/.05	1.84
N X F X Q	.40/2.04	2/18	.20/.11	1.75
VF	.00/ .61	1/9	.00/.07	.06
VF X N	.03/ .45	1/9	.03/.05	.53
VF X F	.09/ .41	1/9	.09/.05	1.95
VF X Q	.08/1.11	2/18	.04/.06	.66
VF X N X F	.00/ .27	1/9	.00/.03	.08
VF X N X Q	.05/1.96	2/18	.03/.11	.24
VF X F X Q	.03/1.24	2/18	.02/.07	.22
VF X N X F X Q	.16/ .99	2/18	.08/.06	1.49

Key to the Table

N : Pair number
F : Pair form
Q : Number of dots in the second pattern of a pair
VF : Visual field of presentation

Table 17

4-way ANOVA of mean number of correct verbal responses.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Blocked number:				
N	81.67/ 58.25	1/9	81.67/ 6.47	12.62***
F	24.07/ 12.69	1/9	24.07/ 1.40	17.08***
Q	548.23/554.43	2/18	274.12/30.80	8.90***
N X F	7.35/ 9.56	1/9	7.35/ 1.06	6.91***
N X Q	10.03/ 44.30	2/18	5.02/ 2.46	2.04
F X Q	21.23/ 44.76	2/18	10.61/ 2.48	4.27***
N X F X Q	7.30/ 30.03	2/18	3.65/ 1.66	2.19
VF	3.27/ 55.98	1/9	3.27/ 6.22	.53
VF X N	1.35/ 41.06	1/9	1.35/ 4.56	.30
VF X F	2.01/ 8.90	1/9	2.01/ 0.98	2.04
VF X Q	40.03/ 75.96	2/18	20.02/ 4.22	4.74***
VF X N X F	1.07/ 7.01	1/9	1.07/ 0.78	1.37
VF X N X Q	1.30/ 24.03	2/18	.65/ 1.34	.49
VF X F X Q	8.23/ 23.01	2/18	4.11/ 1.28	3.21
VF X N X F X Q	8.23/ 31.43	2/18	4.12/ 1.74	2.36
Blocked form:				
N	5.10/ 47.68	1/9	5.10/ 5.29	.96
F	49.50/ 53.95	1/9	49.50/ 5.99	8.26***
Q	14.43/ 39.98	2/18	7.22/ 2.22	3.25
N X F	24.70/ 33.92	1/9	24.70/ 3.76	6.55***
N X Q	10.23/ 37.35	2/18	5.12/ 2.07	2.47
F X Q	11.63/ 75.78	2/18	5.81/ 4.21	1.38
N X F X Q	4.43/ 58.81	2/18	2.22/ 3.26	.68
VF	12.60/ 17.02	1/9	12.60/ 1.89	6.66***
VF X N	.70/ 21.75	1/9	.70/ 2.41	.29
VF X F	2.20/ 23.25	1/9	2.20/ 2.58	.85
VF X Q	4.23/ 33.01	2/18	2.12/ 1.83	1.15
VF X N X F	2.60/ 12.35	1/9	2.60/ 1.37	1.90
VF X N X Q	1.43/ 40.98	2/18	.72/ 2.27	.31
VF X F X Q	2.43/ 37.48	2/18	1.22/ 2.08	.58
VF X N X F X Q	1.43/ 34.98	2/18	.72/ 1.94	.37

Table 17 (continued)

4-way ANOVA of mean number of correct verbal responses.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Mixed form and number:				
N	138.02/ 13.90	1/9	138.02/ 1.54	89.36***
F	198.02/ 21.23	1/9	198.02/ 2.36	83.93***
Q	67.90/260.85	2/18	33.95/14.49	2.34
N X F	72.60/ 15.43	1/9	72.60/ 1.71	58.60***
N X Q	14.23/ 43.85	2/18	7.12/ 2.43	2.92
F X Q	4.93/ 85.31	2/18	2.46/ 4.74	.52
N X F X Q	11.20/ 51.05	2/18	5.60/ 2.83	1.97
VF	1.67/ 18.75	1/9	1.67/ 2.08	.80
VF X N	1.35/ 36.56	1/9	1.35/ 4.06	.33
VF X F	4.81/ 15.53	1/9	4.81/ 1.71	2.81
VF X Q	10.43/ 49.65	2/18	5.22/ 2.75	1.89
VF X N X F	.60/ 8.15	1/9	.60/ 0.90	.66
VF X N X Q	.70/ 50.38	2/18	.35/ 2.79	.13
VF X F X Q	8.13/ 27.11	2/18	4.06/ 1.50	2.70
VF X N X F X Q	4.80/ 21.45	2/18	2.40/ 1.19	2.01

Key to the Table

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

VF : Visual field of presentation

Table 18

4-way ANOVA of mean confidence rating.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Blocked number:				
N	155.20/ 50.67	1/9	155.20/ 5.63	27.57***
F	.20/ 28.67	1/9	.20/ 3.18	.06
Q	787.67/200.07	2/18	393.84/11.11	35.43***
N X F	5.70/ 30.04	1/9	5.70/ 3.33	1.71
N X Q	188.05/ 89.19	2/18	94.03/ 4.95	18.98***
F X Q	3.90/ 85.34	2/18	1.95/ 4.74	.41
N X F X Q	17.26/ 59.15	2/18	8.63/ 3.28	2.63
VF	24.70/ 84.00	1/9	24.70/ 9.33	2.65
VF X N	.70/ 13.83	1/9	.70/ 1.53	.46
VF X F	1.50/ 49.37	1/9	1.50/ 5.48	.27
VF X Q	22.60/133.80	2/18	11.30/ 7.43	1.52
VF X N X F	.94/ 69.10	1/9	.94/ 7.67	.12
VF X N X Q	5.10/ 84.52	2/18	2.53/ 4.69	.54
VF X F X Q	5.10/ 98.14	2/18	2.55/ 5.45	.47
VF X N X F X Q	.52/ 45.56	2/18	.26/ 2.53	.10
Blocked form:				
N	11.27/ 15.48	1/9	11.27/ 1.72	6.55***
F	5.40/102.18	1/9	5.40/11.35	.48
Q	85.10/ 86.97	2/18	42.55/ 4.83	8.81***
N X F	36.82/ 46.93	1/9	36.82/ 5.21	7.06***
N X Q	32.25/ 88.99	2/18	16.13/ 4.94	3.26
F X Q	7.27/ 85.14	2/18	3.64/ 4.73	.77
N X F X Q	45.06/ 76.19	2/18	22.53/ 4.23	5.32***
VF	1.67/ 49.41	1/9	1.67/ 5.49	.30
VF X N	7.35/ 41.56	1/9	7.35/ 4.61	1.59
VF X F	18.15/ 28.93	1/9	18.15/ 3.21	5.65***
VF X Q	6.86/120.55	2/18	3.43/ 6.69	.51
VF X N X F	1.67/ 24.25	1/9	1.67/ 2.69	.62
VF X N X Q	4.57/101.00	2/18	2.28/ 5.61	.41
VF X F X Q	12.02/104.39	2/18	6.01/ 5.79	1.04
VF X N X F X Q	10.51/ 67.07	2/18	5.24/ 3.72	1.41

Table 18 (continued)

4-way ANOVA of mean confidence rating.

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Mixed form and number:				
N	32.27/ 42.81	1/9	32.27/ 4.75	6.78***
F	19.27/126.15	1/9	19.27/14.01	1.37
Q	86.70/149.30	2/18	43.35/ 8.29	5.23***
N X F	11.27/ 21.65	1/9	11.27/ 2.40	4.68***
N X Q	5.63/ 37.53	2/18	1.35/ 2.08	1.35
F X Q	2.63/ 61.20	2/18	1.32/ 3.40	.39
N X F X Q	38.43/ 85.90	2/18	19.22/ 4.77	4.03***
VF	.02/128.23	1/9	.02/14.24	.00
VF X N	.42/ 20.66	1/9	.42/ 2.29	.18
VF X F	7.35/ 54.06	1/9	7.35/ 6.07	1.22
VF X Q	9.73/ 40.26	2/18	4.87/ 2.23	2.18
VF X N X Q	12.13/104.03	2/18	6.07/ 5.77	1.05
VF X N X F	.15/ 73.43	1/9	.15/ 8.15	.02
VF X F X Q	3.70/ 79.13	2/18	1.85/ 4.39	.42
VF X N X F X	2.70/ 52.96	2/18	1.35/ 2.94	.46

Key to the Table

N : Pair number
F : Pair form
Q : Number of dots in the second pattern of a pair
VF : Visual field of presenation

Table 19

3-way ANOVA of mean sensitivity (P(I))

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Blocked number:				
F	.09/ .07	1/9	.09/.01	11.52***
Q	1.72/1.29	2/18	.86/.07	11.93***
F X Q	.08/ .21	2/18	.04/.01	3.53***
VF	.00/ .11	1/9	.00/.01	.09
VF X F	.01/ .05	1/9	.01/.01	1.76
VF X Q	.06/ .24	2/18	.03/.01	2.26
VF X F X Q	.00/ .06	2/18	.00/.03	.40
Blocked form:				
N	.03/ .04	1/9	.03/.00	7.09***
Q	.09/ .10	2/18	.04/.01	7.38***
N X Q	.05/ .11	2/18	.02/.01	4.39***
VF	.00/ .06	1/9	.00/.01	.04
VF X N	.00/ .05	1/9	.00/.01	.11
VF X Q	.03/ .10	2/18	.02/.01	3.19
VF X F X Q	.01/ .11	2/18	.00/.01	.76
Mixed form and number:				
TD	.55/ .08	2/18	.27/.00	59.91***
Q	.13/ .53	2/18	.07/.03	2.28
TD X Q	.22/ .12	4/36	.05/.00	15.78***
VF	.00/ .14	1/9	.00/.01	.04
VF X TD	.00/ .03	2/18	.00/.00	.21
VF X Q	.07/ .20	2/18	.04/.01	3.18
VF X Q X TD	.06/ .18	4/36	.02/.00	3.08***

Key to the Table

N : Pair number

F : Pair form

Q : Number of dots in the second pattern of a pair

TD : Type of differnce between two patterns of a pair

VF : Visual field of presentation

Table 20

3-way ANOVA of mean decision bias (B'')

Source of Variance	SS/SSe	df/dfe	MS/MSe	F
Blocked number:				
F	.24/ .88	1/9	.24/.09	2.51
Q	.78/2.18	2/18	.39/.12	3.22
F X Q	.31/2.61	2/18	.16/.14	1.07
VF	.05/1.77	1/9	.05/.19	.26
VF X F	.04/ .86	1/9	.04/.09	.39
VF X Q	.13/1.53	2/18	.07/.08	.78
VF X F X Q	.01/2.41	2/18	.01/.13	.05
Blocked form:				
N	.14/ .55	1/9	.14/.06	2.38
Q	.54/1.92	2/18	.27/.11	2.53
F X Q	.02/1.25	2/18	.01/.07	.11
VF	.00/ .61	1/9	.00/.07	.03
VF X N	.08/ .51	1/9	.08/.06	1.37
VF X Q	.02/2.06	2/18	.01/.11	.10
VF X F X Q	.04/ .98	2/18	.02/.05	.38
Mixed form and number:				
TD	3.42/2.47	2/18	1.71/.13	12.48***
Q	.18/1.66	2/18	.09/.09	.97
TD X Q	1.39/1.98	4/36	.35/.05	6.27***
VF	.00/ .31	1/9	.00/.03	.05
VF X TD	.12/ .59	2/18	.12/.03	1.87
VF X Q	.51/1.65	2/18	.25/.09	2.80
VF X Q X TD	.48/3.38	4/36	.12/.09	1.29

Key to the Table

N	: Pair number
F	: Pair form
Q	: Number of dots in the second pattern of a pair
TD	: Type of differnce between two patterns of a pair
VF	: Visual field of presentation

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