POSITION AND IDENTITY IN VISUAL INFORMATION PROCESSING

by

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ABSTRACT

Information that is presented visually can be described in terms of its identity and in terms of its position, and a distinction can be drawn between *what* an item is and *where* that item is. For example, a letter displayed on a screen has both an identity (its name) and a spatial position; the spatial position can be specified either absolutely (the upper right quadrant) or relatively (beside the "x" and above the "y"). There is an obvious and intimate relationship between the identity component and the position component, and it is this relationship, between the the processing of position information and the processing of identity information, that forms the subject of the present thesis.

First, the relevant literature is reviewed. The relationship between position and identity is examined in the context of two major research areas: iconic memory and short term visual memory. Second, the concept of dimensional separability is considered with reference to the appropriate literature. The purpose is to indicate a theoretical framework within which the issue of concern may be profitably addressed. The key idea to be developed is that position and identity are asymmetrically separable dimensions. A small group of studies that offer tentative support to this conceptualization will be discussed.

Third, the results of eight related experiments are reported. These experiments involve the recognition of position and/or identity information in a discrete trials procedure. The eight experiments fall into three separate groups. Experiments 1 to 3 examine the recognition

of either position or identity information, with the two types of information presented in relative isolation. Several stimulus factors are manipulated in order to demonstrate differential effects upon the two dimensions. Experiments 4 to 6 examine the effect of the irrelevant dimension upon recognition of the relevant dimension. Experiment 4 uses a logically balanced set of stimuli, so that the irrelevant dimension is either consistent or inconsistent, whereas in Experiments 5 and 6 each dimension is examined in the context of consistent, inconsistent, or neutral information on the irrelevant dimension. Experiments 7 and 8 explore the integration of position and identity information by varying the task requirements. Shared attention conditions are contrasted with selective attention conditions to show the impact of attentional strategy.

The thesis concludes with a general discussion of the results, and their accordance with the hypothesis of asymmetric separability.

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ERRATA

Page 18. Second paragraph, last line: "recall of letter identity" should read "recall of letter position".

Page 60. Second paragraph: "Subjects were four female" should read "Subjects were fourteen female".

Page 137. Figure legend should be reversed, so that the open circles correspond to the selective-shared task order, and the open squares correspond to the shared-selective task order.

PREFACE

The processing of visual information has received substantial research attention during the past twenty-five years. The purpose of this thesis is to examine in detail one facet of visual information processing: the relationship between position information and identity information.

Position information concerns *where* a visually presented item is: its spatial position or location. Identity information refers to *what* that item is: its name or other identifying attribute, such as shape. These are fundamental aspects of visually presented information, but the relationship between them has not received sufficient consideration. Much of the literature focuses on the processing of identity information, and the processing of position information is either disregarded, or viewed only in conjunction with identity information processing.

Although it is obvious that what and where information are often integrated, so that particular items are seen in particular places, it does not necessarily follow that identity and position are conjoined throughout the processing sequence. My intention in the experiments reported here was to try to disentangle position information processing from identity information processing, in order to better understand the separate processes involved.

In reviewing the literature I found that the position/identity issue had been approached primarily from two complementary viewpoints: iconic memory and short-term memory. This organization of research reflects the

model of visual information processing that was dominant during the 1960's and early 1970's, in which the essential components were iconic memory, short-term memory, and long-term memory. The thesis begins by reviewing this literature, considering first studies conducted within the iconic memory field, and then research carried out in the area of short-term memory. It should be pointed out that the procedures used and the specific questions asked show considerable variation across the different studies. Nevertheless, there seem to be certain trends in the results reported, and it is these salient findings that the literature review highlights.

From about 1975 onwards, there has been a shift away from the three-component formulation of information processing, and an increasing emphasis on cognitive operations, flexible processing, resource allocation, and so forth. In essence, a structuralist approach has been replaced by a functionalist approach.

The research reported here fits into this newer perspective. A dimensional analysis is applied to visually presented position and identity information. The specific hypothesis put forward is that position and identity are asymmetrically separable dimensions.

To assist development of this idea, a selective review of the literature concerning dimensional relationships is presented. The purposes of this section are twofold: to outline the main types of dimensional relationships, and to show how matching or comparison procedures have been used in the study of dimensional relationships.

The subsequent section discusses the reasons why a relationship of asymmetric separability might be expected for position and identity information. It indicates how such a conceptualization can accommodate the main results from the iconic and short-term memory research, and

reviews a small number of existing studies that support the hypothesized relationship of asymmetric separability.

POSITION AND IDENTITY IN ICONIC MEMORY

The research reviewed in this chapter is concerned with the initial processing of visual information. From the archival studies of iconic memory two major findings emerged that indicated the importance of a distinction between position information and identity information.

The first of these findings was that spatial position functioned as a particularly effective partial report cue. Von Wright (1968, 1970) followed up the suggestion in Sperling's (1960) pioneering work that, although physical selection cues produced partial report superiority, symbolic or categorical cues did not. Von Wright examined a variety of selection cues for the partial report of letter displays, and found that cues of location (row), color, size, and brightness produced partial report superiority, whereas cues of orientation, alphanumeric category, alphabetic category, and version did not. The greatest difference between partial and whole report was obtained with the location cue, implying a greater salience of location information.

The second finding was that, given a brief display of a horizontal array of letters, report accuracy varied as a function of serial position, with greater accuracy for letters that appeared in end and in central positions (Averbach & Coriell, 1961; Bryden, 1966; Crovitz & Schiffman, 1965; White, 1969). This W-shaped accuracy curve has been interpreted in terms of both sensory variables (Estes, 1972) and processing strategies (White, 1976). However, Townsend (1973) and Lowe (1975) have pointed out that variations in accuracy as a function of serial position may instead reflect variation in the processing of

spatial information, and the conjoining of spatial to identity information. Expansion of this suggestion has resulted in the formulation of a sophisticated model of performance in tachistoscopic recognition, in which a clear distinction between the processes of letter identification and letter localization is made (Campbell & Mewhort, 1980; Mewhort, Campbell, Marchetti, & Campbell, 1981; Mewhort, Marchetti, & Campbell, 1982). A series of studies by Butler (1980a, 1980b, 1981) indicates further that the localization process is the main constraint on performance in tachistoscopic tasks.

Although the research concerned with cue effects and serial position effects in iconic memory indicates the necessity of distinguishing between position and identity information, neither avenue of research readily permits an examination of separate processing. This is because, in the tasks typically used, all potential positions are occupied by items. Successful performance therefore requires an integration of position information with identity information, so that the focus is upon the process of item localization.

The remainder of the research considered in this chapter has attempted to separate position information processing from identity information processing. Two general features of experimental design facilitate the achievement of this aim. (1) Task requirements are varied, so that characteristically either the report of position information or the report of identity information is required. The report of both types of information in combination (that is, localization) is sometimes included for comparative purposes. (2) The items presented appear in a subset of possible positions, so that there is uncertainty concerning both item identity and item location. This

permits position information processing and identity information processing to be studied either singly or jointly (Den Heyer, 1972). In addition, a number of researchers have elected to use non-letter items in order to eliminate the influence of processing strategies specific to letters.

Four experimental procedures have been used in this research: partial report with cue delay, forced-choice recognition, single item report, and multiple item report.

Partial Report With Cue Delay Studies

In Den Heyer's (1972) study, both type of information presented and type of information reported were varied. A partial report procedure was used, with bar markers as the cue, and with cue delay varied from 0 to 700 msec. Five partial report tasks were used, which Den Heyer designated P, I, PX, IX, and PI.

In the P task subjects were presented with three 8-cell matrices with three position markers in each, and were cued to report one of the matrices. In the I task subjects were presented with three columns of three letters each, and were cued to report one of the columns. In the PX, IX, and PI tasks subjects were presented with three 8-cell matrices each containing three letters. In the PX task the positions in the cued matrix were reported; in the IX task the letters in the cued matrix were reported. In the PI task letters in conjunction with positions were reported, although position accuracy and identity accuracy were scored separately.

Accuracy decreased with cue delay in all tasks. Cue delay did not interact with task, indicating equal rates of decay for position and identity information. Accuracy was considerably greater for position

information than for identity information, such that the least accurate position task was superior to the most accurate identity task. Accuracy also varied with type of task: tasks in which a single type of information was presented (P and I tasks) were more accurate than tasks in which both types of information were presented (PX, IX, and PI tasks). Where both types of information were presented, accuracy did not differ as a function of report requirement. That is, for a given type of information, subjects were as accurate when reporting a single type as when reporting both types of information. (Data were also collected for whole report, and these data showed report of position information to be uniformly inferior to report of identity information.)

Den Heyer (1972) drew three main conclusions from these results. The equal decay rates, unaffected by either type of information or task requirement, demonstrated the simultaneous encoding and parallel "fading" of both types of information. The higher accuracy found for position information was attributed to the greater clarity of that information in iconic storage, with clarity an inverse function of complexity. The reduction in accuracy which occurred with presentation of both types of information, irrespective of the report requirement, indicated the presence of perceptual interaction, using the criteria of Garner and Morton (1969). As some of the multiple item report studies also address the issue of interaction/independence, elaboration of this point will be deferred.

Finkel and Smythe (1973) reversed the standard partial report procedure, and used item identity as a cue to report item position. Their purpose in doing so was to estimate the capacity of iconic memory for spatial information. In one experiment, four geometric forms (from a set of nine) appeared in a 3x3 matrix; in the other experiment, a fixed

set of eight forms appeared in varying positions in a twelve cell grid. Cue delay was varied from 0 to 1000 msec.

Accuracy did not decrease with cue delay, in contrast to the typical finding when position is used to cue the partial report of identity. Since partial report performance did not exceed that characteristically obtained with whole report, the absence of decay with cue delay was attributed to very rapid decay occurring prior to responding, and hence "invisible" in performance measures. Two reasons were offered to account for this early decay: the time required to identify the item cue, and the reorientation required by the use of unpredictable stimulus locations.

Position memory capacity was estimated by multiplying percentage correct by the number of items in a display, yielding estimates of 3.5 and 3.0 positions for the four and eight item displays, respectively. This method of estimation seems questionable, however. It is a tenable argument that the correct multiplier should be the number of possible positions, since if subjects know where an item is, presumably they also know where it is not. This would change the estimates to approximately 7.0 and 4.5 for the nine cell and twelve cell displays, respectively. This issue cannot be resolved here; in order to do so, the confound between number of items and number of possible positions would need to be removed.

The important point to note is that the partial report procedure (both the reversed procedure used by Finkel and Smythe, 1973, and the standard procedure) actually demands the localization of items. That is, in order to successfully utilize an identity cue to report item position, or a position cue to report item identity, identities must have been "allocated" to positions. The observation that item

Localization is required in the partial report task can be used to reconcile two differing interpretations of cue delay functions. Finkel and Smythe (1973) maintain that cue delay functions represent loss of the type of information to be reported, whereas other authors (Clark, 1969; Dick, 1969) interpret cue delay functions as representing loss of the type of information used as the cue. Given that the partial report procedure requires item localization for accurate performance, it is conceivable that what is lost over time is the integration of position and identity information.

Forced Choice Recognition Studies

Studies by Cumming and Coltheart (1969) and by Henderson (1972b) employed a forced-choice recognition design. In both experiments digits were briefly displayed in a 3x3 matrix, and followed, after a short interval during which visual noise was presented, by a forced-choice recognition test between two digits and two positions; one of the digits having occurred in one of the positions. The former study used six digits and a two second interval; the latter study used five digits and a one second interval. Despite the similarity in procedure, there were striking differences in the results.

In the Cumming and Coltheart (1969) study responses were classified according to whether position or identity or both were correctly reported, and these proportions were compared via chi-square tests to the expected frequencies predicted by four different processing hypotheses. These hypotheses were: position and identity independent, position contingent on identity, identity contingent on position, and mutual contingency. The results supported the latter three hypotheses; moreover, the authors state that joint occurrence of the two single contingencies is equivalent to mutual contingency.

There are, however, several important qualifications to these conclusions. Accuracy when corrected for guessing averaged only 19%, so that inferences about the nature of processing under these conditions may not be generalizable, as the authors noted. The summing of chi-square values and degrees of freedom over subjects may be misleading; at the level of individual subjects, all but the independence hypothesis were supported by three subjects each. Finally, according to Cumming and Coltheart (1969), the identity contingent on position hypothesis holds that subjects may forget the identity of a remembered position, while the position contingent on identity hypothesis states that subjects may forget the position of a remembered identity. A combination of these two hypotheses would seem to be equivalent to mutual contingency only in the limiting case of one item in one position. The forced-choice recognition procedure may approximate this limiting case; that is, the particular procedure may have artificially constrained the conclusion.

In Henderson's (1972b) study recognition accuracy for position and identity information was examined in three experiments. When display duration was varied from 400 to 1000 msec, recognition accuracy increased with duration for both types of information, with a slightly higher level and degree of improvement for identity information. When display duration was held constant at 250 msec, position accuracy was superior with both identity priority and position priority instructions, with the latter type of instructions producing a larger difference in accuracy. When blank versus noise intervals were contrasted, position accuracy was again superior to identity accuracy, although it was differentially impaired by visual noise during the delay interval.

Henderson (1972b) applied the same chi-square analysis used by Cumming and Coltheart (1969) and found that, instead of mutual

contingency, the hypothesis of independent processing was supported. Henderson noted that apparent dependencies may occur at the extremes of the psychometric function, and he suggested that this artifact underlay the conclusions of Cumming and Coltheart.

Further empirical clarification could be useful here, particularly if a procedural problem was eliminated. Although position recognition and identity recognition were separately tested, both types of information were tested on each trial. Thus, successful performance necessitated the processing of both types of information. The task as structured was therefore analogous to a localization task. The processing relationship which eventuates under these conditions may or may not also occur when processing of just one type of information is required. Use of a single type of recognition test would overcome this difficulty.

Single Item Report Studies

In the studies using the single item report procedure, one of a number of possible items is presented at one of a number of possible locations on each trial, and the report of the identity or the position, or both, of the item is required.

Dick and Dick (1969) displayed one of four letters, or one of four lines differing in orientation, at one of four locations. In the first experiment, subjects were postcued to report either item identity or item location. Letters were more accurately located than they were identified, whereas locating and identifying were equivalent for lines. Moreover, when subjects were required to report both types of information, letter report was often correct for location and incorrect for identity, but rarely the reverse; for lines, report of identity and

of location generally covaried. In a second experiment, exposure duration was systematically varied in order to ascertain the 50% threshold for the two types of stimulus materials in the two tasks. Threshold exposure durations were very similar for locating lines, locating letters, and identifying lines, but they were significantly longer for identifying letters. These results were taken as indicative of serial, hierarchical processing of position and identity information, which occurs as a consequence of the physiological structure of the visual cortex. Thus, the detection of location occurs at a neurologically lower, and hence temporally prior, level than does the detection of identity.

Logan's (1975a, 1975b) studies were designed to test the specific hypothesis that identification is contingent upon locating. Subjects were presented with one of four possible letters at one of four possible locations, and they were precued to report either item identity or item position, with the non-reported type of information either known in advance or unknown. Non-target locations were either blank or occupied by distractors; the nature of these distractors was varied both between subjects (1975a) and within subjects (1975b).

The first important finding was that prior knowledge of the non-reported information had differential effects upon location report and identity report. Prior knowledge of location facilitated the report of identity, whereas prior knowledge of identity did not improve the report of location. The second important finding was that the relative accuracies of location and identity varied as a function of target/distractor discriminability. When distractors were absent or easy to discriminate from the letter targets (dots or triangles), location accuracy was superior to identity accuracy, but when

distractors were difficult to discriminate (other letters), location accuracy dropped to the level of identity accuracy. Identity accuracy remained at a relatively constant level irrespective of distractor type.

Logan (1975a, 1975b) argued that this pattern of results typified an independent but interactive model. This conclusion should be treated cautiously, because as distractor composition changes, the task requirements also change. With simple or no distractors, the location and identification tasks require processing of either where an item occurred or which item occurred. With letter distractors, all possible positions are occupied, and both tasks require subjects to determine which letter occurred where. Thus, the changes in the apparent processing relationship and in the task requirements are parallel, supporting the earlier suggestion that the processing of position or identity information in isolation may be different from the processing of these types of information in conjunction.

Multiple Item Report Studies

The multiple item report procedure has been used in at least three studies. The main features of this procedure are that a number of target items appear in a subset of possible positions, with varied report requirements. The three studies have in common the use of geometric forms, instead of letters. As well, two studies have focused on developmental differences.

Finkel (1973) examined the processing of position and identity information across a range of age groups. All experiments involved the presentation of a number of position markers and/or geometric forms in an imaginary 3x3 matrix. In two experiments an exposure duration of 150 msec was used, whereas unlimited viewing time was allowed in the third

experiment. Following presentation, subjects reproduced the display using a response board.

The first experiment examined the processing of position information in isolation. Displays contained from two to five position markers. Accuracy varied with age and number of markers. Older subjects were more accurate than younger, and the number of positions correct increased as the number of markers in the array increased.

Two criticisms need to be made here, concerning the method of scoring and the analysis of those scores; these points are also relevant to the subsequent experiments. The first point is that position accuracy was scored with some flexibility, so that responses that systematically increased or decreased the distance between tokens, or deviated from center, were not rejected. Although the aim of this procedure may be reasonable, a more straightforward solution would have been to include the grid lines of the matrix in the display and response board. The second point is that the analysis of accuracy plotted number of positions correct against number displayed. Thus, the finding that accuracy increases as a function of number of positions simply demonstrates that the "span of immediate memory" has not been exceeded. A more meaningful analysis would have used percentage correct as the dependent measure, thereby permitting any detrimental effect of increases in the number of positions to be assessed.

Experiments 2 and 3 differed principally in terms of exposure duration. Displays of four items, consisting of a mixture of position markers and geometric forms, were used in both experiments. In the second experiment the number of position markers ranged from zero to three, and the number of forms ranged conversely from four to one. In the third experiment displays contained four markers, four forms, or two

of each. As reconstruction was required, this was equivalent to requiring report of items in position (localization), although responses were scored for correct position, irrespective of identity, and correct identity, irrespective of position.

The pattern of results was identical in the two experiments, although the unlimited viewing time of the third experiment had a generally beneficial effect. Both position accuracy and identity accuracy increased as a function of age. Position accuracy decreased as the number of forms increased, showing no interaction with age. Identity accuracy varied interactively with age, such that the number of forms reported increased with the number presented, but less so for the younger subjects.

Finkel (1973) concentrated on the effects of age on identity and position accuracy, and particularly on the interaction between age and items for identity but not position accuracy. He asserted that this pattern of results indicated independent processing mechanisms that become increasingly integrated with age.

There are several important reservations regarding this conclusion. First, as indicated above, the method of analysis may be misleading. A reconsideration of the data from Experiments 2 and 3 in terms of percentage correct suggested, if anything, a reversal of findings, so that the interaction was stronger for position than for identity accuracy. Second, it is not altogether clear that there are age related differences. The interactions reported may be artifactual, since adult performance was consistently at or near ceiling level, and the data for the youngest age group is peculiar in several respects. Finally, even if the argument of age related changes were accepted, this need not imply increasing integration. It may instead reflect increased capacity, or increased ability to perform the two independent types of processing.

In Smythe and Finkel's (1974) study, displays of four geometric forms located in imaginary 3x3 matrices were presented for 40 msec. The interstimulus interval preceding a visual noise mask was varied within subjects from 0 to 200 msec. The mode of response and type of information reported were varied between subjects. One group reported identity verbally, one group reported identity nonverbally by pointing to item tokens, one group reported position by placing position markers on a response card, and the remaining group reported both identity and position by placing item tokens on a response card.

Identity accuracy increased with interstimulus interval and interacted with mode of report, with verbal report inferior to nonverbal report at short intervals, but as good or better at longer intervals. Position accuracy also increased with interstimulus interval, particularly for the group which reported position information alone. The requirement to report both types of information had a deleterious effect on position but not identity accuracy. Accuracy for the combined report of position and identity likewise increased with interstimulus interval, but the level was below that for all other groups, including the separate position and identity scores for the combined group.

Since, for any given amount of processing time, more position than identity information was recalled, and because of the differential accuracy decrement that occurred with combined report, Smythe and Finkel (1974) concluded that separate mechanisms were responsible for the processing of the two types of information.

Whereas Smythe and Finkel (1974) presented both types of information and varied report requirement, Blake (1976) manipulated type of information presented, and required report of whatever had been

presented. Children and adults were shown either position information, consisting of four X's in a 3x3 matrix; identity information, consisting of four geometric forms located in the four corners of the display; or both, where four forms appeared in a 3x3 matrix. Exposure duration varied from 30 to 250 msec, and was followed by visual noise. All subjects performed each task, using a response board to reconstruct displays. In the combined task, correct position and correct identity were separately scored.

Children, but not adults, showed decreased position accuracy when they were required to process both types of information. Identity accuracy was unaffected by the requirement to process both types of information. For both age groups in both tasks accuracy increased as a function of exposure duration. At the longest exposure duration (250 msec), adults correctly recalled about 3.5 positions and 2.5 items.

Since adults showed no decrement in accuracy for either type of information when required to process both types, Blake (1976) concluded that adults, but not children, process position and identity information independently.

A comparison of the procedurally similar studies by Blake (1976) and by Finkel and Smythe (1974) produces two puzzles: the difference in results for position information, and the difference in conclusions. The (adult) subjects in the Smythe and Finkel study and the children in Blake's study showed decreased position accuracy in the combined task, while the adults in Blake's study did not. Close consideration of these latter results suggests that the functions did begin to diverge at the longer exposure durations, before ceiling effects limited the "position alone" function. Thus, an appropriate trend was present although the interaction was insignificant.

At first inspection the difference in conclusions seems peculiar. Blake (1976) asserts that the *absence* of an accuracy decrement in the combined task indicates independence, while Smythe and Finkel (1974) argue that the *presence* of an accuracy decrement denotes independence.

But it seems that the term "independence" is being used to represent two different concepts. Blake (1976), and also Den Heyer (1972), are using "independence" to mean that performance on two simultaneous tasks is equivalent to performance on either alone. This interpretation is based on the work of Garner and Morton (1969). Perceptual independence is indicated by the absence of an accuracy decrement when the tasks are combined, whereas perceptual interaction is indicated by the presence of such an accuracy decrement.

Smythe and Finkel (1974), and also Finkel (1973), are using "independence" to mean separate encoding and/or processing. Approximate synonyms for this conceptualization are "isolable codes" (Posner, 1978) and "separable dimensions" (Garner, 1974). In this conceptualization, differential effects of stimulus parameters or task requirements are taken as evidence for separate processing mechanisms.

The two concepts are related, in that independence, in the performance parity sense, is logically possible only with processing tasks that are independent, in the isolable/separable sense. Thus, some assessment of isolability or separability is required prior to any consideration of the perceptual independence/interaction issue. The studies reviewed in this section are germane to such an assessment. Almost without exception, the experimental manipulations employed had differential effects upon position and identity performance. In general, position performance was superior to identity performance, but it tended to be more seriously affected by a task requirement to process both

types of information. This consistency of findings, across four different procedures, offers convincing evidence for independent processing of the two types of information. Before developing this idea into a specific rationale for the present research, I will review studies that examine the issue of position versus identity within the context of short term visual memory.

POSITION AND IDENTITY IN SHORT TERM VISUAL MEMORY

In short term visual memory research there are two main groups of studies that are relevant to the topic of position and identity in visual information processing. The first group focuses on the nature of the coding of position and identity information, and employs the selective interference paradigm. The second group examines the automaticity of location encoding, in contrast to item encoding, and does this by contrasting intentional and incidental learning conditions. In addition there are several studies employing complex pictorial material that have also suggested differences in the processing of item and location information.

Selective Interference Studies

In the selective interference design the interval between stimulus presentation and stimulus recall is occupied by an interpolated task or activity. Variation in the nature of this interpolated task, so that different processing resources are utilized, allows inferences to be made about the coding or processing of the stimulus information.

Where this design has been applied to position and identity information, the general finding has been of an interaction between the type of information to be remembered and the type of interpolated task. Specifically, interpolated tasks that tap visual processing resources impair position recall, whereas interpolated tasks that tap verbal processing resources impair identity recall. Moreover, this occurs whether one type of information is selectively processed, or both types are processed in conjunction.

Meudell (1972) required subjects to recall either the identity or the position of four letters that appeared in a 16 cell matrix for one second, and that were followed by 3, 9, or 30 seconds of interpolated activity. Position recall was equally affected by both types of interpolated activity, visual tracking and backwards counting, and decreased with interval duration. (As no control group was included, the degree of impairment cannot be ascertained.) Interpolated verbal activity impaired the recall of letter identity, particularly as the interval lengthened; interpolated visual activity produced near perfect identity recall at all interval durations.

Salthouse (1975) presented diamond-shaped arrays of 25 numbers for four seconds with seven of the numbers circled. Recall of either the position or the identity of the circled items was required after 10, 20, or 30 seconds of interpolated activity. Comparison with a control group, which performed no interpolated task, showed that recall of letter identity was more seriously impaired by interpolated verbal activity (backwards counting) than by interpolated visual activity (a mental rotation task). The reverse pattern of impairment was observed for the recall of letter identity, although the effect was smaller. *position?*

Den Heyer and Barrett (1971) presented eight letters in a 24 cell matrix for 50 msec. After 10 seconds of interpolated activity, subjects reproduced the displays. Performance was assessed relative to a control group, and expressed in terms of percentage loss. Percentage loss was greater for position information with the interpolated visual task (a visual oddity task based on position information), and greater for identity information with the interpolated verbal task (mental addition). The selective effect of the interpolated tasks was more pronounced for position information. Overall performance was very low,

averaging about 25% correct in the control condition, and this was undoubtedly due to the very short exposure duration.

Considering a slightly different issue, Murray and Newman (1973) presented a circle, a square, and a triangle in a 12 cell matrix for three seconds. Various types and combinations of interpolated activities were examined over retention intervals of 0, 6, 12, and 20 seconds, before subjects reproduced the display. Performance was scored for correct position, irrespective of item, and correct localization (items in position). Position recall was unaffected by interpolated verbal activity (counting), but it was impaired by interpolated visual activity (drawing lines or copying arrows), with the degree of impairment increasing as a function of retention interval. Combining the verbal task with either visual task, however, added to the impairment obtained with the visual task alone. Localization recall was impaired by all tasks: With visual tasks, the impairment was no greater than it was for position recall, but with verbal tasks (either alone or in combination), the impairment was substantially greater than that which had occurred for position recall. The authors concluded that the integration of position and identity information requires both visual and verbal coding, whereas visual coding is sufficient for the retention of position information alone.

Allen, Marcell, and Anderson (1978) presented two letters in a six cell matrix for 500 msec, and required reproduction of the display after 10 seconds of interpolated auditory, kinesthetic, or visual activity. (In all cases, the interpolated task was the classifying of numbers as odd or even, with numbers presented in an auditory, kinesthetic, or visual mode.) All types of interpolated activity reduced performance relative to a control group. With interpolated auditory activity,

position was better recalled than identity. With interpolated kinesthetic and interpolated visual activity, identity was better recalled than position. This study is of particular interest, since it takes account of a number of criticisms made by Clayton and Warren (1976) of the selective interference design.

Two additional studies that focused on interpolated task performance as a function of the type of information remembered provide additional support for the hypothesis of coding differences. Henderson (1972a) examined the recall of nine consonants presented in a 3x3 matrix, interpolated between either the recall of nine auditorially presented digits with serial order relevant or the reproduction of a visually presented matrix with six of the nine cells shaded. Accuracy on the interpolated task was scored in terms of items correct, irrespective of position, and items correct in position. The latter method produced lower scores, but the same pattern of results: A concurrent auditory load impaired performance, but a concurrent spatial load did not. Henderson concluded that position information was coded visually since a spatial load did not affect recall of consonants.

Salthouse (1974) found that an interpolated visual matching task was impaired by concurrent retention of position information, whereas an interpolated verbal matching task was impaired by the concurrent retention of identity information. The information to be retained was either the positions or the identities of seven circled items in arrays of 25 items. In the first experiment the interpolated visual task was matching schematic faces, and this was impaired only by concurrent position retention. In the second experiment the interpolated visual task of matching photographs of airplanes was particularly impaired by

concurrent retention of position information, and the interpolated verbal task of matching sets of three words was particularly impaired by concurrent retention of identity information. Salthouse (1974) concluded that position information is visually coded, and that identity information is verbally coded.

The consistency found in the foregoing studies supports the hypothesis of coding differences, such that position information is predominantly visually coded and identity information is predominantly verbally coded. Another point of consistency is that identity information is generally better remembered than position information, both in the absence of interpolated tasks, and when averaged across the interpolated auditory-verbal and visual-spatial tasks. This contrasts with the typical finding in iconic memory studies of better position performance. Although there are numerous differences between the two groups of studies, this reversal in relative accuracy likewise supports the idea of coding and processing differences, with the processing of position information occurring more rapidly but being of lesser durability than the processing of identity information.

Incidental versus Intentional Learning Studies

Hasher and Zacks (1979) proposed five interlocking criteria for the definition of automatic processing. Processes that are automatic show: (1) equivalent performance with intentional and incidental learning conditions, (2) no improvement with specific instructions or practice, (3) no interference with other operations, (4) no reduction in performance under stress conditions, and (5) little change with age. A continuum of processing was hypothesized, rather than a strict dichotomy

between automatic and effortful processing. Spatial, temporal, and frequency information processing were hypothesized to fall at the automatic end of the continuum. A number of studies, to be discussed below, examine the automaticity of spatial location (position) processing using the intentional/incidental criterion. Various stimulus materials have been used including prose text, displays of discrete words or pictures, and three-dimensional object displays.

Several studies have examined memory for the location of information in prose text, and have shown a high degree of consistency in the results. Studies by Rothkopf (1971), Zechmeister and McKillip (1972), and Zechmeister, McKillip, Pasko, and Bessalec (1975) all found above chance performance for the recall of location, and more accurate location recall for correctly recalled than for incorrectly recalled items of information. Zechmeister et al. (1975) explicitly contrasted intentional and incidental recall of location information, and found no difference between the two conditions. Given the high degree of similarity between pages of prose text, these findings support the contention that location is automatically encoded. A more recent study by Lovelace and Southall (1983) confirmed these results, and also demonstrated that providing either the relevant item or location information facilitated recall of the other type of information. This latter finding was interpreted by the authors as reflecting a clustering of attributes in memory. I would suggest that it could alternatively be construed as reflecting the relatively automatic integration of item and location information.

Studies using displays of discrete words or pictures have shown similar results. Schulman (1973) presented 25 displays of four words each, with the words located at the "compass points" of the display. Memory for item information was tested by an expected recognition test, while memory for location was tested by either an expected or unexpected recall test. Incidental learning of location produced slightly better performance than did intentional learning (35% versus 31%); both were above the chance level of 25%. Although location and item recall covaried, the intentional learning of location resulted in poorer item recognition. When items were differently colored as well as spatially distributed, and color was intentionally learned and location incidentally learned, location recall exceeded color recall. Again, item recognition and attribute recall covaried, with the item-location relationship stronger than the item-color relationship. These results, like those of Lovelace and Southall (1983), argue for the automatic encoding of location and the clustering (or integration) of attributes in memory.

Von Wright, Gebhard, and Kartunnen (1975) presented ten displays of four pictures each, with one picture centered in each quadrant of the display; the pictures in each display were either thematically related or unrelated. Three different age groups were tested on either the intentional or incidental recall of the quadrant location of each picture. Older subjects were more accurate than younger, and the use of related pictures enhanced overall performance. However, intentional and incidental conditions were equivalent. Location recall was generally higher than in Schulman's (1973) study, a difference that Von Wright et al. (1975) attributed to the greater salience of location in the interpretation of pictures, relative to words.

More recently, Park and Mason (1982) contrasted memory for words and their corresponding pictures. Items were presented in lists of 16, with items appearing in one of four colors at one of four locations. Subjects were asked to remember the items only, the items plus their locations, the items plus their colors, or the items plus both attributes. Item recognition was tested after each list, with recall of the instructed attribute(s) for those items which were recognized. In addition, there was an unexpected final recognition test, together with recall of both attributes of recognized items. Performance on the immediate test was excellent for both item recognition and attribute recall, and was affected only by type of stimulus material, with pictures superior to words. On the final test item recognition again varied as a function of stimulus material, with pictures retaining their superiority. Recall of location was better with pictures than with words, and was enhanced by prior instructions to attend to either, or both, of the attributes. Recall of color was unaffected by type of stimulus material, but was better with prior instructions to attend to color. The authors concluded that the processing of color information was effortful, since it was improved only by specific attention to color, while the processing of location was relatively automatic, since it was enhanced by attention to either attribute. Like Von Wright et al. (1975), Park and Mason suggested that the finding of better location recall for pictures than for words reflects the greater importance of spatial location in the comprehension of pictures.

Mandler, Seegmiller, and Day (1977) examined memory for item and location information across a range of age groups using a three-dimensional object display. This display consisted of 16 small toys,

located in the cells of an imaginary 6x6 matrix. Three instructional conditions were used: (1) intentional learning of items and locations (intentional condition), (2) intentional learning of items and incidental learning of locations (standard incidental condition), and (3) incidental learning of items and locations using a price estimation task (true incidental condition). Following presentation of the display, for 40 seconds in Experiment 1 and 60 seconds in Experiment 2, subjects recalled as many items as possible, and then reconstructed the display by assigning the 16 toys to 16 indicated locations. In Experiment 1, item recall exceeded location recall, whereas the reverse occurred in Experiment 2. In both experiments the true incidental condition produced lower item and lower location recall than did the standard incidental and intentional conditions, which did not differ significantly. However, even this lowered location accuracy was well above chance: about seven items in Experiment 1 and nine items (for adults) in Experiment 2. Consistent with the findings of other researchers, location accuracy was greater for items that had been recalled, but it was still better than chance for items that had not been recalled. Although accuracy was higher for older subjects, all age groups showed similar patterns of recall and relocation. Thus, the hypothesis of automatic processing of location was supported, in that the standard incidental condition produced location performance as accurate as the intentional condition. Moreover, the intention to remember location did not impair item recall accuracy.

Complex Pictorial Studies

Several studies by Mandler and her colleagues suggest that, with respect to the processing of complex pictorial stimuli, different types of information are subject to different coding strategies. Although the main thrust of this research is not really relevant here, the conclusions regarding the differential encoding of item and location information are of some interest. The basic strategy of the Mandler studies has been to contrast the recall or recognition of different types of information from pictorial displays containing six or eight items in either an organized or unorganized format.

Mandler and Parker (1976) found that the recognition of items, among distractors that differed in size, orientation, or appearance, did not vary as a function of display organization, and showed little decrement after a one week interval. Performance on a spatial reconstruction task, however, was superior for organized pictures, and declined markedly after one week.

Mandler and Johnson (1976) distinguished four kinds of information inherent in pictorial displays: inventory, descriptive, spatial location, and spatial composition. Recognition accuracy for inventory and descriptive information, both of which pertain to item identity, was unaffected by the organization variable. Recognition accuracy for spatial location and spatial composition information, both of which pertain to item position, showed differential (and divergent) effects of display organization. Spatial location information was better recognized in organized pictures, while spatial composition information was better recognized in unorganized pictures.

Mandler and Ritchey (1977) examined recognition accuracy for four types of information -- inventory, descriptive, spatial relation, and

spatial composition -- as a function of display organization, at retention intervals ranging from immediate to four months. Spatial composition information was better recognized in unorganized pictures than it was in organized pictures, although this difference was reversed at four months. Spatial relation information was better recognized in organized pictures, and this difference persisted over time. The recognition of descriptive information was unaffected by organization. The recognition of inventory information was likewise unaffected by organization, except at four months, where lack of organization impaired performance.

The pertinent conclusion drawn from these studies was that the processing of spatial location/relation information is mediated by schemata of real-world object relationships. Schemata may also be relevant in the processing of inventory information, but not in the processing of descriptive information or spatial composition information. If the presented spatial location/relation information fails to accord with a particular schema, retention of that information over time will be poor. Although the notion of schema-based retention is limited to complex displays of the sort used by Mandler, the findings reported in these studies extend the earlier observation that the relative accuracies of position and identity performance depend on the general temporal framework employed.

One additional study needs to be considered here. Pezdek and Evans' (1979) research has been placed at the end because it makes contact with each of the three preceding sections through the choice of stimulus material and experimental procedure. The main issues of concern were the inter-relationship of visual and verbal coding with pictorial

stimuli, and the relationship between memory for identity and memory for location.

In three experiments, subjects studied a three dimensional, map-like display of 16 "buildings", the nature of which varied across conditions. Buildings could be a wooden block with attached photograph, a block with photograph accompanied by a functional name, or the name label alone. Subjects received a variety of tests: name recall, name recognition, picture recognition, and spatial relocation of the appropriate buildings on the display. Picture recognition was superior when no name label was used. Neither name recall nor name recognition was affected by the presence of an accompanying photograph. Spatial relocation was poorer when photographs were used, irrespective of whether the photograph appeared alone, was accompanied by a name, or was given a name by the subject.

In the last experiment, all subjects viewed buildings which consisted of photograph plus name, and they were tested on name recall, picture recognition, and spatial relocation. Because subjects were forewarned of only one type of test, which varied across groups, one type of information was intentionally learned and the other two types were incidentally learned. Name recall and spatial relocation performances did not differ as a function of prior instructions. Picture recognition accuracy was superior for the group instructed to remember the photographs, while the other two groups did not differ.

Pezdek and Evans (1979) drew two main conclusions from these results. They concluded that when both visual and verbal information is available for the coding of pictorial material, the latter predominates, but concede that this may be confined to complex pictorial material that is not easily labelled. Of greater interest in the present context is

their conclusion that location is verbally encoded, since location recall covaries with name recall or recognition. According to the authors, if location were visually encoded, then the covariation would be with picture recognition.

An alternative interpretation is possible, however, if it is assumed that both picture and location information are visually coded, but that there is competition between the two for visual coding resources. Then, when the task does not demand picture processing, location processing is enhanced, but when the task demands picture processing, the resources available for location processing are diminished. A potential problem for this explanation are the data from the fourth experiment. Pezdek and Evans (1979) suggest that if resources were a problem, then increased picture recognition should be at the expense of name and location performance. In the group that intentionally processed photographs there was in fact a (nonsignificant) trend towards poorer location performance but not poorer name performance, suggesting some competition for visual coding resources. Such an analysis suggests that location encoding is relatively automatic, with the degree of automaticity a function of the type of concurrent processing. If such processing is verbal, then a high degree of automaticity prevails, whereas if concurrent processing is visual, then a somewhat reduced level of automaticity is obtained.

DIMENSIONAL RELATIONSHIPS

The conclusion to be drawn from the iconic and the short term visual memory research is that there are differences in the nature of position and identity information processing. The main findings from iconic memory research are a superiority for position task performance, an advantage for identity task performance with preknowledge of position but not vice versa, and a deleterious effect of a dual reporting requirement on position but not on identity accuracy. Evidence of coding differences, with position visually coded and identity verbally coded, and of automatic processing of position information are the main findings from short term visual memory research. In addition, identity task accuracy tends to be greater than position task accuracy.

The hypothesis that position and identity function as asymmetrically separable dimensions, which is fundamental to the experiments reported in this thesis, can accommodate these findings. Here, some background information concerning dimensional relationships will be presented, so that the derivation of this hypothesis can be understood. The extension of this theoretical framework to the matching design will also be outlined so that the logic of the present experiments can be seen. Subsequently I will show how the hypothesis of asymmetric separability can be applied to visually presented position and identity information, and how such a conceptualization can integrate the results of previous research.

Types of Dimensional Relationships

The pivotal study in this area was conducted by Garner and Felfoldy in 1970. In seven experiments, subjects sorted decks of 32 cards under six different conditions. These six conditions were formed by crossing two stimulus dimensions (with two values on each dimension) with three relations between dimensions: control, correlated, or orthogonal. In control conditions, a neutral value on the irrelevant dimension was paired with values on the relevant dimension, and card sorts were by value on the relevant dimension. In correlated conditions, a value on one dimension was consistently paired with a value on the other dimension. In orthogonal conditions, each value on one dimension was paired with each value on the other dimension. In both correlated and orthogonal conditions, card sorts were on the basis of one or other dimension. Using a variety of dimensions -- value and chroma, horizontal and vertical position of a dot, circle size and angle of inscribed diameter -- Garner and Felfoldy (1970) found that some pairs of dimensions showed facilitation in correlated conditions and interference in orthogonal conditions. Such pairs of dimensions were said to be integral. Those pairs that did not show facilitation and interference were said to be separable.

The conclusion was that dimensions that are integral function as a single entity, so that selective attention to one or other dimension is impossible. Hence, facilitation and interference occur. Dimensions that are separable function as separate entities, so that selective attention is possible. Hence, the absence of facilitation or interference. Garner (1974) identifies other distinguishing characteristics of integral and separable dimensions. With integral dimensions, classification is based on similarity structure, and direct

distance scaling conforms to a Euclidean metric. With separable dimensions, classification is based on dimensional structure, and direct distance scaling conforms to a city-block metric.

In later work Garner (1974, 1976) has emphasized a continuum of dimensional relationships, rather than an integral/separable dichotomy. Two additional types of dimensional relationships have been described by Garner (1976). One type, configural, emerges from a particular combination of dimensions in a specific context. Configural dimensions do not permit selective attention, they show interference in orthogonal conditions but no facilitation in correlated conditions, and they use configural properties as the basis for direct distance scaling and classification. Pomerantz and Garner (1973) have provided an example of configural dimensions: type of parenthesis, left or right, and spatial position, left or right.

Another type of dimensional relationship, and one that is of particular interest here, is that of asymmetric separability. Essentially, one dimension functions as an integral dimension, and the other functions as a separable dimension. Asymmetrically separable dimensions show facilitation in correlated conditions, and unidirectional interference in orthogonal conditions. Garner (1976) has proposed that direct distance scaling conforms to a city-block metric, and that classification is based on dimensional structure. Selective attention is possible for one, but not the other, dimension.

An example of asymmetrically separable dimensions are the auditory dimensions of pitch and consonant. Wood (1974) found facilitation under correlated conditions, and interference for consonant but not for pitch under orthogonal conditions. That is, subjects could selectively attend

to pitch but not to consonant. Other researchers have inferred an asymmetrical relationship between two dimensions when the degree of interference has been unequal. Pomerantz and Sager (1975) concluded that the dimensions of element and configuration of visual patterns were asymmetrically related, since elements interfered more when configuration was the relevant dimension than did configurations when element was the relevant dimension. Clark and Brownell (1976) found that arrow position, in both orthogonal and negatively correlated conditions, interfered more with judgments of arrow direction than vice versa. Eimas, Tartter, Miller, and Keuthen (1978) observed unequal amounts of interference in orthogonal conditions for the phonetic dimensions of place of articulation and manner of articulation. This asymmetry did not depend on the discriminability of the primary (manner) dimension.

Garner (1974, 1976) offered two, not mutually exclusive, explanations for the occurrence of asymmetric separability. It may occur as a consequence of the logical relationship between the two dimensions, or because of a difference in processing level. These explanations will be dealt with presently.

Extension to the Matching Procedure

Three main tasks -- card sorting, free classification, and direct distance scaling -- were used in the seminal studies of dimensional relationships. Several studies have extended the dimensional conceptualization to the simultaneous and/or successive matching procedure, thereby permitting contact with a wider research area. As the experiments reported in this thesis employ a successive matching procedure, these studies will be reviewed in some detail.

In a study by Keuss (1977), pairs of stimuli were simultaneously presented for one second, and subjects responded on a go/no go basis to same or different pairs. Squares and rectangles were used as stimuli, with the relevant dimension of size, form, or orientation of inscribed line a between-subjects factor. For any relevant dimension, one irrelevant dimension was varied and one was fixed. Same RT was faster than different RT for all dimensions and conditions, and responses to orientation were slower than those to size or form, except in control conditions. When the varying irrelevant dimension was consistent with a "same" response, RT was somewhat slower than in control conditions; when the varying irrelevant dimension was consistent with a "different" response, RT was substantially slower than in control conditions.

Keuss (1977) concluded that size and form functioned as dimensions integral to each other, whereas orientation of inscribed line was separable from both. The relationship was asymmetrical in that neither size nor form was easily ignored when irrelevant to orientation, although orientation was easily ignored when irrelevant to either size or form. Keuss further asserted that same RT was based on a fast, holistic identity response, whereas different RT was based on a slower, analytic difference count. This last conclusion seems somewhat doubtful: the author had argued that if different responses were made by default in the absence of an identity match, then the difference between same RT and different RT should be constant. As plotted, however, the functions are approximately parallel, suggesting a relatively constant difference.

Boer and Keuss (1979) replicated the procedure of Keuss (1977), and varied the interval between first and second stimulus presentation. Intervals of 0 seconds (simultaneous matching), 1.5, 3, and 6 seconds (successive matching) were used. Interval length had a significant

effect on RT: Performance was best with an interval of 1.5 seconds, and worst with intervals of 0 (simultaneous) and 6 seconds. Different RT was significantly slower than same RT only with simultaneous matching. The dimensional relations paralleled those found by Keuss (1977). With orientation as the relevant dimension, irrelevant size or form slowed RT at all intervals. With size or form as the relevant dimension, irrelevant orientation had no effect of RT at any interval, and irrelevant form or size affected performance only with simultaneous matching. Boer and Keuss (1979) concluded that the holistic/analytic dual process model was supported only when matching was simultaneous. When matching was successive, the interval was used to filter out the irrelevant information.

In a later study, Boer and Keuss (1981) directly compared card sorting and simultaneous matching tasks, using the stimuli and data from Keuss (1977) and Boer and Keuss (1979). There was substantial agreement across tasks, in that evidence of mutual integrality between size and form, and of an asymmetric relationship with line orientation, was also found in the card sorting procedure.

Santee and Egeth (1980), however, concluded that patterns of integrality/separability may be task dependent. They compared performance on speeded classification (card sorting), simultaneous matching, and successive matching tasks using the same set of stimuli. The relevant dimension was form (circle versus square), and the irrelevant dimension was either size or shading, with three levels on each of the irrelevant dimensions. In the speeded classification task, comparison with control conditions showed no effect of the irrelevant dimension(s) on sorting speed, indicating dimensional separability. In both the simultaneous and successive matching tasks, however, the

irrelevant dimension did affect RT. Same RT increased as the degree of disparity on the irrelevant dimension increased, while different RT did not. Thus, there was interference, with the implication of integrality, with dimensions that were separable in the speeded classification task. Santee and Egeth (1980) concluded that the data were consistent with a dual process, holistic/analytic comparison model, with normalization of irrelevant dimension disparity necessary prior to a "same" response.

Garner, Podgorny, and Frasca (1982) used both simultaneous and successive matching tasks in their investigation of physical, "intermediate", and cognitive dimensions. In the first experiment the Arabic and Roman numerals 6, 10, VI, and X were used; these vary along the dimensions of length, system, and name. In the case of simultaneous matching, the order of difficulty, measured in terms of RT, was from the physical dimension of length, through the intermediate dimension of system, to the cognitive dimension of name. In the case of successive matching, performance was equivalent on the dimensions of name and system, indicating the use of name as a processing mechanism.

A second experiment supported this interpretation. Simultaneous matching of the numerals 3, 4, 6, and 7, that vary along the dimensions of curvilinearity, oddness, and magnitude, produced the most rapid performance with the cognitive dimension of magnitude. It appears that cognitive dimensions do not necessarily behave in the same way as do physical dimensions; cognitive factors such as familiarity can be important. Garner et al. (1982) stressed the importance of delineating the functional, rather than the nominal, role of a dimension.

POSITION AND IDENTITY AS ASYMMETRICALLY SEPARABLE DIMENSIONS

The theoretical framework of dimensional relationships can be applied to the issue of position and identity information processing. Specifically, the proposed hypothesis is that position and identity are asymmetrically separable dimensions, with position integral to identity but identity separable from position. This conceptualization can integrate research findings from the iconic and short term visual memory areas concerned with the position/identity relationship, and is consistent with several extant studies. Before examining these issues, I will discuss why position and identity might function as asymmetrically separable dimensions.

Why Asymmetry?

Garner (1974, 1976) proposed that asymmetry may be a consequence of the logical relationship between the two dimensions. Three kinds of logical relationships, producing three kinds of dimensional relationships, were identified by Garner (1976). One logical relationship is bidirectional, or double implication, which produces integral dimensions. In this case, if one dimension exists the other must also, and vice versa. Another is a "no constraints" relationship, where either dimension may occur in the presence or absence of the other; this produces separable dimensions. The relationship of interest here, which produces asymmetrically separable dimensions, is that of implication: Dimension A implies dimension B, but dimension B does not

imply dimension A. That is, B can occur in the absence of A, but A cannot occur in the absence of B. This is precisely the relationship which characterizes visually presented position and identity information: A spatial position can occur (or be specified) with or without an associated identity, but any particular identity (letter, form, word) must occur in some spatial position. It would seem that there are good logical grounds on which to base the hypothesis of asymmetric separability of position and identity.

Garner (1974, 1976) also suggested that a difference in processing level could result in a relationship of asymmetric separability. It is a plausible argument that position and identity are processed at different levels, with position information processed at a lower neurological level than identity information. Support for this argument comes chiefly from studies with non-human species. Held (1968), Schneider (1967, 1969), and Trevarthen (1968) concluded that there was a physiological basis underlying a distinction between identification/discrimination processes and orientation/localization processes. Insofar as the processing of position information in humans is related to or developed from the orientation and localization processes of non-human species, it seems reasonable to assume somewhat different physiological bases for the processing of position information and the processing of identity information.

Integration of Research Findings

I will now outline how a conceptualization of position and identity as asymmetrically separable dimensions can serve to integrate existing research findings.

In the area of iconic memory, the main findings of superior position performance, a differential advantage for precued position, and a deleterious effect of a dual report requirement on position accuracy, are all consistent with the view that position processing is the more fundamental process, and integral to the processing of identity information.

Conditions in iconic memory studies, by virtue of the temporal limitations involved, stress performance. Under such conditions it seems reasonable to expect that the more fundamental dimension will be accorded priority in processing, resulting in superior position accuracy.

The differential effect of precuing position or identity is also explicable in these terms: Supplying the more fundamental, integral position information permits resources to be applied to the processing of the secondary, separable identity information. Supplying the separable identity information is irrelevant to position information processing and no advantage of precuing is obtained.

The selective effect of a dual report requirement arises because a distinction between single and dual task processing requirements is valid only for position information. In the single task, position but not identity can be selectively processed; the dual task, then, is functionally equivalent to the single task for identity information, and so no dual task impairment is observed.

Within the short term visual memory field, the conclusion that position and identity are differently coded is consistent with the idea of a difference in processing level. Position information appears to be visually coded; visual processing is developmentally and

phylogenetically prior to verbal processing, and is presumably less subject to optional processor strategies, given the physiological evidence for topographical mappings of visual space in the brain (Trevarthen, 1968). Identity information appears to be verbally coded, at least when verbal items are used; verbal processing is a later and more flexible process.

The more important conclusion derived from the short term visual memory research area is that of automatic position encoding. This agrees precisely with the asymmetry hypothesis: Processing of the integral dimension (position) is automatic, occurring irrespective of intention, whereas processing of the separable dimension (identity) is effortful and optional.

The typical finding of superior identity performance in short term (and long term) memory studies suggests that, given sufficient processing time, the more cognitive dimension of identity may overshadow the more physical dimension of position, as suggested by Garner et al. (1982).

Initial Supporting Evidence

A number of studies offer tentative support for the the asymmetric separability hypothesis, although none were designed with specific reference to dimensional relationships. As these are pertinent to the thesis experiments, they will be discussed in detail.

Using a recognition matching procedure with RT as the dependent measure, Santa (1977) examined memory for equivalent verbal and figural displays. Of interest are the results for figural displays, which consisted of three geometric forms appearing in either a horizontal array or within an outline square. Sample arrays were presented for two

seconds, and comparison arrays were classified as "same" if they contained the same forms, irrespective of position.

Horizontal arrays were used in the first two experiments, and subjects were faster, by 200 to 300 msec, at matching arrays when the forms appeared in the same positions than when they appeared in interchanged positions. Similarly, subjects in the third experiment were faster at matching outline square displays when the positions were the same than when they were interchanged. When the comparison displays for outline square sample displays were horizontal arrays, RT was equivalent for same (defined as preserving a left-right, top-bottom order) and interchanged positions, and at the level for the interchanged positions condition when both displays were outline squares.

Same RT reflected the length of the interstimulus interval, with longer RTs associated with longer intervals. (In Experiments 1, 3, and 2, respectively, interstimulus intervals of .5, 2, and 5 seconds were used. Same RTs, collapsed over position condition, were approximately 1000, 1200, and 1350 msec in the three experiments.) Different RTs did not vary with length of the interstimulus interval but did vary with number of mismatching items, being most rapid when all three items were different, and least rapid when only one item was different.

In the context of letter-matching research, Angiolillo-Bent and Rips (1982) found the time required to verify that two trigrams contained the same letters depended upon the degree to which the order of the letters was consistent. Sample (or memory set) trigrams were presented in upper case for 500 msec followed by a comparison (or probe) trigram in either upper or lower case, and with the letters in either the same or a changed order. In Experiment 1, the interstimulus interval was 500 or

2500 msec; interstimulus intervals of 200, 600, 1800, and 5400 were used in Experiment 2. Three levels of positional change were possible: no change, intermediate change (interchange of either end letter with middle letter), or maximal change (all letters changed or end letters interchanged). Same RTs were fastest with no change and slowest with maximal change. Different RTs did not vary with degree of positional change. There were main effects of case, interstimulus interval, and familiarity, such that responses were faster with same case comparisons, short interstimulus intervals, and familiar trigrams, but none of these factors interacted with degree of positional change.

Angiolillo-Bent and Rips (1982) formulated a position-sensitive comparison model the essence of which is that comparison time for any pair of letters depends upon the amount of positional change from sample to comparison display. The time required to make a "same" response depends upon the longest of the three comparisons, so that increased perturbation of order lengthens RT. Different RTs are not so affected, since they depend on mismatching times at all positions.

The Santa (1977) and Angiolillo-Bent and Rips (1982) studies indicate that interchanging the positions of items interferes with the recognition of item identity. A related point emerges from a study by Ratcliff (1981), in which sample and comparison displays of five letters were classified as "same" only if both identity and position matched. Comparison displays were classified as different more accurately and more rapidly if they contained two different letters than if two letters were interchanged in position, with performance on interchanged comparisons improving as distance between the interchanged letters increased. That is, a greater degree of change in item order facilitated a "different" response based on an exact match criterion, and interfered with a "same" response based on an item identity criterion.

A study by Sheingold and Finkel (1977) using a two-alternative forced-choice recognition procedure also demonstrated the effect of a change in position, and hence overall configuration, on both exact match and item identity tasks. Sample displays consisted of four Hebrew letters arranged in a simple configuration, and these were shown for 200 msec. Subjects subsequently selected the correct comparison from the two which were presented.

In the first experiment, selection of an exact match was more accurate, across a range of age groups, when the incorrect comparison consisted of the same items in a different configuration (one item moved) than when it consisted of four slightly different items in the same configuration. This indication of a greater reliance on position information was supported by data from a forced-error condition: When neither comparison display was an exact match, subjects preferred the display with correct positions but incorrect identities over the display with correct identities but incorrect positions.

In a second experiment, incorrect comparison displays had incorrect items in the correct configuration, while correct comparison displays had correct items in either the same or a changed configuration. Younger subjects tended to be more accurate when position was the same than when it was changed, but neither the main effect of condition nor the interaction of age and condition reached significance (both p 's $< .10$). Overall, accuracy was significantly enhanced by the explicit instructions to ignore configuration.

From these results, Sheingold and Finkel (1977) concluded that configuration and/or position information is given priority in processing, and that the ability to ignore irrelevant position information increases with age.

All of the above-mentioned studies have found deleterious effects of a change in the position of items upon the speed or accuracy with which identity information is recognized. Two additional studies using a Stroop-like procedure have examined the effect of identity information on position task performance, as well as the effect of position information on identity task performance.

Palef and Olson (1975) presented the words "above", "below", and "chair" either above, below, or in place of a central asterisk. Subjects responded to word meaning or absolute position of the word, with RT as the dependent measure. When absolute position was relevant, word meaning had no effect on RT: Congruent, neutral, and incongruent words were responded to with equal speed. When word meaning was relevant, absolute position affected RT. Incongruent spatial positions slowed response speed, although congruent spatial positions did not facilitate RT. Overall, spatial position RT was about 60 msec faster than word meaning RT.

In Palef and Olson's (1975) second experiment, judgments of relative position were compared with judgments of word meaning. Words were centered on the screen, with an asterisk above or below. Both relative position RT and word meaning RT were slower when the irrelevant information was incongruent than when it was congruent or neutral, and relative position RT was slower than word meaning RT. The overall effects, however, masked the differential effects of practice and task order. In the first session, word meaning RT was substantially faster than relative position RT; this difference was eliminated by the third (final) session. Word meaning RT was initially impaired only by incongruent relative position, and finally by both congruent and incongruent relative position. Relative position RT was initially

impaired by incongruent word meaning; by the final session, the effect of word congruency was minimal. Finally, the effect of relative position congruency was present only when subjects performed the relative position task prior to the word meaning task, not vice versa.

A study by Palef (1978) extended these findings. The words "above" or "below" were presented either above or below an asterisk, and either above or below the midline of the screen. Subjects responded to word meaning, absolute position, or relative position, in a between-subjects design. Absolute position RT was the most rapid, and was unaffected by word meaning or relative position. Relative position RT was the slowest, and was affected by both types of irrelevant information: Congruent word meaning produced facilitation and incongruent word meaning produced interference, with additional interference from incongruent absolute position. Word meaning RT was unaffected by relative position, and showed interference with both congruent and incongruent absolute position. Palef concluded that absolute position affects an initial pictorial encoding stage, whereas word meaning affects a subsequent linguistic encoding stage. The indiscriminate effect of absolute position of word meaning RT was attributed to an elevation in response threshold due the occurrence of pictorial codes in a task reliant on linguistic codes.

Thus, the results of Palef and Olson (1975) and Palef (1978) are consistent in demonstrating that judgments of absolute position are unaffected by identity (word meaning), but judgments of identity are affected by absolute position -- in particular, incongruent absolute position impairs identity task performance.

Although the asymmetric separability hypothesis can accommodate the findings of previous research, it requires confirmation by

experimentation addressed specifically to this conceptualization. This is attempted in the eight experiments of this thesis. The fundamental prediction resulting from the hypothesis that position and identity function as asymmetrically separable dimensions is that subjects should show an asymmetry in their ability to selectively attend to the dimensions. Specifically, they should be able to selectively attend to the position dimension, so that there is (generally) neither facilitation nor interference as a function of the accompanying identity information. Selective attention to the identity dimension should not be possible, however, so that facilitation and interference should occur as a function of the accompanying position information. A more detailed explanation of the rationale for the thesis experiments will be given in the next section.

RATIONALE AND GENERAL METHOD

Rationale

Having reviewed the literature relevant to the position and identity issue, and having developed a theoretical framework that can accommodate the various findings and guide further research, it is appropriate now to describe the rationale and general method of the eight experiments reported in this thesis.

The aims of the experiments are: (1) To examine performance in unidimensional control conditions, (2) to test the fundamental predictions of the asymmetric separability hypothesis, and (3) to investigate performance when the dimensions are combined. The eight experiments fall into three logical groups, each group being concerned with one of these aims.

A successive matching procedure is used throughout, with response time (RT) to matches as the principle dependent variable. A matching procedure was selected because it is the only procedure that has the flexibility to permit the achievement of all three aims. Speeded classification and recall procedures, the other possible procedures, have limitations in this respect. Speeded classification generally requires fairly simple stimuli that can easily be assigned to one or the other of two response alternatives. It is useful for assessing performance in unidimensional conditions and for examining the effect of irrelevant information, but it is not easily adapted to measuring performance when the dimensions are combined. This, together with the

use of relatively complex stimuli, precludes the use of a speeded classification procedure. A recall procedure, although widely used in both iconic and short-term visual memory studies, does not readily permit the effect of irrelevant information to be investigated: Information that is required to be recalled cannot be irrelevant, and there is no performance measure for information that is not required to be recalled. A matching procedure overcomes these limitations.

A combination of theoretical considerations, specific dimensional constraints, and experimental constraints resulted in the choice of a successive, rather than a simultaneous, matching procedure. The research reviewed earlier concerning dimensional relationships suggested that the interstimulus interval in a successive matching procedure facilitates selective attention to the relevant dimension, by permitting time for the filtering out of the irrelevant dimension. A demonstration that selective attention to identity information does not occur with a successive matching procedure would therefore provide strong evidence for the asymmetric separability hypothesis.

The nature of the position dimension itself favored successive matching over simultaneous matching. In a simultaneous matching procedure the items of one display cannot appear in the same absolute positions as the items of another display; they can only appear in the same positions relative to each other and/or the display borders. In a successive matching procedure this difficulty is overcome.

A final consideration was the desire that performance not be "data limited" due to acuity factors. Practical limitations of the available equipment, especially with respect to screen size, also made successive matching preferable to simultaneous matching.

A general description of the experiments will indicate how the aims of the study have been addressed. The principal feature of the experiments is the presentation of position and identity information in the initial display, with subjects required to attend to either the position dimension or the identity dimension, or, in later experiments, both dimensions. The identity information consists of four items, either letters or forms. The position information consists of the four cells of a matrix occupied by the four items. The subsequent comparison displays either match exactly with respect to either identity or position, or mismatch by virtue of having the identity of one item changed or the position of one item changed. Thus, the Position task and the Identity task are formally equivalent, requiring the recognition of either four positions or four items.

The first group of three experiments (Experiments 1 to 3) examines performance in unidimensional control conditions. Ordinarily, in such conditions, a neutral value on the irrelevant dimension is paired with various values on the relevant dimension. But the complexity of the stimuli used here makes selection of appropriate neutral values difficult. Accordingly, a slightly different approach is adopted where both types of information are presented in the initial sample display, but the subsequent comparison display consists only of information on the relevant dimension, and so is neutral with respect to the irrelevant dimension. As the irrelevant dimension is not represented in the comparison display, performance should be affected only by variation of the information on the relevant dimension. In order to test this prediction, Experiments 1 and 2 manipulate the variables of item class, matrix outline presence, and matrix size. Experiment 3 represents a

shift of focus onto the position dimension per se, as it involves a contrast between the recognition and the recall of position information.

The second group of experiments (Experiments 4 to 6) directly tests the asymmetric separability hypothesis by including both dimensions in the comparison displays. In Experiment 4, the irrelevant dimension is either consistent (correlated) or inconsistent (orthogonal) from sample to comparison display. The asymmetric separability hypothesis predicts that the status of the irrelevant dimension will markedly affect Identity but minimally affect Position task performance. That is, subjects will show a clear asymmetry in their ability to selectively attend to the dimensions. In Experiments 5 and 6 performance on each dimension is examined when the information on the irrelevant dimension is consistent, neutral, or inconsistent. The asymmetric separability hypothesis predicts that (1) When the position dimension is relevant, there will be some facilitation but no interference with consistent and inconsistent identity information, respectively, and (2) When the identity dimension is relevant, there will be both facilitation and interference with consistent and inconsistent position information, respectively.

The last two experiments (Experiments 7 and 8) examine performance when the two dimensions are combined, and when attention is shared between them. One way of combining the dimensions is to combine conjunctively, so that a match occurs when the information on both dimensions matches. Another way of combining the dimensions is to combine disjunctively, so that a match occurs when the information on either dimension matches. Attentional and perceptual interpretations of

dimensional relationships make different predictions concerning the effects of sharing attention between dimensions. These predictions will be discussed in detail in the introduction to Experiments 7 and 8. Choosing between the two competing explanations can therefore be facilitated by comparing shared attention and selective attention conditions. Experiment 7 includes both conjunctive and disjunctive conditions, whereas Experiment 8 focuses on the disjunctive condition in greater detail.

General Method

This section describes the experimental procedures and stimulus materials common to the eight experiments. Exceptions or modifications to these procedures and materials will be described in each experiment's Method section.

Procedure

A successive matching procedure was used throughout. Although the number of sessions and number of trials per session varied across the eight experiments, the events in a single successive matching trial were the same for all experiments.

A successive matching trial consisted of four events:

- (1) A sample display presented for one second.
- (2) An empty interstimulus interval lasting for five seconds (Experiment 1) or one second (Experiments 2 through 8).
- (3) A comparison display presented for three seconds.
- (4) An empty intertrial interval lasting for five seconds.

The total time required for a single trial was 14 seconds in Experiment 1 and 10 seconds in Experiments 2 through 8.

Before beginning a session subjects were given written instructions to read at their own pace, with opportunity given for questions. The instructions described the general procedure, the nature of the displays, which dimension should be attended to, and how responses should be made. Subjects were told to respond only when the two displays matched on the specified dimension(s); in the event of a mismatch, they were not to respond (go/no go response). A same/different response procedure could have been used. However, the results of Boer and Keuss (1979), Santee and Egeth (1980), and Miller and Bauer (1981) suggested that the status of the irrelevant dimension may affect "same" and "different" responses differently. In the interests of clarity and simplicity, I decided to focus on "same" responses, and not to monitor "different" responses.

During the course of a session at least one brief rest period of two to three minutes' duration occurred. A rest period was inserted between blocks of trials. Rest periods also permitted the changing of slide trays by the experimenter. Following the final session of an experiment subjects were orally debriefed.

Sample and comparison displays were back projected as 35 mm negatives, using three tachistoscopic slide projectors. Displays were centered on a screen which measured 230 mm X 230 mm, the midpoint of which was 85 cm above floor level. Room illumination was slightly reduced from normal in order to minimize glare or reflection from the display screen. Subjects were seated approximately one metre from the

screen, with no restraint on head movements. Two response keys were placed on a small table positioned between the subject and the screen. Subjects were instructed to press both keys simultaneously with right and left index fingers when a match occurred. Response time was measured in milliseconds from the onset of the comparison display. Any responses made after the offset of the comparison display (that is, longer than 3000 msec) were not recorded.

Stimulus Materials

The stimulus materials for all experiments were slide displays, of which there were four main types. Display types were identified jointly by the type(s) of information contained in the display, and by their function as sample or comparison display. Only the PI Sample displays, which were common to all experiments, will be described in this section; the three types of comparison displays will be described where appropriate.

All sample displays contained both position and identity information and hence were designated PI Sample displays. The identity information consisted of four different letters selected from the set H, M, T, V, W, and X, or four different forms selected from the set $\bigcirc$, $\square$, ∇ , $\diamond$, $\triangle$, and $\square$. The position information consisted of the four cells of a 3x3, 4x4, 5x5, or 6x6 matrix occupied by the items. For all matrix sizes, a set of 30 letter displays was constructed; for the 3x3 matrix size, a set of 30 form displays was also constructed.

These sets of 30 displays were constructed by first generating a set of 30 patterns for each matrix size. A pattern consisted of four cells, randomly selected according to the following rule: For the first three cells not more than one cell in any row or column could be used, while

the fourth cell was selected from those that remained. (For the 3x3 matrix size, there were only 36 patterns that could be generated using this rule; of these, six patterns were randomly eliminated to form a set of 30.) Then, a grouping of four items was assigned to each pattern; these groupings were the 15 possible combinations of four different items from the letter set or the form set, and each combination was assigned to two patterns. Finally, within each pairing of pattern and item grouping, items were randomly allocated to cells. Figure 1 provides some examples of PI Sample displays.

Displays were initially constructed on white card, using Letraset 552 for letter displays and Letraset 283 for form displays. Matrix outlines were drawn separately. The display cards were then photographed, with appropriate reduction to give a matrix cell size of 3 mm x 3 mm on the negative, and hence a matrix cell size of 17 mm x 17 mm on the display screen.

Since the size of an individual matrix cell was held constant at 17 mm x 17 mm, display dimensions and hence visual angles varied with matrix size. For the 3x3, 4x4, 5x5, and 6x6 matrix sizes, respectively, the screen display dimensions (both vertical and horizontal) were 51, 68, 85, and 102 mm, and the corresponding visual angles were 2.92, 3.90, 4.87, and 5.84 degrees.

In each experiment the same sequence of PI Sample displays was used for all subjects within and across conditions. The same sequence of comparison displays was used for all subjects within a condition, and across conditions where possible. These sequences were random, subject to the constraints that there were equal numbers of matches and mismatches within a block (or sub-block) of trials, and that not more than three matches or mismatches occurred in succession.

Figure 1
PI SAMPLE DISPLAYS

	V	
X	T	
		H

3 x 3 (letters)

	◇	
◐	▽	
		○

3 x 3 (forms)

				T	X
		H			
V					

6 x 6

			X
		H	
V	T		

4 x 4

		X		
	T			
		V		
			H	

5 x 5

EXPERIMENTS 1, 2, AND 3: UNIDIMENSIONAL CONTROL CONDITIONS

The first three experiments examine performance on the dimensions of position and identity, in unidimensional control conditions. Subjects are required to attend to either the positions of the four items or the identities of the four items that are presented in the PI Sample displays. The comparison displays present information on the relevant dimension only. As the irrelevant dimension is not represented in the comparison display, its characteristics should not affect performance. That is, variation of the informational content of the position dimension should affect Position but not Identity task performance, and variation of the informational content of the identity dimension should affect Identity but not Position task performance.

In Experiment 1 identity information is varied by using two different classes of items, letters and forms, whereas position information is varied by presenting items within a 3x3 matrix outline that can be either present or absent. Experiment 2 focuses on Position task performance. Position information is varied by using three different matrix sizes and by manipulating presence/absence of the matrix outline. To investigate more fully the processing of position information in unidimensional control conditions, position recognition is compared with position recall in Experiment 3.

EXPERIMENT 1

Selective attention to either the position dimension or the identity dimension is required in Experiment 1. All subjects are presented with both types of information in the sample displays, but only the relevant type of information is represented in the comparison displays. This is achieved by the use of "neutral" comparison displays, consisting of either four items in a central square arrangement, or four dots. The dimension to be attended is a between-subjects factor, with both position information and identity information varied within subjects.

The main predictions are: (1) Identity task performance will be affected by stimulus class (such that letters are matched more rapidly and more accurately than forms) but not by the matrix outline factor. (2) Position task performance will be affected by the matrix outline variable (such that positions are matched more rapidly and more accurately when the matrix outline is present than when it is absent) but not by the stimulus class factor.

Method

Stimulus Materials. Two sets of PI Sample displays were used. One set of 30 displays contained letters in the cells of 3x3 matrices, and the other set of 30 displays contained forms in the cells of 3x3 matrices.

For each set of sample displays, two sets of comparison displays were constructed. The P Comparison display set consisted of 60 displays containing position information only, while the I Comparison display set consisted of 60 displays containing identity information only.

The 60 P Comparison displays represented 30 pairs of comparison displays, one pair per PI Sample display. Both members of the pair contained four dots, three of which corresponded to three positions in the sample display. In the matching member of the pair, the position of the fourth dot was the same as the fourth position in the sample display. In the mismatching member of the pair, the position of the fourth dot was different from the fourth position in the sample display. Because of the limited number of patterns at this matrix size, a mismatching P Comparison display was in fact another sample pattern. In order to ensure that patterns were evenly represented, the rule was adopted that any particular mismatching display was used only once.

Similarly, the 60 I Comparison displays represented 30 pairs of comparison displays with one pair per PI Sample display. Both members of the pair contained four items, three of which corresponded to three items in the sample display. In the matching member of the pair, the identity of the fourth item was the same as the fourth item in the sample display, whereas in the mismatching member of the pair, the identity of the fourth item was different from the fourth item in the sample display. Across the 30 mismatching I Comparison displays, each item was deleted five times and replaced once by each of the other five items. The four items of an I Comparison display appeared in a central, square arrangement, without a matrix outline or display border. The precise locations of the items were the intersections that would be formed by the grid lines of a 3x3 matrix were the matrix present. The four items were randomly assigned to the four locations, while maintaining correspondence between matches and mismatches. Figure 2 illustrates the sample and comparison displays used in this experiment.

Figure 2

EXPERIMENT 1: SAMPLE AND COMPARISON
DISPLAYS

Position Match

Position Mismatch

Sample Display
(letters)

Identity Match

Identity Mismatch

Procedure. Subjects were assigned alternately to the Position task and the Identity task in the order of their appearance at the laboratory. Each served in a single session of 120 trials. The trials were blocked in groups of 60 by stimulus class, letter (L) or form (F) and in groups of 30 by presence (+) or absence (-) of the matrix outline. Four different orders of blocks of 30 trials were used: L+L-F+F-, L-L+F-F+, F+F-L+F-, and F-F+L-L+. Two subjects were assigned to each block order and the eight block orders (four orders by two subjects) were randomized separately for the Position task and the Identity task. Within each block of 30 trials, the first ten were practice, and subjects were so informed.

Subjects. Subjects were four female and two male nursing student volunteers. Each was paid \$2.50 for participating.

Results

Mean correct RTs were entered into a three-way mixed ANOVA, with task as the between-subjects factor, and stimulus class and matrix outline presence as within-subjects factors. Position task RTs were faster than Identity task RTs [$F(1,14) = 29.95, p < .001$]. The overall means were 895 msec and 1785 msec in the Position task and in the Identity task, respectively. Letter matches were faster than form matches [$F(1,14) = 10.30, p < .01$], and the interaction of task and stimulus class was also significant [$F(1,14) = 9.63, p < .01$]. An analysis of the simple main effects of this interaction indicated that stimulus class had no effect on RTs in the Position task ($F < 1$), but it did have an appreciable effect in the Identity task [$F(1,7) = 11.61, p < .025$]. The main effect of matrix outline presence was not significant,

nor was the interaction of task and matrix outline presence (both F 's < 1). Figure 3 plots RTs as a function of task, stimulus class, and matrix outline presence. It can be seen that (despite the failure to reach significance) Position task RTs were approximately 100 msec faster when the matrix outline was present than when it was absent, while Identity task RTs were not thus affected.

In Figure 4, mean percentage correct responses are shown as a function of task, stimulus class, and matrix outline presence. These were also analyzed by means of a three-way mixed ANOVA, and the results paralleled those found in the RT ANOVA. Mean percentage correct was 97.9 in the Position task and 86.2 in the Identity task [$F(1,14) = 27.42$, $p < .001$]. Letter matches were more accurate than form matches [$F(1,14) = 29.93$, $p < .001$], and the interaction of task and stimulus class was significant [$F(1,14) = 24.58$, $p < .001$]. An analysis of the simple main effects of this interaction indicated that stimulus class had no effect on accuracy in the Position task ($F < 1$), but that letters were matched more accurately than forms in the Identity task [$F(1,7) = 30.76$, $p < .001$]. Neither matrix outline presence nor its interaction with task were significant (both F 's < 1).

EXPERIMENT 1:
MEAN RTs

Discussion

Three features of the results require comment: (1) the presence of a selective effect of variation along the identity dimension on Identity task performance, (2) the absence of a selective effect of variation along the position dimension on Position task performance, and (3) the substantial overall difference in the level of performance for the Position and Identity tasks.

It was predicted that variation of the identity information presented would affect performance when identity was the relevant dimension, but not when position was the relevant dimension. This prediction was confirmed: Letters were matched faster than forms in the Identity task, but not in the Position task. Collapsed across matrix presence/absence, mean RTs for letters and forms respectively were 1597 and 1974 msec in the Identity task, and 892 and 899 msec in the Position task. Letters were also matched more accurately than forms, 96% versus 77%, in the Identity task. This superior performance with letters was anticipated, and can be reasonably attributed to the greater familiarity of letters.

Compared with data reported in other studies employing similar procedures, the absolute levels of performance in the Identity task are relatively slow, for both forms and letters. For example, Santa (1977) reported a mean RT of about 1275 msec to match three forms, using a sample display duration of two seconds and an interstimulus interval of two seconds, and neutral comparison displays. The longer mean RT of 1974 msec presently found might well reflect the use of four rather than three forms, as well as the longer interstimulus interval of five seconds. The present results are also consistent with values obtained in a pilot study (see Appendix) using the form sample displays, and varying

sample display duration and interstimulus interval. There, a mean RT of 2058 msec was found for the equivalent condition, with an accuracy level of 85%. Thus, subjects in the present study were slightly faster but also slightly less accurate.

The mean RT of 1597 msec found for letters is considerably slower than the typical response times reported when horizontal arrays of four letters are successively matched. Taylor (1976) and Proctor and Hurst (1982) reported RTs around 500 msec, whereas Kreuger (1984) reported RTs around 1000 msec. Two factors may have contributed to the elevation in RT that I found. First, the relatively long interstimulus interval slowed responses, since the pilot study showed that increments in interstimulus interval slowed RTs in both tasks, but to a significantly greater extent in the Identity task.

Second, responses were slowed because the comparison stimuli were not truly neutral with respect to position information. As noted earlier the nature of the logical relationship between position and identity is such that visually presented identity information must occur in some spatial position, although spatial positions need not have an identity. Although the comparison displays in the Identity task contained items in central, predictable locations, without a matrix outline or display borders, the positions occupied by the items in the comparison displays were nevertheless different from those occupied in the sample displays. If position information was processed even when irrelevant, as the asymmetric separability hypothesis holds, then this change in position may have produced interference. (This possibility is explored in Experiments 4 and 5, where Identity task performance with consistent, neutral, and inconsistent comparison displays is examined.)

It was also predicted that variation in the position information presented would affect performance when position was the relevant dimension but not when identity was the relevant dimension. This prediction was not supported. However, it can be seen from Figure 3 that an appropriate trend was present in the RT data: Matrix outline presence/absence had no effect on Identity task performance whereas Position task performance was faster when the matrix was present than when it was absent. A tentative explanation for the failure of the matrix outline factor to reliably influence Position task performance is that matching four positions in a nine-cell matrix is so easily accomplished that the additional information provided by the matrix outline is of little use. If the Position task was made more difficult, then matrix outline presence might facilitate performance. This idea is tested in Experiment 2.

There was a robust effect of dimension attended, or task. Position matches were faster than Identity matches, by about 700 msec in the case of letters and by almost 1100 msec in the case of forms; Position matches were also significantly more accurate. As precisely the same information was initially presented in both tasks and under the same conditions, this marked difference as a function of task indicates that the recognition of the identities of four items involves processes different to those involved in the recognition of the positions of four items.

The superiority of Position task performance supports the conceptualization of position and identity as asymmetrically separable dimensions. Position information logically precedes identity information; the processing of position information probably occurs at a

lower neurological level than does the processing of identity information; position information processing is characterized by a high degree of automaticity. For all of these reasons, Position task performance should be superior to Identity task performance.

EXPERIMENT 2

In Experiment 2 the informational content of the position dimension is again manipulated, and performance on the Position task and the Identity task in unidimensional control conditions is examined. This experiment attempts to confirm the prediction that variation of the position information presented in the PI Sample display will affect performance when the relevant dimension is position but not when the relevant dimension is identity. Experiment 1 failed to confirm this prediction when position information was varied through presenting or omitting the 3x3 matrix outline, a failure tentatively attributed to task simplicity. In order to increase the difficulty of the Position task, matrix size is varied in Experiment 2. Four items appear in four cells of 4x4, 5x5, and 6x6 matrices. Matrix outline presence is concomitantly varied at each matrix size.

Studies concerned with successive matching of patterns have found that performance becomes poorer (less accurate and/or slower) as pattern complexity increases (Checkosky & Whitlock, 1973; Farkas & Smothergill, 1979; Phillips, 1974; Sebrechts & Garner, 1981). Pattern complexity has been manipulated in various ways: (1) by covarying matrix size and number of occupied cells, (2) by varying the number of occupied cells in a constant size matrix, and (3) by manipulating pattern goodness using the criteria of Garner and Clement (1963). In Experiment 2 complexity is manipulated by holding constant the number of occupied cells and varying matrix size from 16 cells to 36 cells. It is predicted that as matrix size increases, performance in the Position task will deteriorate so that RTs should increase with increments in matrix size.

If the presence of a matrix outline is unimportant when the Position task is simple, then as the difficulty of the Position task increases,

the additional information afforded by the presence of the matrix outline should become more important. An interaction between matrix outline presence and matrix size is therefore predicted such that the performance advantage when the matrix outline is present increases with increments in matrix size.

Letters are used in the PI Sample displays at all matrix sizes. (Since the selective effect of variation of identity information was so clearly demonstrated in Experiment 1, I felt it was unnecessary to further manipulate identity information.) Neither the matrix size nor the matrix outline manipulation is expected to affect Identity task performance, although it is expected that Identity task performance will be inferior to Position task performance. As in Experiment 1, dimension to be attended (task) is a between-subjects factor, whereas matrix size and matrix outline presence are within-subjects factors.

Method

Stimulus Materials. There were three sets of 30 PI Sample displays. One set contained four letters in the cells of 4x4 matrices, a second set contained four letters in the cells of 5x5 matrices, and a third set contained four letters in the cells of 6x6 matrices.

For each matrix size a set of 60 P Comparison displays was constructed as in Experiment 1. Thus, there were 30 matching comparison displays and 30 mismatching comparison displays, each corresponding to a particular PI Sample display. The 60 I Comparison displays containing four letters from Experiment 1 were also used in Experiment 2.

Procedure. Subjects participated in a single experimental session of 180 trials. Trials were blocked in groups of 60 by matrix size and in

groups of 30 by matrix outline presence/absence, with presence/absence alternating across blocks. One subject was assigned to each of the 12 block orders formed by crossing the six possible orders of matrix size with initial presence/absence of the matrix outline. The 12 block orders were randomized separately for the Position and Identity tasks, and subjects were assigned alternately to the two tasks in the order of their appearance at the laboratory. As in Experiment 1, the first ten trials in each block of 30 trials were practice trials. The interstimulus interval between sample and comparison displays was reduced to one second.

Subjects. A total of 28 psychology student volunteers participated in this experiment, 13 in the Position task and 15 in the Identity task. The results of one subject in the Position task were unusable because of equipment malfunction. The results of three subjects in the Identity task were discarded because overall error rates exceeded 10%. A 90% accuracy criterion was adopted in order to avoid any possibility of a speed-accuracy tradeoff in the results that would hinder interpretation, and also to obviate the potential problem of insufficient RTs due to a large number of misses. The final sample, therefore, consisted of 24 subjects, 6 males and 18 females.

Results

Figure 5 shows mean correct RT as a function of task, matrix size, and matrix outline presence. The RTs were entered into a three-way mixed ANOVA, with task as the between-subjects factor, and matrix size and matrix outline presence as within-subjects factors. Position matches were significantly faster than Identity matches [$F(1,22) = 45.62$, $p <$

.001]. No other effects or interactions attained an acceptable level of significance.

Across all conditions, accuracy averaged 98% in the Position task and 96% in the Identity task. A three-way mixed ANOVA on the error data revealed only a main effect of task [$F(1,22) = 13.23, p < .01$].

EXPERIMENT 2:
MEAN RTs

Discussion

The predictions made at the outset of this experiment were not well supported by the results. The discussion of the results will concentrate on the main effect of task, performance in the Identity task, and performance in the Position task.

The difference between the speed of Position matches and the speed of Identity matches was large and reliable. Collapsed across matrix size and matrix outline conditions, mean RT was 857 msec in the Position task and 1573 msec in the Identity task. These values are very close to those found in Experiment 1 with letter sample displays -- 892 msec in the Position task and 1597 msec in the Identity task -- notwithstanding the difference in interstimulus interval. Position matches were also made more accurately than were Identity matches. This correspondence between the two experiments is encouraging and demonstrates that although the tasks are formally equivalent Identity matches are more difficult than Position matches in unidimensional control conditions. However, this large difference in performance itself presents a problem: namely, an overshadowing of within-task effects by the large between-task effect. In order to overcome this difficulty, separate analyses (two-way ANOVAs) of the two tasks were conducted.

When performance in the Identity task was separately examined there was a reliable effect of matrix size [$F(2,22) = 4.09$, $p < .05$]. This finding was unexpected since matrix outlines never appeared in I Comparison displays; in fact, identical sets of comparison stimuli were used for all matrix sizes. Moreover, the form of the effect was peculiar: When the PI Sample display consisted of letters in a 5x5 matrix, responses were faster (1513 msec) than when the letters appeared in a 4x4 matrix (1653 msec) or in a 6x6 matrix (1552 msec).

Examination of the results by blocks indicated that faster 5x5 matches were found only in the third block; matches at the 4x4 size showed little change across blocks, and matches at the 6x6 size got increasingly slower. Examination of the results for individual subjects revealed that only three of the 12 subjects were faster at the 5x5 matrix size in both matrix outline conditions, with an additional three in each matrix outline condition faster at the 5x5 matrix size. Although reliable, the effect of matrix size is perhaps best regarded as a peculiarity for which there is no reasonable explanation.

Of greater interest, since variation of position information formed the basis of this experiment, was performance on the Position task. When a separate analysis of Position RTs was undertaken, none of the main effects or interactions reached an acceptable level of significance. Nevertheless, there were small trends in the appropriate directions. Positions were matched slightly faster when the matrix outline was present than when it was absent (837 versus 876 msec). This advantage also varied with matrix size, from -34 msec at the 4x4 matrix size, to 45 msec at the 5x5 matrix size, through to 109 msec at the 6x6 matrix size. It would seem that the manipulations used were affecting position performance but without much potency.

At the outset of this experiment it was predicted that such an interaction would occur concomitantly with, and as a consequence of, increases in task difficulty. Graphically, both functions would be characterized by positive slopes, with a greater slope for the matrix outline absent condition. But there was no evidence that task difficulty did increase with matrix size: Position matches were most rapid at the 5x5 matrix size (817 msec), intermediate at the 4x4 matrix size (858 msec), and slowest at the 6x6 matrix size (894 msec).

The failure to find a reliable effect of matrix size is strange. Intuitively, recognizing which four of 36 positions were occupied would seem to be more difficult than recognizing which four of 16 positions were occupied. If the value obtained in Experiment 1 with 3x3 matrices (892 msec) is included for consideration, then it appears that RT is relatively invariant across a fourfold increase in the number of possible positions.

Although other studies using a successive matching procedure have found that increments in complexity have produced decrements in performance, the present study can be distinguished by the manner in which complexity was manipulated: The number of positions to be recognized was held constant at four, while the number of unoccupied positions was varied by increasing matrix size. The reason for adopting this approach was, of course, to maintain the formal similarity with the Identity task. It appears from the data that this manipulation does not in fact affect complexity and hence task difficulty.

Why should this be? An answer requires a consideration of how subjects recognize positions. One possibility is that subjects code positions on the basis of their absolute location on the display screen. Such a strategy is feasible only with a successive matching procedure, and where sample and comparison displays appear in exactly the same locations and are of the same physical dimensions. This option may also be restricted to a fairly small number of positions. Phillips (1974) found that successive matching performance deteriorated when the number of cells comprising a pattern increased from eight (from a total of 16) to 32 (from a total of 64).

Another possibility is that subjects code positions relative to each other, to unoccupied positions, and to display borders or matrix

outlines. If this is so, then increases in matrix size, which would increase the average distance between positions, the number of unoccupied positions, and the average distance to the display borders, should impair performance. The results of Experiment 2 indicate that this strategy does not feature significantly in the position recognition task used. Instead, it appears that coding of absolute position underlies Position task performance.

This argument suggests that if the Position task could be structured so that relative position information was utilized to a greater extent, then increments in matrix size should impair performance. How could this shift in emphasis be achieved? Within a successive matching procedure, sample and comparison displays could be presented at different locations, or with different physical dimensions, so that the comparison display was larger or smaller than the sample display. Another approach would be to use a recall procedure. This, too, would force an increased reliance on relative position information, and would have the advantage of permitting contact with research on pattern recall. As far as I can ascertain, an explicit contrast between the recall and the recognition of visually presented position information has not been reported in the literature. A comparison between the recognition and the recall of position information represents a diversion from the main concerns of this thesis, but it is one that I felt was warranted, in view of the unexpected results of Experiment 2.

EXPERIMENT 3

The purpose of Experiment 3 is to explore the distinction between absolute position information and relative position information, by comparing position recognition and position recall tasks. The results of Experiment 2 suggested that position recognition depends primarily on absolute position information, and hence is insensitive to variations of matrix size. A recall procedure, on the other hand, requires the use of relational information for successful performance, since subjects must actively select four positions from the available alternatives, and this selection is in a different physical location from the display screen.

A within-subjects design is employed, with all subjects performing both Recall and Recognition tasks. In both tasks, the same information is presented to subjects: four letters in four cells of a 4x4, 5x5, or 6x6 matrix. Because increases in matrix size increase the complexity of the relational information, performance in the Recall task should deteriorate as matrix size increases. Performance in the Recognition task should not be affected, and therefore the results of Experiment 2 should be replicated.

The two tasks use different measures of performance to assess the effect of variations in matrix size. This difference in performance measures may be undesirable, but appears to be unavoidable: Experiments 1 and 2 showed recognition accuracy to be nearly perfect at all matrix sizes, and measuring speed of recall seemed to be neither meaningful nor easily accomplished.

Method

Stimulus Materials. The PI Sample and P Comparison displays from Experiment 2 for the 4x4, 5x5, and 6x6 matrix sizes were used. Response sheets were used in the Recall task. These presented a matrix outline of the same dimensions as the visual display and approximately centered on the page, and were stapled into booklets of 22.

Procedure. The experiment had six sessions of 60 trials each, with one session for each of the six combinations of matrix size and task. The 60 trials within a session were divided into three groups of 20, with the first group being practice trials.

The three sessions for each task were run on separate, not necessarily successive, days within the same week. The two sets of sessions were run in successive weeks. Half the number of subjects performed the Recall task first, and half performed the Recognition task first. Within these groups, one subject was assigned to each of the six possible orders of matrix size. For a given subject, the same order of matrix sizes was used in both tasks.

The procedure for the Recognition task was identical to that used in Experiment 2, with the addition of a 500 msec warning tone commencing halfway through the intertrial interval.

The procedure for the Recall task differed in that, instead of a comparison display of four dots appearing after the interstimulus interval, only the (appropriate size) matrix outline appeared. Subjects were told that the appearance of the matrix outline was their cue to recall the positions occupied by the letters, and to mark (with an X) the appropriate cells on the response sheet. The warning tone signalled subjects to stop writing, turn to the next response sheet, and then

focus their attention on the screen. Subjects were asked to begin a new booklet of response sheets for each group of 20 trials.

Subjects. Nine female and five male psychology student volunteers served as subjects. Two subjects, both males, were discarded; one because of experimenter error and the other because of an apparent failure to understand the instructions. Subjects were each paid \$6 for their participation.

Results

Figure 6 shows mean correct RT as a function of matrix size in the Recognition task. Mean RTs were 820, 784, and 807 msec for the 4x4, 5x5, and 6x6 matrix sizes, respectively. The effect of matrix size was not significant ($F < 1$). Error rates were less than 2% for all matrix sizes.

Recall task performance was scored by summing the number of positions correctly recalled, which could range from zero to four, across the 40 sample displays at a given matrix size. The maximum possible score was 160. These scores were converted to percentages, and the means of these values are also shown in Figure 6 as a function of matrix size. For the 4x4, 5x5, and 6x6 matrix sizes, respectively, the mean percentage correct values were 97.9, 86.4, and 80.0. The overall decrement in recall accuracy is significant [$F(2,22) = 34.45$, $p < .001$], as are both of the successive decrements [$F(1,11) = 47.47$, $p < .001$ for 4x4 versus 5x5, and $F(1,11) = 8.61$, $p < .025$ for 5x5 versus 6x6]. An analysis using an arcsin transformation of the data gave equivalent results.

EXPERIMENT 3:
POSITION RECOGNITION MEAN RTs
AND POSITION RECALL ACCURACY

Discussion

Manipulations of matrix size, and consequently the number of possible positions in which items could occur, had no effect on Recognition task RT but a significant effect on Recall task accuracy. This differential effect of matrix size as a function of task supports the contention that position recognition is based on the coding of absolute position information, whereas position recall involves the use of relational information.

Before elaborating on this distinction some comments on performance in the two tasks and comparisons with other studies are in order. The first point is that the results obtained in Experiment 3 for the Recognition task show a high degree of consistency with the results found in Experiment 2 for the equivalent conditions. A two-way ANOVA with experiment as the between-subjects factor and matrix size as the within-subjects factor showed no effect of experiment ($F < 1$), matrix size [$F(2,44) = 1.36$], or their interaction ($F < 1$). Both experiments were also consistent in showing RT to be slightly faster at the 5x5 matrix size, a trend also observed for Identity matches in Experiment 2. It may be that, by virtue of its possession of a single central cell, the 5x5 matrix size facilitates fixation on the relevant area of the display screen. Neither the 4x4 nor the 6x6 matrices possess this feature. In any event the differences are small, and the results indicate that the number of possible positions is not a significant determinant of the speed of position recognition.

Performance in the Recall task showed the predicted decline in accuracy as a function of matrix size. The inference to be drawn from this finding is that because recall involves the use of relational information, variation in the number of alternative positions influences

task complexity when recall of position information is required. Other means of manipulating complexity have been found to influence the accuracy of pattern recall. For example, Attneave (1955) found a reduction in accuracy as matrix size increased from 12 to 35 cells, and approximately half the cells were occupied by dots; this reduction was greater for random than for symmetrical patterns. Using patterns of eight filled cells in 4x4 matrices, Schnore and Partington (1967) found that accuracy decreased as complexity (measured in bits of information) increased. Studies by Howe (1980) and Howe and Brandau (1983) found that pattern goodness functioned as an important determinant of recall accuracy, although Bell and Handel (1976) found accuracy to vary with pattern goodness only when a masking stimulus followed display presentation.

The overall level of performance in the Recall task (88% correct over the three matrix sizes) is consistent with results reported in other studies. Bell and Handel (1976) reported an average accuracy of 93% for patterns of four or five dots in (imaginary) 3x3 matrices, and Christie and Phillips (1979) reported accuracy to be around 90% for patterns of eight filled cells in 4x4 matrices.

The most important result of Experiment 3 was the differential effect of variation in matrix size upon performance in the Recognition and the Recall tasks. This finding permits certain inferences concerning the coding of positional information. The absence of any effect of matrix size on position recognition, which was clearly observed in Experiments 2 and 3, is consistent with the argument that in the Recognition task, positions were coded in terms of their absolute location on the display screen, so that neither the number nor the

distribution of unoccupied cells affected performance. In the Recall task successful performance required reconstruction of the relationships between occupied cells, unoccupied cells, and the display borders. Because increments in matrix size increased the complexity of this relational information, performance deteriorated as matrix size increased.

A related concept in the coding of position information is that of configuration. Several studies have shown that multiple positions, or patterns, are coded holistically as a configuration. For example, Sekuler and Abrams (1968) examined the simultaneous matching of patterns under two instructional conditions. In the "similarity" condition patterns were classified as same when at least one pair of filled cells matched; in the "identity" condition all pairs of filled cells had to match for a pair to be classified as same. Patterns consisted of one, two, or four filled cells in a 4x4 matrix. The similarity condition produced substantially longer RTs and showed a more pronounced effect of the number of matching/mismatching cells than did the identity condition. Of particular interest is the observation that when every pair of cells matched, thus requiring a "same" response in both conditions, or every pair of cells mismatched, thus requiring a "different" response in both conditions, identity RT was faster than similarity RT for every level of task difficulty. Sekuler and Abrams concluded that similarity subjects engaged in serial processing of each position whereas identity subjects adopted a holistic strategy of comparing the entire configuration. Since the identity condition is generally used in studies of pattern recognition, it is reasonable to argue that the results of most studies reflect the use of a holistic comparison strategy.

Farkas and Smothergill (1979) also concluded that since the accuracy with which a probe dot could be recognized as belonging to a previously presented five-dot pattern increased as pattern goodness increased, patterns were coded as holistic entities. If positions were encoded independently, then pattern goodness (a property of the entire pattern and not of constituent positions) should not affect recognition accuracy. A further prediction can be made here: If patterns are processed holistically, then a comparison stimulus that consisted of the entire pattern should be better recognized than a single probe dot. Podgorny and Shepard (1983) found precisely this: With patterns comprising two, three, or four shaded cells in a 3x3 matrix, RT was significantly faster when the probe consisted of two, three, or four dots (respectively) than when the probe consisted of a single dot.

Additional support for the notion of holistic encoding comes from a study of pattern recall by Howe and Brandau (1983). They found that even with minimal processing time (40 - 80 msec) an average minimum of three positions were correctly recalled, indicating parallel processing of those three positions. If parallel processing of positions is tantamount to holistic encoding of a pattern this finding suggests that such a strategy occurs in both the recall and the recognition of patterns.

Experiment 3 qualifies this generalization, by showing that decisions based on configuration are especially facilitated by the use of a recognition procedure. Since the same positional information (configuration) was presented in the two tasks and the same experimental manipulation (variation of matrix size) was used, the different patterns of results indicate that the recall of a configuration is more difficult than its recognition. A recognition response is essentially a holistic response: Position information either matches or mismatches. A recall

response requires four discrete decisions to reconstruct a pattern. The holistic encoding of positions as a configuration appears to be more compatible with a holistic recognition response than with a more analytical recall response.

A final point of discussion concerns the relative accuracies of position recall and identity recall reported in other studies. Some researchers have found that position recall is more accurate than identity recall (Blake, 1976; Finkel, 1973; Finkel & Smythe, 1974) whereas others have found the reverse (den Heyer & Barrett, 1971; Meudell, 1972; Salthouse, 1974, 1975). The studies that found position superiority used 3x3 matrices and geometric forms as stimuli, whereas the studies that found identity superiority used larger arrays (16 to 25 possible positions) and letters as stimuli. The results of Experiment 1 indicated that letters are more efficiently processed in terms of both speed and accuracy than are geometric forms. The results of Experiment 3 indicate that position recall is poorer at larger matrix sizes. Putting the two findings together, the conditions used in the studies that found position superiority were generally more favorable to position performance, whereas those used in the studies that found identity superiority were generally more favorable to identity performance.

This means that the selection of stimulus parameters and task structure can jointly affect performance, so that the absolute and relative levels are subject to fluctuation. Although this observation is not particularly surprising it does mean that comparisons between the dimensions, and the assessment of their relationship, need to be made under equivalent stimulus and task conditions.

SUMMARY OF EXPERIMENTS 1, 2, AND 3

The first three experiments have examined performance under unidimensional control conditions where the irrelevant information was absent from the comparison display. Under these conditions variation along a dimension should have affected performance when that dimension was relevant but not when it was irrelevant. Experiment 1 confirmed this prediction when identity information was varied: Stimulus class had a marked effect on the speed of identity recognition and had no effect on the speed of position recognition. Variation of position information resulted in less clear-cut effects. In Experiment 1, the presence of a matrix outline had a slight (insignificant) effect on Position task RT and had no effect on Identity task RT. Concomitant variation of matrix size and matrix outline presence (Experiment 2) produced mixed effects. In the Identity task matrix size unexpectedly influenced RT, such that RT was faster when 5x5 matrices were used, whereas matrix outline presence had the expected null effect. In the Position task neither variable produced significant effects, although matrix outline presence and its interaction with matrix size showed appropriate trends.

An explanation for the failure of matrix size to influence Position task RT was tested with success in Experiment 3, where the recall and recognition of positional information was compared across the three matrix sizes used in Experiment 2. The conclusion from this experiment was that the holistic coding of configuration is facilitated by a recognition procedure. The conclusion helped to explain the absence of significant effects of position information variation in Experiments 1 and 2: The recognition of four positions is so directly and so easily accomplished that manipulation of matrix outline and matrix size are of little benefit to successful performance.

In general it may be said that Identity task performance appears sensitive to the experimental manipulations employed here and that Position task performance is insensitive to such manipulations. As well, and with formally equivalent tasks, position processing is substantially faster than identity processing. These differences in speed and sensitivity to informational variation agree with the conceptualization of position as the more fundamental of the two dimensions, allowing less flexibility in processing strategies, and being characterized by rapid and automatic processing of information.

EXPERIMENTS 4, 5, AND 6: SELECTIVE ATTENTION TO ONE DIMENSION

In Experiments 1 to 3 the successive matching of four positions or four identities was studied under unidimensional control conditions: Although both dimensions were represented in the sample displays, only the relevant dimension was included in the subsequent comparison display. The asymmetric separability hypothesis, however, is concerned with the *relationship* between the two dimensions. To investigate this relationship, information on both dimensions must be made available to the decision process. Therefore, comparison displays must include both position and identity information.

In Experiments 4 to 6 both sample and comparison displays consist of four items in four cells of a matrix. Sample and comparison displays may match or may mismatch on the irrelevant dimension, as well as on the relevant dimension. Selective attention to one or other dimension is required, and the effect of informational variation along the irrelevant dimension is assessed. If position and identity work as asymmetrically separable dimensions selective attention should be possible for the primary dimension of position but not for the secondary dimension of identity. The ability to selectively attend to a dimension is demonstrated experimentally by an insensitivity to variation along the irrelevant dimension; sensitivity to such variation indicates the absence of selective attention.

Contrasting a neutral, control condition with both consistent and inconsistent conditions provides the best means of assessing the effect of variation along the irrelevant dimension. That is, with respect to

the information presented in the sample display, the information in the comparison display is either unchanged (consistent), absent (neutral), or changed (inconsistent); the observed patterns of facilitation and interference will permit inferences about the dimensional relationship.

Unfortunately ideal conditions do not always prevail in psychological experimentation. Here the problem concerns the difference in the appropriate control conditions, coupled with a desire to maintain intra-experiment consistency. I therefore decided to address this problem by means of three separate experiments each of which would maintain internal consistency. Taken together these three experiments should allow a good test of the asymmetric separability hypothesis.

Experiment 4 compares Position task and Identity task performance with comparison displays in which the irrelevant information is either consistent or inconsistent. Experiment 5 examines Identity task performance in the presence of consistent, neutral, and inconsistent position information. Experiment 6 looks at Position task performance in the presence of consistent, neutral, and inconsistent identity information.

EXPERIMENT 4

Selective attention to either position information or identity information is varied as a between-subjects factor in Experiment 4. The status of the irrelevant dimension, consistent or inconsistent, is varied within subjects. Sample and comparison displays may match on both dimensions, on the position dimension, on the identity dimension, or on neither dimension. If selective attention is possible, performance should be unaffected by whether or not the irrelevant dimension also matches. If selective attention is not possible, and the irrelevant dimension is also processed, a mismatch on the irrelevant dimension should produce performance inferior to that when the irrelevant dimension also matches.

The asymmetric separability hypothesis says that selective attention is possible for the position dimension, so that the status of the irrelevant identity dimension should not affect Position task performance. In the Identity task the status of the irrelevant position dimension should affect performance, since selective attention to the identity dimension is not possible. An interaction between task and irrelevant dimension status is required, as is a main effect of task with Position task performance showing an overall superiority to Identity task performance.

Method

Stimulus Materials. The set of 30 PI Sample displays for the 5x5 matrix size that was used in Experiments 2 and 3 was also used in Experiment 4 with each sample display containing four letters in four cells of a 5x5 matrix. These sample displays were used to generate four

types of comparison displays, all of which contained both position and identity information. The 5x5 matrix size was selected because in Experiments 2 and 3 Identity task RT was found to be fastest at this size. The overall difference between Position task RT and Identity task RT should be minimized with this matrix size thereby reducing the problem of task effects overshadowing other effects. At the same time, the 5x5 matrix size permits sufficient flexibility in the design of comparison displays.

The 30 PI Sample displays were used as the basis for construction of four-member comparison display sets, with the four members of a set representing four types of match relationship to the PI Sample display. These various types of matches were derived by holding constant three letters in three positions across the four members of the set, and varying the position and/or identity of the fourth letter.

The four types of comparison displays were:

1. P matches: The identity of the fourth letter was varied so that this type of comparison display matched its PI Sample on the position dimension only.
2. I matches: The position of the fourth letter was varied so that this type of comparison display matched its PI Sample on the identity dimension only.
3. Neither matches: The preceding two variations were combined so that the mismatching letter occurred in the mismatching position. Hence, this type of comparison display "matched" its PI Sample on neither dimension.
4. PI matches: Neither the position nor the identity of the fourth letter was varied so that this type of comparison display matched its PI Sample on both dimensions.

To increase the number of stimuli, advantage was taken of the fact that the four-member comparison display sets thus constructed also balanced in reverse. That is, if a Neither match was designated as a new PI Sample display then what were Position matches and Identity matches became Identity matches and Position matches, respectively, for the new PI Sample. The old PI Sample display became a new Neither match, whereas the new PI Sample display was its own new PI match. Conceptually therefore, there were 60 four-member comparison display sets, corresponding to the 30 original PI Sample displays and the 30 new PI Sample displays. Figure 7 gives an illustration of such a set.

Each of the 60 PI Sample displays (30 original and 30 new displays) was shown twice. Half the number of original PI Sample displays and half the new PI Sample displays were followed once by a PI match and once by a Neither match. The remaining original and new PI Sample displays were followed once by a Position match and once by an Identity match. Match types were allocated to sample displays so that each of the 120 comparison displays (30 sets X 4 match types) appeared exactly once, divided equally between original and new PI Sample displays.

Presentation order of the 120 PI Sample displays was subject to the constraint that within each block of 20, each of the four match types appeared equally often. As well, not more than three positive or three negative responses in succession were allowed. Positive responses were defined as PI and P matches in the Position task, and as PI and I matches in the Identity task. The same slide sequence was used for all subjects in both tasks.

Procedure. Subjects participated in a single experimental session of 120 trials. The trials were divided into three groups of 40, with the first group being practice trials. Subjects were assigned alternately to

Figure 7

EXPERIMENT 4: A COMPARISON DISPLAY SET

		M		
	T			
		V		
			H	

Position Match

	T			
		V		
	X			
			H	

Identity Match

		X		
	T			
		V		
			H	

PI Sample Display

	T			
		V		
	M			
			H	

Neither Match

		X		
	T			
		V		
			H	

PI Match

the Position and Identity tasks in the order of their appearance at the laboratory. In all other respects the procedure was identical to the recognition task procedure used in Experiment 3.

Subjects. Twenty-seven psychology student volunteers participated in this experiment. The results from three Identity task subjects were discarded because their error rates exceeded 10%. The remaining 24 subjects were 11 females and 13 males.

Results

Figure 8 shows mean correct RTs as a function of task and irrelevant dimension status. In the Position task, the mean RTs with consistent and inconsistent identity information were 898 and 924 msec, respectively. In the Identity task, the mean RTs with consistent and inconsistent position information were 1059 and 1234 msec, respectively. A two-way mixed ANOVA was conducted on the RT data, with task (position or identity) as the between-subjects factor and irrelevant dimension status (consistent or inconsistent) as the within-subjects factor.

Position matches were faster than Identity matches [$F(1,22) = 8.64$, $p < .01$], and consistent matches were faster than inconsistent matches [$F(1,22) = 18.72$, $p < .001$]. The interaction of task and irrelevant dimension status was also significant [$F(1,22) = 10.25$, $p < .01$]. An analysis of the simple main effects of irrelevant dimension status revealed that Position matches did not benefit from identity consistency [$F(1,11) = 1.62$, $p < .25$], whereas Identity matches were greatly enhanced by position consistency [$F(1,11) = 17.62$, $p < .01$].

Position task accuracy was slightly superior to Identity task accuracy, 98.8% versus 96.6%. Across 960 experimental trials, the 12

EXPERIMENT 4:
POSITION AND IDENTITY MATCHING

Position task subjects made 12 errors and the 12 Identity task subjects made 33 errors.

Discussion

The results support the asymmetric separability hypothesis: The status of the irrelevant dimension had a major effect on the speed of Identity matches and no effect on the speed of Position matches. Moreover, Position matches were faster than were Identity matches. Position information processing is characterized by rapidity and automaticity, resulting in an asymmetrical relationship between the two dimensions.

Automaticity of position information processing is indicated by the differential effect of irrelevant dimension status. When presented with position and identity information, Identity subjects were unable to ignore the irrelevant position information so that altering the position of one letter from sample to comparison display slowed the detection of an Identity match by 175 msec. On the other hand, Position subjects were able to ignore irrelevant identity information so that altering the identity of one letter from sample to comparison display slowed the detection of a Position match by an insignificant 26 msec. In short, selective attention to position information is possible whereas selective attention to identity information is impossible. According to the framework of dimensional relationships proposed by Garner (1974, 1976) this pattern of unilateral selective attention exemplifies the asymmetrically separable relationship.

The present results are similar to the results of other studies using different stimulus materials and/or experimental procedures. Santa (1977) found that interchanging the positions of geometric forms

increased RT for identity matches, and Angiolillo-Bent and Rips (1981) found the same effect for letter trigrams. Sheingold and Finkel (1977) found that altering the position of one item (a Hebrew letter) influenced recognition accuracy. Palef (1978) and Palef and Olson (1975) using a Stroop-like procedure, found that irrelevant identity information (word meaning) had no effect on the speed with which absolute position was judged, but that irrelevant position information did affect judgment speed for word meaning. This consistency across various studies implies that the asymmetrical relationship between position and identity observed in Experiment 4 is not confined to the materials and methods used here.

Rapidity of position information processing is indicated by the main effect of task, or dimension to be attended. Collapsed across status of irrelevant dimension, Position matches were 236 msec faster than Identity matches. Putting it another way, when the status of the irrelevant dimension was consistent and a match occurred on both dimensions, decisions based on the position dimension were 161 msec faster than decisions based on the identity dimension. This superiority for position information processing agrees with the findings of other researchers. Dick and Dick (1969) found lower thresholds for letter localization than for letter identification, and Logan (1975a, 1975b) found location accuracy to be superior to identity accuracy. In the Palef (1978) and Palef and Olson (1975) studies referred to above, judgments of word position were made 60 to 90 msec faster than judgments of word meaning.

The automaticity and rapidity of position information processing is of considerable importance to the asymmetric separability hypothesis.

Because of this rapidity and automaticity, position information is available earlier than is concomitantly presented identity information, and hence has greater potential influence on decision processes. The effect of this is seen principally in the asymmetrical influence of irrelevant dimension consistency in the successive matching task.

Further support for this interpretation comes from the errors committed in the two tasks. Most errors in the Position task (75%) were misses whereas the majority of errors in the Identity task were false alarms. False alarms to P matches were especially prevalent, comprising 50% of all Identity task errors. So it appears that Identity task subjects responded erroneously on the basis of the automatic and rapid detection of a position match. In contrast, Position subjects rarely responded erroneously to I matches. Since identity information was irrelevant and selective attention to position is possible, identity processing was undoubtedly at a minimal level.

The absolute magnitude of the task effect in Experiment 4 (236 msec) was much smaller than in Experiments 1 and 2 (760 and 720 msec, respectively). A considerable improvement in the speed of Identity matches in Experiment 4 accounted for most of this reduction.¹

Although inter-experiment variation might account for some of the difference in the size of the task effect, this alone seems an insufficient explanation. The mean RTs for Identity matches with neutral comparison displays were 1609 msec in Experiment 1 (letters in 3x3 matrices) and 1515 msec in Experiment 2 (letters in 5x5 matrices). Both values are considerably slower than the mean RTs of 1059 msec for -----

¹ The mean Position RT in Experiment 4 was slightly slower than the mean RTs observed in Experiments 2 and 3 for the 5x5 matrix size; these were 795 and 784 msec, respectively. Inter-experiment variation is the most likely reason for this difference.

consistent matches and 1234 msec for inconsistent matches found in Experiment 4. That is, across Experiments 1, 2, and 4 inconsistent matches were faster than neutral control matches. Although this contravenes the asymmetric separability hypothesis, the problem may reside in the selection of neutral comparisons, a difficulty alluded to in the discussion of Experiment 2.

Although neutral comparison displays were designed to eliminate position information (by virtue of presenting the four items in a constant and therefore predictable location, and by removing the matrix outline) nevertheless it is true that all of the items in neutral comparison displays appeared in positions different to those occupied in sample displays. The inconsistent comparison displays in Experiment 4, however, altered the position of a single letter leaving the positions of three letters unchanged from sample to comparison display. The difference between the speed of Identity matches in Experiments 1 and 2 and Experiment 4 suggests that *amount* of positional change may determine speed of matching on the identity dimension. This possibility is explored in Experiment 5, where Identity task performance with consistent, neutral, and inconsistent comparison displays is examined.

The results of Experiment 4 support the conclusion that position and identity exhibit a relationship of asymmetric separability arising as a consequence of the rapidity and automaticity with which position information is processed. However, I am not arguing that strictly sequential or contingent processing occurs, whereby identity processing depends upon the completion of position processing. The relative difficulty of the two dimensions, and therefore the speed or accuracy of task performance, can be varied by appropriate selection of stimulus and

instructional parameters, a point nicely illustrated in Logan's studies (1975a, 1975b), in which the relative accuracies for location and identity were found to vary as a function of target/noise discriminability. It may be more appropriate to think in terms of "precedence," whereby position information processing generally takes precedence over identity information processing.

EXPERIMENT 5

Investigation of the impact of irrelevant information is more properly undertaken by comparing performance in neutral conditions to performance in consistent (or correlated) and inconsistent (or orthogonal) conditions. This is because one of the fundamental criteria for dimensional integrality is the occurrence of *facilitation* when the dimensions are correlated and *interference* when the dimensions are orthogonal; facilitation and interference are assessed relative to performance in unidimensional control conditions. For asymmetrically separable dimensions Garner (1976, 1983) has asserted that when the primary dimension is relevant there should be facilitation but not interference, and when the secondary dimension is relevant there should be both facilitation and interference.

Because the unidimensional control conditions are not precisely equivalent for the position and identity dimensions, the facilitation/interference criteria are examined separately. In Experiment 5 Identity task performance is examined as a function of the status of the irrelevant position dimension. The results of Experiment 4 showed a difference of 236 msec between consistent and inconsistent conditions. The question to be considered in Experiment 5 is whether, as a dimensional analysis proposes, this difference represents a composite of facilitation and interference. To achieve this aim, three types of comparison displays are used: consistent, neutral, and inconsistent. If both facilitation and interference effects are present then mean RT for the neutral condition should lie between the mean RTs of the remaining two conditions.

An examination of mean RTs for Identity matches for Experiments 1, 2, and 4 suggested a complication: Neutral comparison displays are not

truly neutral. This problem is inherent in the logical asymmetry of the dimensions. Visually presented identity information cannot exist in the absence of spatial position. In particular, the mean RT for the inconsistent condition of Experiment 4 was faster than the mean RTs for the neutral conditions of Experiments 1 and 2. This anomalous result was tentatively attributed to the fact that the neutral comparison displays involved a greater amount of positional change than did the inconsistent comparison displays used in Experiment 4. Experiment 5 tests this interpretation by using inconsistent comparison displays that are characterized by a large degree of positional change. The inconsistency of inconsistent comparison displays is maximized by altering the positions of most or all of the four letters. If amount of positional change is a crucial determinant of performance, response times should be slower for these maximally inconsistent comparison displays than for the neutral comparison displays.

One additional manipulation is undertaken in Experiment 5: Comparison displays that mismatch on the identity dimension but match on the position dimension are omitted so that whenever position information is consistent the identity information also matches. Consistent matches should be especially facilitated by this manipulation because a match decision can be made on the basis of the faster position dimension.

Some small compromises in experimental design were necessary to attain the goals of this experiment. In order to get a sufficient number of RTs for the consistent and inconsistent conditions without unduly increasing the total number of trials, there was a slight inequality between the number of matches and mismatches. And because of technical limitations of the projection system the neutral condition was run separately from the consistent/inconsistent condition, with order of conditions counterbalanced across subjects.

Method

Stimulus Materials. The set of 30 PI Sample displays for the 5x5 matrix size was used. In both the neutral and the consistent/inconsistent conditions 16 sample displays were followed by matching comparison displays, and the remaining 14 sample displays were followed by mismatching comparison displays.

In the neutral condition all comparison displays comprised four letters in a central square arrangement with no matrix outline. (The neutral comparison displays used here were identical to the I Comparison displays used in Experiments 1 and 2.) The matching neutral comparison displays contained the same four letters as their respective sample displays. The mismatching neutral comparison displays contained one letter that was different from those in the sample display.

In the consistent/inconsistent condition all comparison displays comprised four letters appearing in the cells of a 5x5 matrix outline. The matching consistent comparison displays contained the same four letters in the same positions as the sample displays; that is, sample and comparison displays were identical. The matching inconsistent comparison displays contained the same four letters as the sample display, but the letters appeared in different positions. Seventy-five per cent of the matching inconsistent comparison displays had no positions in common with their respective sample displays. The remaining 25% of the matching inconsistent comparison displays had one position in common with their sample displays but this position was occupied by a non-common letter. The mismatching comparison displays for the consistent/inconsistent condition contained three letters that were the same as those in the sample display and one letter that was different. Of these mismatching comparison displays, 43% had no positions in common

with their sample displays, 43% had one common position and 14% had two common positions. In no case was the common position occupied by the same letter in sample and comparison displays.

The 30 PI Sample displays were randomly divided into two sub-blocks of 15 displays, eight of which were followed by a matching comparison display and seven by a mismatching comparison display. In the consistent/inconsistent condition, half the number of matching comparisons were consistent and half were inconsistent. As with the earlier experiments not more than three consecutive matches or mismatches were permitted.

Procedure. All subjects participated in two experimental sessions conducted on separate days in the same week. One session had 90 trials (three repetitions of the 30 PI Sample displays) in the consistent/inconsistent condition, and the other session had 60 trials (two repetitions of the 30 PI Sample displays) in the neutral condition. Half the number of subjects received the consistent/inconsistent condition before the neutral condition, whereas the remainder got the reverse order. In both conditions the first 30 trials were practice trials. In all other respects the procedure was identical to the Identity task procedure of Experiment 4.

Subjects. Eighteen psychology student volunteers, 16 females and 2 males, served as subjects. The results of two subjects, both females, were discarded because their error rates exceeded 10%.

Results

The mean correct RTs were entered into a two-way mixed ANOVA, with condition order as the between-subjects factor and type of comparison display as the within-subjects factor. As can be seen in Figure 9 type of comparison display significantly affected the speed of Identity matches, [$F(2,28) = 45.43, p < .001$]. The main effect of condition order was not significant ($F(1,14) = 2.35, p < .25$), nor was the interaction of condition order and type of comparison display [$F(2, 28) = 1.72, p < .25$].

Because condition order did not reliably affect RT, the data were collapsed across this factor for the assessment of facilitation and interference effects. The mean difference between the consistent and the neutral conditions was 463 msec, and the mean difference between the neutral and inconsistent conditions was 104 msec; both differences were significant [$t(15) = 6.00, p < .001$, and $t(15) = 2.16, p < .05$, respectively].

The accuracy level was similar to that for the Identity task in Experiment 4: 96.1%. In a total of 1440 trials, the 16 subjects made 22 misses and 34 false alarms.

EXPERIMENT 5: IDENTITY MATCHING

Discussion

The examination of Identity task performance undertaken here demonstrates the presence of both facilitation and interference effects as a function of the status of the irrelevant position information. When the position information in the comparison display was consistent responses were speeded by 463 msec relative to control RTs. When the position information in the comparison display was inconsistent responses were slowed by 104 msec, again relative to control RTs. This is precisely the pattern of results predicted by the asymmetric separability hypothesis for the secondary dimension for which selective attention is not possible.

Other studies that have directly examined the impact of consistent and inconsistent position information on the processing of identity information have not found this pattern of facilitation and interference. Interference has been found with inconsistent position information for judgments of word meaning but consistent position information has not produced facilitation (Palef, 1978; Palef & Olson, 1975).

In contrast the present results show stronger facilitation than interference. Several factors may account for this discrepancy. The difference between processing word meaning and letter identity may be relevant; the two are not synonymous although they obviously related.

A more important factor may be the difference between the successive matching design in the present experiment and the speeded classification design in the Palef (1978) and Palef and Olson (1975) studies. Boer and Keuss (1979, 1981) and Santee and Egeth (1980) found that patterns of facilitation and interference varied with the procedure employed. Although speeded classification and simultaneous matching tasks yielded

equivalent dimensional relationships (Boer and Keuss, 1981), the successive matching task differed from both the simultaneous matching task (Boer and Keuss, 1979) and the speeded classification task (Santee and Egeth, 1980). Moreover, the substantial facilitation effect seen in Experiment 5 is similar to the widely observed "fast-same phenomenon" in letter matching studies, which is stronger with successive than with simultaneous matching (Kreuger, 1984).

The most crucial factor may be the selection of appropriate neutral comparison displays for the Identity task, and hence the establishment of an appropriate baseline against which facilitation and interference effects can be measured. That is, the large facilitation effect found in Experiment 5 might be due to the relatively slow RTs found for the neutral condition. The slowness of the neutral condition is, as will be argued below, a consequence of the amount of positional change present in the comparison displays.

Turning to a comparison of the present results with those of Experiment 4, two features stand out: Consistent matches were faster and inconsistent matches were slower here than in Experiment 4. Both effects were predicted from a consideration of the characteristics of the comparison displays employed.

The mean RT for Identity matches with position consistent comparisons was 1059 msec in Experiment 4 and 937 msec in Experiment 5. Although inter-experiment variability could contribute to this difference, the faster RT in Experiment 5 is most probably a reflection of experimental design: An absence of comparison displays that mismatched on the identity dimension but matched on the position dimension. If position information is given precedence in processing so

that position matches are generally detected before identity matches, then positional consistency may essentially bias subjects towards a matching response even if identity processing is incomplete. That this occurs is suggested by the high rate of false alarms to position matches committed by Identity subjects in Experiment 4. Such a biasing effect would be especially strong in Experiment 5 where there were no position-only matches that would necessitate a delay in responding until identity processing was completed. The consequence is an enhancement of the effect of positional consistency.

The mean RT for Identity matches with position inconsistent comparisons was 1234 msec in Experiment 4 and 1504 msec in Experiment 5. While variability between experiments may again play a minor role, the nature of the inconsistent comparison displays is undoubtedly the more potent factor. In Experiment 5 positional inconsistency between sample and comparison displays was maximized by reducing the number of common positions between members of a pair to either zero or one. In Experiment 4 each sample-comparison pair had three positions in common, and these common positions were occupied by the same letters in the two displays. The results of the two experiments indicate that the time required to make an identity match increases as a function of the amount of inconsistency on the irrelevant position dimension.

To return to the problem of neutral comparison displays: The neutral matches of Experiments 1 and 2 were slower than were the minimally inconsistent matches of Experiment 4. The same observation can be made when Experiments 4 and 5 are compared: the neutral matches of Experiment 5 were slower (1400 msec) than the minimally inconsistent matches of Experiment 4 (1234 msec), whereas the maximally inconsistent

matches of Experiment 5 were slower still (1504 msec). The minimally inconsistent matches of Experiment 4 were characterized by positional change for just one letter, whereas both the neutral matches and the maximally inconsistent matches of Experiment 5 were characterized by positional change for all four letters. The advantage of about 100 msec for neutral comparison displays over maximally inconsistent comparisons reflects the contribution of predictability. Obviously the beneficial effect of predictability does not offset the detrimental effect of maximal positional change. It appears, then, that RT for non-consistent identity matches falls along a continuum, with placement on the continuum a joint function of the amount of positional change and predictability. An alternative means of expressing this point is to say that the neutral comparison displays are only nominally so. In practice they function as position inconsistent comparison displays.

The fact that RT to the predictable neutral comparisons is so slow refutes an interpretation of the detrimental effect of inconsistency in terms of incremented search time to locate the items to be compared. Presenting letters in a constant and predictable location should minimize or eliminate any increment in search time thus bringing RT for neutral matches down to the level for consistent matches. That this reduction in RT did not eventuate implicates a more fundamental effect of positional change upon identity processing.

EXPERIMENT 6

Experiment 6 focuses on Position task performance as a function of the status of the identity dimension. According to Garner (1976, 1983) the primary dimension of an asymmetrically separable pair of dimensions should show some facilitation when the dimensions are correlated, and no interference when the dimensions are orthogonal. This was the pattern reported by Wood (1974) for the auditory dimensions of pitch and consonant.

Most studies of position information processing have either omitted or held constant the identity information. A hint of facilitation was shown in Experiment 4, where Position matches were 26 msec faster with consistent than with inconsistent comparisons. This difference, however, was not significant, and the separate contributions of facilitation and interference were impossible to ascertain. Palef and Olson (1975) and Palef (1978) varied the irrelevant identity information in a position judgment task, and found neither facilitation nor interference. So although the prediction made by the asymmetric separability hypothesis is straightforward, its confirmation is as yet uncertain.

Experiment 6 requires selective attention to the position dimension. Sample displays are followed by comparison displays in which the irrelevant identity information is consistent, neutral, or inconsistent. The asymmetric separability hypothesis predicts that the consistent condition will show facilitation relative to the neutral condition, but that the inconsistent condition will not produce interference.

To provide a strict test of the asymmetric separability hypothesis, the irrelevant identity information is either maximally consistent or maximally inconsistent. This is achieved by using items from two stimulus classes, letters and forms. Consistent comparison displays

contain the same four items as are present in the PI Sample displays, whereas the inconsistent comparison displays contain four items from the alternative stimulus class. The consistent and inconsistent items can, of course, appear in the same (matching) or different (mismatching) positions.

To avoid confounding stimulus class and irrelevant dimension consistency two types of PI Sample displays are used, letter displays and form displays. The factor of sample display type is not expected to affect the speed of position matching, since the results of Experiment 1 showed no difference in Position RT as a function of sample display type.

Experiment 6 also attempts to alter the overall level of Position task performance by increasing the disparity between matches and mismatches. Instead of changing the position of one item (as in Experiments 1 - 4) the positions of several items are changed. Across the set of PI Sample displays, mismatches differ by an average of 2.33 positions. The greater contrast between matches and mismatches is expected to result in a considerable speeding of Position RT.

Although Experiment 6 is conceptually parallel to Experiment 5, there are some minor procedural differences. Since all displays appear within a matrix outline, there is no technical impediment to including neutral displays with the consistent and inconsistent displays; accordingly, all three types of comparison display appear equally often in a block of trials. This, coupled with the manipulation of sample display type, reduces the number of RTs for any one combination of sample display type and irrelevant dimension status obtained from a block of trials, and therefore two identical sessions are conducted for each subject.

The sample displays used in Experiment 6 are in fact those designed for use in Experiment 1 with a 3x3 matrix outline. In order to maintain correspondence with Experiments 4 and 5, they are projected within a 5x5 matrix outline. This has the effect of framing the display with a surround of empty cells. This small change in display characteristics was considered unlikely to alter position task performance, since neither matrix outline presence nor matrix size reliably affected position matching in Experiments 1, 2, and 3.

Method

Stimulus Materials. Sixty PI Sample displays were used. Half the number were the PI Sample displays containing four letters and designed for the 3x3 matrix size, and the remainder were the PI Sample displays containing four forms, also designed for the 3x3 matrix size. Here they were presented within a 5x5 matrix outline, such that the outermost "ring" of cells was not occupied by items.

One-third of the sample displays (ten of each type) were paired with comparison displays containing four letters. Another one-third of the sample displays (ten of each type) were paired with comparison displays containing four forms. The remaining sample displays were paired with comparison displays containing four dots. Thus, for both sample display types, one-third were consistent with respect to the (irrelevant) identity information, one-third were inconsistent, and one-third were neutral.

For all three conditions (consistent, neutral, inconsistent) of the irrelevant dimension, half the number of the sample-comparison pairs were matches and half were mismatches. Mismatching comparison displays

differed from their respective sample displays by an average of 2.33 positions.² In the consistent condition the same letters or forms appeared in sample and comparison displays for both (position) matches and mismatches.

The sequencing of the 60 sample-comparison pairs was subject to the constraint that within each block of 12 trials each of the 12 trial types -- formed by crossing sample display type, status of the irrelevant dimension, and match/mismatch -- occurred exactly once.

Procedure. Subjects participated in two experimental sessions conducted in consecutive weeks. Each session consisted of two repetitions of the 60 display pairs with the first 24 trials of a session regarded as practice trials. In all other respects the procedure was identical to that used in Experiment 4.

Subjects. Eight psychology student volunteers, equally divided between the two sexes, served as subjects. Each was paid \$5 for their participation. All subjects met the 90% accuracy criterion.

Results

Figure 10 shows mean position RT as a function of sample display type and irrelevant dimension status. Mean correct RTs were entered into a two-way ANOVA with repeated measures on both factors.

Irrelevant dimension status had a significant effect on the speed of Position matching [$F(2, 14) = 11.60, p < .001$], with consistent matches being the most rapid and inconsistent matches the least rapid. There was

² The average difference of 2.33 positions occurs because the 60 sample-comparison pairs were generated from 15 discrete pairings of patterns. Of these, two had three positions in common, seven had two positions in common, five had one position in common, and one had no common positions.

EXPERIMENT 6:
POSITION MATCHING

a trend for letter samples to be matched more rapidly than form samples, but the effect was not significant [$F(1,7) = 4.69, p < .10$]. The interaction of the two factors was not significant [$F(2,14) = 1.26$].

Since there was no interaction between sample display type and irrelevant dimension status, the assessment of facilitation and interference effects was collapsed across the sample display type factor. The overall mean RT of 498 msec for consistent matches was significantly faster than the overall mean RT of 540 msec for neutral matches [$t(7) = 3.84, p < .01$]. The overall mean RT of 559 msec for inconsistent matches was marginally slower than that for neutral matches [$t(7) = 2.68, p < .05$].

There were 21 errors across 1536 experimental trials yielding an accuracy level of 98.6%. All but one of the errors were false alarms; of the 20 false alarms, seven occurred to consistent mismatches, six to inconsistent mismatches, and seven to neutral mismatches.

Discussion

The results of Experiment 6 generally supported the hypothesis of asymmetric separability, which predicts facilitation but not interference when the primary position dimension is relevant and the secondary identity dimension is irrelevant. There was a significant facilitation effect of 42 msec. There was also a marginally significant interference effect of 19 msec, contrary to expectations. I shall discuss this latter finding before returning to the issue of facilitation.

Although the 19 msec interference effect was significant at the .05 level, a number of points suggest that this finding is actually quite weak. First, application of a quite lenient data correction eliminated

the effect. When RTs which exceeded their respective means by three standard deviations or more were removed (there were eight of these, from a total of 768 observations) the interference effect was reduced to 10 msec and this 10 msec decrement was not significant [$t(7) = 1.06$]. (The same 3-sd correction reduced the facilitation effect from 42 to 38 msec, which was still significant at the .01 level.) Second, examination of the data separately for the two sessions indicated that facilitation effects were present in both sessions [$t(7) = 2.67$, $p < .05$ and $t(7) = 5.00$, $p < .01$], but that interference effects were present in neither session [$t(7) = 1.60$ and $t(7) = 1.33$, both ns].

Perhaps most importantly the false alarm rate to consistent mismatches was not inflated. The false alarm rates to all three types of mismatches were low (around 2.5%) and virtually identical. The apparent presence of an interference effect implies processing of identity information. If this were occurring, an increased false alarm rate to consistent mismatches would be expected. The absence of such an increase argues against the occurrence of identity processing and favors the conclusion that position information is selectively attended.

It might be assumed that the ability to selectively attend to position information would preclude the occurrence of a facilitation effect. Certainly the facilitation effect of 42 msec found in Experiment 6 does not approach the magnitude of the facilitation effect for Identity matches with consistent position information obtained in Experiment 5, which was 463 msec. There, facilitation effects were attributed to the biasing effect of the early detection of position matches, that occurs as a consequence of the automaticity and rapidity of position information processing. Here, the absolute amount of facilitation (42 msec) is insufficient to be attributed to any biasing

effect produced by identity information processing -- especially since Position matches were made far more rapidly (overall mean of 526 msec) than were Identity matches.

Garner (1974) accounts for facilitation when dimensions are correlated and the primary dimension is relevant in terms of an increase in interstimulus differences. Correlating the values on the two dimensions reduces the number of potential stimuli, so that those that do occur are more distinctive. However, such an account is pertinent only when correlated pairings occur in a block of trials, as is done in a speeded classification (card-sort) procedure. In a successive matching procedure where consistent, neutral, and inconsistent pairings are interspersed -- and there are many possible pairings -- the facilitation that occurs may be more akin to the "fast-same phenomenon," as noted in the discussion of Experiment 5. A favored explanation for this phenomenon is that pairs of displays that are exactly alike, as were the consistent matches in this experiment, permit a rapid, holistic response to be made. A re-pairing extension of the present procedure, in which the same items occur and the same positions are occupied, but with a redistribution of items to positions, could be used to test this interpretation. Since the time scale involved in position matching precludes a substantive effect of identity processing, a decrement for re-paired matching comparisons would indicate a disruption of the holistic response to identical displays.

The greater amount of positional disparity between samples and mismatching comparison displays was expected to produce a general improvement in RT in Experiment 6. This prediction was confirmed. The overall mean RT in Experiment 6 was 526 msec, which is markedly faster

than the overall mean RTs found in earlier experiments: 895 msec in Experiment 1, 857 msec in Experiment 2, 804 msec in Experiment 3, and 911 msec in Experiment 4. This improvement, of 300 to 400 msec, is far too large to be attributed to the vagaries of subject selection or to the presentation of 3x3 displays in 5x5 matrix outlines. Nor is this speed achieved at the expense of accuracy: Error rates are comparable across experiments.

In Experiments 1 through 4 mismatching comparisons differed by one cell, whereas in Experiment 6 they differed by an average of 2.33 cells. As the number of mismatching cells increases, matches and mismatches become more discriminable, and so overall RT for matches is facilitated. An improvement in performance when matches and mismatches are made more discriminable is a not uncommon finding. Checkosky and Whitlock (1973) reported a speeding of RT, and Paivio and Bleasdale (1974) reported an improvement in accuracy as the difference between mismatching patterns increased. Similarly, Kroll and Hershenson (1982) and Bagnara, Boles, Simion, and Umiltà (1983) found improved letter matching performance as the disparity of different comparisons was increased. Although unremarkable in itself, the general facilitation of RT found in Experiment 6 does, by comparison with the levels of performance found in Experiments 1 to 4, indicate a sensitivity to manipulation of position information -- a demonstration noticeably absent in Experiments 1, 2, and 3.

A last point of interest is that the absolute level of performance found here is quite similar to that reported by Sebrechts and Garner (1981) in their study of the successive matching of patterns where no identity information whatsoever appeared. Sebrechts and Garner used

more complex patterns but fewer of them; temporal parameters were similar. In one experiment mean RT for matches was 422 msec and in the other experiment it was 540 msec. That the present value of 526 msec should agree with their values offers further support to the conclusion that position information is selectively attended in the present task.

To sum up: The successive matching of position information shows some facilitation but minimal interference with consistent and inconsistent identity information, respectively, when compared with a neutral control condition containing no identity information. This is predicted by the hypothesis that position and identity function as asymmetrically separable dimensions, with position integral to identity. Thus, selective attention to position is possible, whereas selective attention to identity is not. However, the facilitation effect is small in absolute magnitude and the precise reason for its occurrence is still a matter of uncertainty, requiring further study.

SUMMARY OF EXPERIMENTS 4, 5, AND 6

Experiments 4, 5, and 6 have provided support for the conceptualization of position and identity as asymmetrically separable dimensions. In these three experiments both relevant and irrelevant information was presented in the comparison display and the status of the information on the irrelevant dimension was manipulated. The reason for doing this was to test the fundamental prediction of the asymmetric separability hypothesis: Selective attention to position information is possible but selective attention to identity information is not. The occurrence of selective attention is shown by a performance insensitivity to the status of the irrelevant dimension such that facilitation and interference effects with consistent and inconsistent comparison displays are (generally) absent.

The results of Experiment 4 indicated that position information could be selectively attended, since RTs for Position matches with inconsistent identity information were not significantly longer than those for Position matches with consistent identity information. Identity information however could not be selectively attended: RTs for Identity matches with consistent position information were significantly faster (175 msec) than were those for Identity matches with inconsistent position information.

Identity matching was examined in greater detail in Experiment 5, using comparison displays that were consistent, neutral, or inconsistent with respect to position. There was a substantial and significant facilitation effect with consistent position information, and a smaller, but still significant, interference effect with inconsistent position information. The difficulty of establishing a true baseline against which facilitation and interference effects could be assessed was noted.

Position matching was examined in greater detail in Experiment 6. There was a small (42 msec) facilitation effect when identity information was consistent, although the origin of this effect is still subject to debate. There was a small (19 msec) interference effect when identity information was inconsistent, but several aspects of the results suggested that this was more apparent than real. This pattern of results approximates that predicted for the primary dimension of an asymmetrically separable pair.

As a whole the results from these three experiments demonstrate a clear asymmetry of selective attention: Identity information can be successfully ignored when position information is relevant to task performance, but not vice versa. This is the defining feature of an asymmetrically separable relationship between two dimensions.

EXPERIMENTS 7 AND 8: SHARED ATTENTION BETWEEN DIMENSIONS

In Experiments 1 to 6 selective attention to either the position or the identity dimension was required. In Experiments 7 and 8 attention is *shared* between the dimensions of position and identity so that both position information and identity information are explicitly relevant to task performance.

The reasons for this shift in emphasis are: On the practical side, many real world activities depend upon combining position and identity information. To take just one example, reading requires an integration of position and identity information, particularly at the word but also at the sentence level. The set of letters {a, e, m, t} can produce the words mate, meat, tame, or team, depending on the positions of the individual letters. Similarly, the meaning of "the woman ate the fish" is different from "the fish ate the woman."

On the theoretical side, two general conceptualizations of the nature of dimensional relationships can be distinguished. I will call these "perceptual" and "attentional". The perceptual conceptualization interprets dimensional relationships as resulting from stimulus structure and/or invariant cognitive processing so that a pair of dimensions is characterised by a stable and unchanging relationship. This view is essentially a structural one since the structure of stimuli and cognitive mechanisms determines performance. The attentional conceptualization sees dimensional relationships as a consequence of the attentional strategies invoked by the processor. There may be structural constraints but there is also room for cognitive flexibility. This view

is essentially a functional one since performance is a function of attentional strategy.

These two broad viewpoints can lead to differing predictions regarding the effects of sharing attention between dimensions. Determining the patterns of performance under conditions of shared attention might, therefore, help to distinguish between the two alternatives.

It is to be noted that these last two experiments are of a more exploratory or empirical nature than were the earlier experiments. They are designed to answer the question: What happens when attention is shared between the dimensions of position and identity, dimensions that exhibit a relationship of asymmetric separability under conditions of selective attention? Although the Garnerian framework of dimensional relationships does not address this issue, there are a few studies conducted in related areas that allow some preliminary hypotheses to be developed.

Logan and Zbrodoff (1979) challenged the traditional interpretation of performance in a Stroop task -- invariant selective attention to the reported dimension -- by demonstrating that the advantage for consistent stimuli, and the disadvantage for conflicting stimuli, varied as a function of the proportion of conflicting trials. Stimulus displays consisted of the words ABOVE or BELOW appearing above or below fixation. Subjects responded either to the spatial position of the word or to the meaning of the word, and the proportion of conflicting trials was varied (in three experiments) from 10% to 90%. The frequency manipulation had no effect on performance in the spatial position task which was performed more rapidly than the word task, but it had a marked effect in

the word meaning task. When the proportion of conflicting trials was low the typical Stroop effect occurred: RT for consistent displays was faster than RT for conflicting displays. However when the proportion of conflicting trials was high the usual Stroop effect was reversed, and RT for conflicting displays was faster than RT for consistent displays. The authors concluded that such a pattern of results reflected the operation of a strategy of divided attention between dimensions, with utilization of the faster position dimension in proportion to its validity as a cue for the slower word meaning dimension.

But Logan and Zbrodoff (1979) also found evidence of an automatic, strategy-invariant component, in that consistent stimuli produced greater facilitation and interference effects than did conflicting stimuli. This observation provided the departure point for Logan's (1980) investigation of automatic and attentional factors in judgments of relative position. The irrelevant dimensions of absolute position and word meaning could be consistent or conflicting, and the proportion of conflicting trials was either 20% or 80%. Both irrelevant dimensions produced the usual Stroop advantage for consistent stimuli when these were frequent. When conflicting stimuli were frequent, the position dimension resulted in a reversal and the word meaning dimension resulted in an attenuation of the Stroop effect. Logan concluded that attentional strategies could dominate automatic effects, without affecting their functioning.

These two studies are important because they showed that subjects can divide their attention between dimensions even when they are not required by the task structure to do so. They also demonstrated the impact of flexible strategies, and refuted the notion of invariant processing.

Two other relevant studies need to be mentioned here. In studies by Hoffman (1980) and Miller (1981), shared attention between dimensions was explicitly required, and the two dimensions -- global letter identity and local letter identity -- displayed a relationship of asymmetric separability. Navon (1977) had previously shown that variation in local letter identity had no impact on RT to recognize a target letter at the global level, whereas variation in global letter identity did affect the speed with which a target letter at the local level was recognized. In the Hoffman and Miller studies subjects responded positively if a target letter appeared at either the local or the global level. Target letters could appear at either level alone or at both levels simultaneously. Both studies also compared shared attention with selective attention to the global level and to the local level. In Hoffman's study, target letters were presented prior to each trial, whereas in Miller's study, one or two target letters were used for an entire block of trials.

First consider the shared attention condition per se. In both studies mean RT was faster when a target was present at both levels than when it was present at a single level. When a target was present at just one level, Hoffman (1980) found no difference between global and local levels, whereas Miller (1981) found a small advantage (50-80 msec) for targets at the global level. Increasing the memory set from one to two letters lengthened RT, but it did not alter the pattern of results.

Now consider the selective versus shared attention conditions. When a target was present at just one level, RTs were slower in the shared than in the relevant selective attention condition. When a target was present at both levels, and memory set size was one, Hoffman (1980) found RT to be equivalent for the selective local, selective global, and

shared attention conditions, whereas Miller (1981) found the selective global condition to be slightly faster than the shared attention condition, which in turn was slightly faster than the selective local condition.³

Both authors concluded that a perceptual interpretation -- that global processing invariably precedes local processing -- could not account for the observed pattern of RTs. Instead, attention and decision processes were held responsible. The authors did not agree on the characteristics of these latter processes, but that is of no immediate relevance. What is important is the implication that attention can be shared between dimensions, but that there is a cost in doing so. These two experiments also provide a model for the pattern of results to be expected in Experiments 7 and 8 under an attentional interpretation of dimensional relationships.

The central feature of Experiments 7 and 8 is a within-subjects comparison of performance under conditions of shared attention and of selective attention. Briefly, a perceptual interpretation of dimensional relationships predicts that performance in shared attention conditions would represent an amalgamation of performance in the two selective attention conditions. The invariant processing underlying the observed dimensional relationship would produce a pattern of performance in shared attention conditions which precisely mimics selective attention performance. An attentional interpretation would predict a reallocation of attention, a shift in strategy, so that shared attention performance conforms to a different pattern than does selective attention

³ The studies also differed in their results for the selective attention conditions. Miller found asymmetrical interference, but Hoffman found interference to be symmetrical. Speculatively, this may relate to the different means of establishing target letters.

performance.

The design of these final two experiments has the additional benefit of permitting a within-subjects replication of the asymmetrical interference effect found in Experiment 4 with a between-subjects design. As this finding is fundamental to the asymmetric separability hypothesis, its replication is desirable. Since the relationship of asymmetric separability between position and identity (under conditions of selective attention) is postulated to be a general phenomenon, asymmetrical interference should occur with a within-subjects design, as well as with a between-subjects design.

An exploration of the effects of prior experimental experience with shared or selective attention tasks upon subsequent performance of selective or shared attention tasks is incorporated into Experiments 7 and 8. If dimensional relationships reflect strategy selection and attentional allocation, then prior experimental experience might well influence response patterns. If dimensional relationships reflect invariant processing, then prior experience should not alter response patterns.

The two experiments differ in the particular manipulations employed. Experiment 7 includes two shared attention conditions: conjunctive and disjunctive. In the conjunctive condition, positive responding is required when both dimensions match. In the disjunctive condition, positive responding is required when either dimension matches. The two shared attention conditions precede or follow the two selective attention conditions. Experiment 8 varies type of selective task experience prior to the disjunctive shared attention condition, assesses the effect of practice in the shared attention condition by doubling the number of trials, and examines selective task performance before and after the shared attention task.

EXPERIMENT 7

Experiment 7 looks at performance in four successive matching tasks involving the position and identity dimensions. The four tasks are (1) selective attention to position information, (2) selective attention to identity information, (3) conjunctive shared attention to position and identity information, and (4) disjunctive shared attention to position and identity information. For the sake of convenience the tasks will be designated the Position task, the Identity task, the AND task, and the OR task. The designation "AND" reflects the fact that both position and identity must match for a positive response in the conjunctive task; the designation "OR" reflects the fact that either position or identity must match for a positive response in the disjunctive task.

The perceptual and the attentional interpretations of dimensional relationships lead to different predictions about the effect of sharing attention between dimensions. The perceptual viewpoint contends that the relationship of asymmetric separability observed in selective attention conditions stems from invariant processing of the two dimensions. When attention is shared between dimensions, the same pattern of effects should appear. The attentional viewpoint says that the relationship of asymmetric separability found in selective attention conditions results from strategic deployment of attentional resources, with perhaps some constraint from automatic or invariant processes (Logan & Zbrodoff, 1979; Logan, 1980). Sharing attention between dimensions is likely to cause a change in strategy and so the pattern of performance under shared attention conditions will probably differ. An example of the sort of changes to be expected is provided in the studies by Hoffman (1980) and Miller (1981), who also used asymmetrically separable dimensions.

To translate these general predictions into specific predictions for the present experiment, consider the case where both dimensions match: This is defined as a positive response (PI match) in all four tasks. Under a perceptual interpretation, mean RT in the OR task should approximately equal mean RT in the Position task, and mean RT in the AND task should approximately equal mean RT in the Identity task. This is because performance in the OR task, where either dimension may match, will be governed by the faster of the two relevant dimensions, namely position. Performance in the AND task, where both dimensions must match, will be governed by the slower of the two dimensions, namely identity.

On the other hand, an attentional interpretation predicts changes in performance levels as a function of the way in which attention is divided between the dimensions. Generally, a strategy of sharing attention between dimensions should result in an RT cost in both tasks, with the obtained level in the OR task representing the actual amount of attentional reallocation.

In the case where a single dimension matches (P match or I match) the perceptual view predicts that performance in the OR task and the relevant selective task will be equivalent. The attentional view, extrapolating from the Hoffman (1980) and Miller (1981) results, predicts that both types of single dimension matches will be slower in the OR task than in the relevant selective tasks.

(It is possible, under a perceptual interpretation, to argue that increased task complexity will elevate response times in the OR task for all three types of matches. But they should show the same pattern in shared and selective tasks: The functions should be parallel, with PI and P matches at about the same speed and significantly faster than I matches. Deviations from parallelism would implicate attentional strategies.)

With respect to performance in the disjunctive shared attention (OR) task itself, the two viewpoints can be distinguished in terms of the predicted patterns of performance and the effects of prior experience. The perceptual viewpoint predicts, first, that PI matches and P matches should both be faster than I matches, and equally so; this follows from a combination of predictions about the effects of sharing attention upon the different kinds of matches, given above. Second, that the pattern of performance generated by subjects with prior selective task experience will be the same as that generated by subjects without such experience. Although prior experience might produce a general facilitation due to practice, it should do so equally for all three match types.

The attentional viewpoint, since it denies processing invariance, again makes precise prediction difficult, but it does suggest that the pattern of performance may vary as a function of prior experimental experience and that the relative speed of PI, P, and I matches may fluctuate. It predicts that PI matches will be faster than either P or I matches since subjects are sharing attention between both (matching) dimensions (see Miller, 1981). Extrapolation from Figures 2 and 5 of Miller (1981) indicates that the global (primary) dimension was more disadvantaged than the local (secondary) dimension in the OR task, so it might be anticipated that Position matches would be slowed more than Identity matches when attention is disjunctively shared between dimensions.

Finally, both viewpoints predict that the asymmetric interference effect found in Experiment 4 will be replicated here in the selective attention conditions: Irrelevant dimension consistency will differentially facilitate performance in the two tasks, with a major

advantage in the Identity task and a minor advantage in the Position task. However the attentional viewpoint admits the possibility of an interaction with prior experience in shared attention tasks, whereas the perceptual viewpoint does not.

Method

Stimulus Materials. The 120 pairs of displays used in Experiment 4 were used here and in the same sequence. Positive responses were defined differently in the four tasks so that 50% of the display pairs were matches in the Position task and the Identity task, 75% were matches in the OR task, and 25% were matches in the AND task. While this inequality in total number of matches had the possible disadvantage of introducing a general response bias (positive in the OR task, negative in the AND task) it did have the advantage of facilitating comparisons of the different match types across tasks. Because subjects were not informed of the inequality, and performed each task for a single session, I felt that the advantage of equating the number of trials for each match type across tasks outweighed the disadvantage.

Additional written instructions were prepared for the two shared attention tasks. The AND task instructions stressed attention to the two dimensions conjunctively, whereas the OR task instructions stressed attention to the two dimensions disjunctively.

Procedure. Subjects participated in four experimental sessions conducted across four consecutive weeks. Each session consisted of 120 trials divided into three groups of 40 trials. The first group of trials were treated as practice.

Each session was devoted to a different task. For half the number of subjects, the two shared attention tasks preceded the two selective attention tasks; for the remainder, the order was reversed. Within this division, task order was counterbalanced, thereby creating eight distinct orders of sessions. Subjects were randomly assigned to these session orders.

Subjects. Four female and four male psychology student volunteers served as subjects. Each was paid \$10 for participation. (One subject produced a 15% error rate in the Identity task. However, 75% of those errors were false alarms so that missing observations were not a problem. For reasons of economy it was decided to retain this subject, whose data were not elsewhere deviant.)

Results

The results were subject to a variety of analyses relevant to the foci of interest. The following sections will consider performance in shared and selective attention tasks when both dimensions matched, performance in shared and selective attention tasks when a single dimension matched, performance in the OR task per se, and performance in the two selective attention tasks.

Match on Both Dimensions.

Figure 11 shows mean RT for PI matches across the four tasks. A two-way mixed ANOVA was run on these data, with task order as the between-subjects factor and task as the within-subjects factor. The main effect of task was highly significant [$F(3,18) = 11.51, p < .001$]. The effect of task order was not significant [$F(1,6) = 1.51$], nor was the interaction of task with task order ($F < 1$). Collapsed across task

order, the mean RTs for PI matches in the Position, OR, Identity, and AND tasks were 687, 955, 1004, and 1093 msec, respectively. Individual comparisons indicated that the mean difference of 268 msec between the Position and OR tasks was significant [$F(1,7) = 7.903$, $p < .05$], whereas the mean difference of 49 msec between the OR and Identity tasks was not [$F(1,7) = 1.134$]. The mean difference of 89 msec between the Identity and AND tasks was not significant [$F(1,7) = 4.633$, $p < .10$].

Match on a Single Dimension.

Figure 12 plots mean RT for P matches and I matches as a function of task type: shared or selective attention. These data were entered into a three-way mixed ANOVA, with overall task order as the between-subjects factor, and task type and match type as the within-subjects factors. Position matches were faster than Identity matches [$F(1,6) = 21.96$, $p < .01$], and performance in selective attention conditions was superior to that in the shared attention condition [$F(1,6) = 12.35$, $p < .025$]. Match type and task type interacted reliably [$F(1,6) = 37.82$, $p < .001$]. The form of this interaction is apparent in Figure 12: Position matches were more seriously affected by the requirement to share attention between dimensions than were Identity matches. Task order did not affect performance. Neither the main effect of task order nor its interaction with the other factors were significant.

Descriptively, Position matches showed a 396 msec disadvantage in the shared attention task and Identity matches showed a 68 msec disadvantage. An analysis of the simple main effects of the interaction indicated that the former difference was significant [$F(1,7) = 19.65$, $p < .01$], while the latter difference was not ($F < 1$).

EXPERIMENT 7:
MEAN RTs FOR PI MATCHES

EXPERIMENT 7:
MEAN RTs FOR P AND I MATCHES

OR Task Performance.

Figure 13 shows performance as a function of match type in the OR task. A two-way mixed ANOVA was conducted, with task order as the between-subjects factor and match type as the within-subjects factor. Match type exerted a significant effect on response speed [$F(2,12) = 23.12$, $p < .001$]. Task order per se did not affect response speed [$F(1,6) = 1.13$], but it did interact reliably with match type [$F(2,12) = 7.90$, $p < .01$]. Mean RTs for PI, P, and I matches were 861, 954, and 1353 msec for subjects who received the selective-shared task order, and 1048, 1300, and 1280 msec for subjects who received the shared-selective task order. Individual comparisons between the means showed that the two groups gave significantly different RTs for Position matches [$F(1,6) = 7.53$, $p < .05$], but not for PI matches [$F(1,6) = 1.47$] or Identity matches ($F < 1$).

Selective Attention Task Performance.

In Figure 14 performance in the two selective attention tasks is shown as a function of irrelevant dimension consistency. These data were subject to a three-way mixed ANOVA: Task and consistency were the within-subjects factors, and task order was the between-subjects factor. The Position task was performed more rapidly than the Identity task [$F(1,6) = 21.05$, $p < .01$], consistent matches were made more rapidly than inconsistent matches [$F(1,6) = 94.79$, $p < .001$], and the interaction of task and consistency was significant [$F(1,6) = 26.63$, $p < .01$], reflecting the greater advantage for consistent matches in the Identity task.

Task order per se had no effect ($F < 1$), but its interaction with consistency was reliable [$F(1,6) = 30.60$, $p < .01$], and the triple interaction of task order, task, and consistency was also significant

EXPERIMENT 7:
OR TASK PERFORMANCE

EXPERIMENT 7: SELECTIVE TASK PERFORMANCE

[$F(1,6) = 22.51$, $p < .01$]. Descriptively, subjects who performed tasks in the shared-selective order showed a 54 msec advantage for consistent matches in the Position task and a 70 msec advantage for consistent matches in the Identity task. Subjects who performed tasks in the selective-shared order showed a 33 msec advantage for consistent matches in the Position task and a 418 msec advantage for consistent matches in the Identity task. In other words, the asymmetric effect of irrelevant dimension consistency was present only when the selective tasks preceded the shared tasks.

Discussion

The results of Experiment 7 are relatively complex, and will be discussed from several angles, corresponding to the main points of interest: The effect of sharing attention between dimensions, the patterns of performance in the OR task, and the patterns of performance in the selective attention tasks. The general conclusion to be drawn, for reasons which will be made clear as the discussion progresses, is that the attentional interpretation of dimensional relationships provides a more satisfactory account of the various results than does the perceptual interpretation.

Sharing Attention Between Dimensions.

The effect of sharing attention between dimensions can be ascertained from two comparisons, one involving the PI matches common to all four tasks, and the other involving P matches and I matches in the OR, Position, and Identity tasks.

Consider first the case when both dimensions match, which is defined as a positive response (PI match) in all four tasks. The perceptual

viewpoint predicts equivalent performance between the Position and OR tasks and between the Identity and AND tasks. The attentional viewpoint predicts a cost for sharing attention so that the OR task is inferior to the Position task and the AND task is inferior to the Identity task.

Performance in the OR task was significantly slower (268 msec) than in the Position task, a finding that is contrary to the perceptual viewpoint. In fact, OR task performance was (statistically) indistinguishable from Identity task performance. This suggests a substantial reallocation of attention towards the identity dimension. A perceptual interpretation could possibly be "salvaged" by assuming a general elevation in RT in the OR task, applying equally to all match types. A decision between these competing explanations is facilitated by consideration of unidimensional matches in shared and selective tasks, which will be addressed subsequently.

On the other hand, performance in the AND task tended to be slower (89 msec) than performance in the Identity task, but the difference was not significant. So neither viewpoint can be unambiguously accepted or rejected on the basis of the AND task results.

The effect of sharing attention between dimensions is much clearer when unidimensional matches are considered. Position matches were significantly slower (396 msec) in the OR task than in the Position task, but Identity matches were not significantly slower (68 msec) in the OR task than in the Identity task. If processing were invariant, as the perceptual view maintains, then neither type of match should be affected by sharing attention between dimensions. As noted in the discussion of PI matches, the perceptual view could be stretched to accommodate a uniform elevation in RT across all three match types. This

criterion is clearly violated by the data: PI matches were slowed by 268 msec, Position matches by 396 msec, and Identity matches by 68 msec. What is evident is that those matches with a positional component (PI and Position) were seriously retarded when attention is shared, while Identity matches were unaffected. This is consistent with the contention that attention is reallocated towards the identity dimension: Response speed is maintained for Identity matches at the cost of slower PI and (especially) Position matches.

The results concerning the effect of sharing attention upon the three kinds of matches are similar to those reported by Hoffman (1980) and Miller (1981). In those studies, when a target was present at just one level, RTs were slower in the shared attention condition than in the relevant selective attention condition. This corresponds to the finding that both Position matches and Identity matches were slower in the OR task than in the selective Position and selective Identity tasks. The decrement in speed was significant only for Position matches, which is consistent with Miller's finding that global matches were more disadvantaged than local matches. When a target was present at both levels, which corresponds to the PI matches in Experiment 7, Hoffman found no difference between tasks, while Miller found the selective global task to be faster and the selective local task to be slower than the OR task. The results of Experiment 7 fall between these two studies: The speed of PI matches did vary with tasks but only the Position versus OR task comparison was reliable.

The attentional interpretation of dimensional relationships is tentatively supported by the results discussed above. The effect of sharing attention between dimensions does not conform to the pattern predicted by the perceptual account. More definitive support for the

attentional interpretation is provided by a consideration of performance in the separate tasks, as will be seen in the following sections.

OR Task Performance.

In the disjunctive shared attention (OR) task there were three types of matches: both dimensions (PI), position only (P), and identity only (I). The RT patterns in the OR task varied significantly as a function of task order. Subjects who completed the shared attention tasks in the initial two sessions gave mean RTs of 1048, 1300, and 1280 msec for PI, P, and I matches, respectively. Subjects who completed the shared attention tasks in the final two sessions gave mean RTs of 861, 954, and 1353 msec. Between-groups comparisons indicated that the interaction of task order and match type was due to the large difference, 346 msec, in the speed of P matches; the two groups did not differ reliably in the speed of either PI or I matches. The perceptual viewpoint does not allow differences as a function of task order, since processing is held to be invariant. The attentional viewpoint permits (but does not demand) prior experimental experience to influence attentional strategy, and hence the pattern of results obtained. The OR task data can only be accommodated by the attentional point of view.

A consideration of the patterns of performance within each group further supports the contention that OR task performance involves a shift in attentional strategy and not a simple combination of position processing and identity processing. Neither group produced the pattern predicted by the perceptual view, of equally rapid PI and P matches and slow I matches. In the selective-shared group, P matches were 93 msec slower than PI matches, and I matches were 399 msec slower than P matches; both differences were significant [$F(1,3) = 21.33$ and $F(1,3) = 24.13$, both p 's $< .025$]. In the shared-selective group, P matches were

252 msec slower than PI matches, a difference that was significant [$F(1,3) = 12.32, p < .05$]; I matches were 20 msec faster than P matches, an insignificant difference. In other words, P matches were faster than I matches when subjects had prior selective task experience, and were equivalent to I matches when they did not. Although both patterns are indicative of an attentional reallocation, the degree to which attention was shifted towards identity information was influenced by prior selective task experience.

Both groups produced the fastest RTs for PI matches. This finding accords with the hypothesized reallocation of attention towards the identity dimension. As was shown in Experiments 4 and 5, when identity information is selectively attended PI matches are made more rapidly than I matches. This also occurred in Experiment 7. PI matches were 232 msec faster than I matches with the shared-selective task order [$F(1,3) = 11.50, p < .05$], and 492 msec faster with the selective-shared task order [$F(1,3) = 60.58, p < .01$]. That is, both groups of subjects in the OR task behaved as though it were a selective Identity task, with the level at which the "additional" position information was processed depending upon prior experimental experience. The observation that PI matches were fast and P matches were fairly slow in the OR task relates to the distinction between automatic and attentional components, as discussed by Logan (1980). Although the automatic processing of position information is sufficient to facilitate PI matches, because position information is not given attentional priority, P matches are slower.

It is reasonable to conjecture that prior experience with the selective Position task was crucial in producing the overall group difference, since it was the speed of P matches that was most affected. The design of Experiment 7 does not permit the individual contributions

of prior selective Position task and prior selective Identity task experience to be distinguished. This issue is pursued in Experiment 8.

Selective Task Performance.

The present experiment included a within-subjects replication of Experiment 4, with the selective attention tasks performed either before or after the shared attention tasks. Both viewpoints, perceptual and attentional, predict a replication of the asymmetric effect of irrelevant dimension consistency found in Experiment 4 when the selective tasks precede the shared tasks. The attentional view permits alteration of this pattern when the selective tasks follow the shared tasks whereas the perceptual view does not.

The results clearly support the attentional interpretation of dimensional relationships: The selective-shared group exhibited the asymmetric effect of irrelevant dimension consistency, whereas the shared-selective group did not. Figure 14 shows that the two groups produced virtually identical performances in the selective Position task; both showed a small advantage for consistent matches. In the selective-shared group, PI matches were 33 msec faster than P matches, and in the shared-selective group, PI matches were 54 msec faster than P matches. (Both values are comparable to the 26 msec advantage for PI matches over P matches found in Experiment 4, although overall RTs were about 200 msec faster in Experiment 7.) A separate two-way ANOVA on Position task performance found neither of the main effects nor their interaction to be reliable.

The two groups produced quite different performances in the selective Identity task. A separate two-way ANOVA on Identity task performance indicated that not only was the effect of irrelevant dimension consistency reliable [$F(1,6) = 71.01$, $p < .001$], but there was

also a significant interaction with task order [$F(1,6) = 36.04$, $p < .001$]. This interaction reflects the difference in magnitude of the advantage for consistent matches: 70 msec for the shared-selective group, and 418 msec for the selective-shared group. (The latter value is considerably larger than the 175 msec advantage found in Experiment 4, although not as large as the 567 msec advantage found in Experiment 5. The overall means for all three experiments were similar: 1146 msec in Experiment 4, 1220 msec in Experiment 5, and 1155 for the selective-shared group in Experiment 7.)

That is, prior experience with shared attention tasks resulted in a marked reduction in the effect of irrelevant dimension consistency in the selective Identity task. This reduction resulted from both a slowing of PI matches by 116 msec and a speeding of I matches by 232 msec, relative to the selective-shared group. Speculatively it can be hypothesized that both the slowing of PI matches and the speeding of I matches reflects the persistence of attentional reallocation to the identity dimension, resulting from prior experience with shared attention tasks. The combined effect of these two changes was the elimination of the asymmetrical effect of irrelevant dimension consistency for the shared-selective group. Although the attentional viewpoint permits prior experience to modify current performance patterns, the complete absence of asymmetry was not anticipated. To clarify this issue, a closer examination of the effect of prior OR task experience upon selective task performance is undertaken in Experiment 8.

In summary, the results observed in the various tasks of Experiment 7 produced patterns of results that deviated from the predictions made

by the perceptual interpretation of dimensional relationships, but that were consistent with the attentional interpretation of dimensional relationships. Although perhaps no single comparison leads to the refutation of the perceptual viewpoint, when considered together like a set of converging operations, the conclusion that dimensional relationships are influenced by attentional strategies seems inescapable.

EXPERIMENT 8

Experiment 8 extends the examination of OR task performance begun in Experiment 7. Prior experimental experience is varied between groups so that subjects begin the OR task with prior experience in the selective Position task (Group P), prior experience in the selective Identity task (Group I), or no prior experience (Group O). The purpose of this manipulation is to test the hypothesis that it is prior experience in selectively attending to position information that determines the relative speed of P matches in the OR task. If this is so, then the pattern of performance for Group P should differ, particularly with respect to P matches, from the patterns for Groups I and O.

The effect of practice in the OR task is also considered in Experiment 8. Two sessions are devoted to the OR task and these are conducted consecutively. A perceptual interpretation of dimensional relationships predicts that the relative speeds of PI, P, and I matches will remain stable with practice, although a general improvement is permissible. An attentional interpretation admits the possibility of changes in the pattern of performance, since attentional strategies may change with experience.

Selective task performance is assessed both before and after execution of the OR task. This is achieved by adding a final session in which Group P performs the selective Identity task and Group I performs the selective Position task. If sharing attention between dimensions alters subsequent selective task strategy, the elimination or reduction of the asymmetric effect of irrelevant dimension consistency should occur when the selective tasks follow the OR task as was found in Experiment 7.

It is anticipated that sharing attention between dimensions will again be detrimental to performance, particularly for PI and P matches. That is, the results of Experiment 7 should be replicated thereby strengthening the attentional account of dimensional relationships.

Method

Stimulus Materials. The 120 display pairs used in Experiments 4 and 7 were used in Experiment 8. Presentation sequence was not changed. Instructions appropriate to each task and group were prepared in written form. The OR task instructions for Group P stressed the continued relevance of Position matches and the additional relevance of Identity matches. The OR task instructions for Group I stressed the continued relevance of Identity matches and the additional relevance of Position matches. The OR task instructions for Group O gave approximately equal emphasis to the two dimensions.

Procedure. Depending on group assignment, subjects participated in either two or four experimental sessions. The sessions were conducted over consecutive weeks. Each session consisted of 120 trials divided into three groups of 40. The first group of trials were treated as practice.

Four subjects were assigned to each of the three groups. Subjects in Group P completed one session under Position task instructions, two sessions under OR task instructions, and one session under Identity task instructions, in that order. Subjects in Group I completed one session under Identity task instructions, two sessions under OR task instructions, and one session under Position task instructions, in that order. Group O subjects completed two sessions under OR task instructions.

Subjects. Thirteen student volunteers, eight females and five males, served as subjects. They were recruited primarily through a student job centre. One Group O subject (male) was eliminated because he had an excessive error rate (25%). Subjects in Groups P and I were each paid \$15 for their participation, and subjects in Group O were paid \$8.

Results

Presentation of the results of Experiment 8 follows the order used in presenting the results of Experiment 7.

Shared versus Selective Attention.

Mean RTs for PI, P, and I matches as a function of task are shown in Figure 15. The values for the OR task represent the data from the two groups that completed all three tasks. Individual comparisons were used to assess the effect of sharing attention for each match type. PI matches in the OR task were significantly slower than PI matches in the selective Position task [$F(1,7) = 17.54, p < .01$] and significantly faster than PI matches in the selective Identity task [$F(1,7) = 6.00, p < .05$]; the respective mean differences were 172 msec and 112 msec. P matches were 374 msec slower in the OR task than in the selective Position task, and this difference was significant [$F(1,7) = 66.84, p < .001$]. I matches were 72 msec slower in the OR task than in the selective Identity task, and this difference was not significant [$F(1,7) = 1.26$].

OR Task Performance.

Performance in the OR task as a function of match type and group assignment is shown separately for sessions 1 and 2 in Figure 16, and averaged across sessions in Figure 17.

EXPERIMENT 8:
PERFORMANCE IN SELECTIVE AND
SHARED ATTENTION TASKS

EXPERIMENT 8: OR TASK PERFORMANCE BY SESSIONS

EXPERIMENT 8:
OR TASK PERFORMANCE,
COMBINED ACROSS SESSIONS

A three-way mixed ANOVA, with group assignment as the between-subjects factor, and match type and session as the within-subjects factors, was performed on the mean RT data. The main effect of match type was significant [$F(2,18) = 36.75, p < .001$], with PI matches made most rapidly and I matches least rapidly. The main effect of session was also reliable [$F(1,9) = 10.84, p < .01$], with faster responses in the second session. The interaction between group and match type was not significant [$F(4,18) = 1.88, p < .25$]. The F values for all other effects and interactions were less than unity.

The mean RTs for PI, P, and I matches were 1033, 1262, and 1410 msec in the first session; 919, 1082, and 1297 msec in the second session; and 976, 1168, and 1353 msec in the combined data. Since neither session nor group assignment interacted with match type, individual comparisons between the three types of matches were performed using the combined data. The 192 msec difference between PI and P matches was significant [$F(1,11) = 50.57, p < .001$], the 185 msec difference between P and I matches was significant [$F(1,11) = 9.54, p < .025$], and of course the 377 msec difference between PI and I matches was also significant [$F(1,11) = 59.17, p < .001$].

Selective Task Performance.

Performance in the selective Position and selective Identity tasks as a function of irrelevant dimension consistency and group assignment is shown in Figure 18. The mean RTs were entered into a three-way mixed ANOVA, with group assignment as the between-subjects factor, and task and consistency as within-subjects factors. Position matches were faster than Identity matches [$F(1,6) = 31.00, p < .01$], and consistent matches were faster than inconsistent matches [$F(1,6) = 41.68, p < .001$]. The interaction of task and consistency was also significant [$F(1,6) =$

22.61, $p < .01$], reflecting the fact that the mean consistency effect was -21 msec in the Position task and 249 msec in the Identity task. The interaction of group and consistency approached significance [$F(1,6) = 5.23$, $p < .10$], reflecting the fact that the average advantage for consistent matches was 74 msec in Group P and 154 msec in Group I. The F values for all other effects and interactions were less than unity.

In order to ascertain whether selective task performance changed as a function of intervening OR task performance, separate ANOVAs were conducted on selective task performance *before* OR task performance and selective task performance *after* OR task performance. In both analyses task was a between-subjects factor and irrelevant dimension consistency was a within-subjects factor. Figure 19 shows "before" and "after" performance separately.

When the selective attention tasks preceded the OR task, the main effect of task, the main effect of consistency, and the interaction of task and consistency were all significant at the .01 level; the respective $F(1,6)$ values were 20.29, 15.07, and 27.42. When the selective attention tasks followed the OR task, the main effect of task, the main effect of consistency, and the interaction of task and consistency were all significant at the .05 level; the respective $F(1,6)$ values were 6.10, 8.51, and 8.08.

EXPERIMENT 8: SELECTIVE TASK PERFORMANCE

EXPERIMENT 8: SELECTIVE TASK PERFORMANCE BEFORE AND AFTER OR TASK PERFORMANCE

Discussion

The organization of the discussion of Experiment 8 parallels that used in the discussion of Experiment 7.

Shared versus Selective Attention.

The effects of sharing attention between dimensions upon RTs for the three types of matches were generally similar to those found in Experiment 7. PI matches were 172 msec slower in the OR task than in the selective Position task, and P matches were 374 msec slower in the OR task than in the selective Position task. I matches were not significantly slower (72 msec) in the OR task than in the selective Identity task. That is, matches with a positional component were impaired by the requirement to share attention between dimensions and the consequent reallocation of attention to the identity dimension. The differential elevation in RT as a function of match type is fundamentally inconsistent with a perceptual interpretation of dimensional relationships.

The "costs" for sharing attention were very similar in the two experiments for the unidimensional matches. For P matches, the costs were 396 msec in Experiment 7 and 374 msec in Experiment 8; for I matches, the (nonsignificant) costs were 68 msec and 72 msec. The cost of sharing attention for PI matches was smaller in Experiment 8 (172 msec) than in Experiment 7 (268 msec). Furthermore in Experiment 8 PI matches were significantly faster (112 msec) in the OR task than in the selective Identity task, whereas in Experiment 7 they were approximately equal. The intermediacy of PI matches in the OR task was not a function of differential prior experience because both Group P and Group I conformed to this pattern. No reason for this difference between experiments is readily apparent. In any event, the difference does not

affect the conclusion that the speed of PI matches was reduced in the OR task.

The effects of sharing attention for PI, P, and I matches parallel the effects found by Miller (1981) for global and local letter targets. In the OR task global matches were more impaired than local matches when a single dimension matched. When both dimensions matched, performance in the OR task was intermediate to performance in the selective global and selective local tasks. This consistency across different pairs of asymmetrically separable dimensions suggests some generality in processing under conditions of shared attention.

Practice, Prior Experience, and the OR Task.

The main and unsurprising consequence of practice in the OR task was more rapid performance. Collapsed across group and match type, the mean RT was 1235 msec in the first session and 1100 msec in the second session. This improvement occurred for all three groups and for all three match types, as indicated by the absence of any interactions involving the session factor. Numerically, however, P matches showed a greater improvement over sessions (180 msec) than ~~do~~ ^{did} PI matches (114 msec) or I matches (113 msec).

Changes in the relative levels of the different kinds of matches between sessions 1 and 2 would imply an alteration in attentional strategy as a function of experience. The invariance in the relative levels of PI, P, and I matches indicates that the attentional strategy was relatively constant from beginning to end of OR task performance. Such constancy is demanded by the perceptual viewpoint, but it can also be accommodated by the attentional viewpoint.

The kind of prior selective task experience -- position, identity, or none -- had a minimal impact on the pattern of performance in the OR task. Contrary to expectations the interaction between group assignment (determining prior experience) and match type was not significant. This finding contrasts with the results of Experiment 7 where subjects with prior selective task experience produced a pattern of performance quite different to that produced by subjects with no prior experience. In order to isolate the component responsible for that difference only a single kind of prior selective task experience was used in Experiment 8. Two possible results were envisioned: A different pattern of results for Group O indicating that general experience with a selective attention task was the critical factor, or a different pattern of results for Group P indicating that specific experience with the Position task was the critical factor.

Inspection of Figure 16 suggests that the pattern for Group O was "deviant" in the first session, and the pattern for Group P was "deviant" in the second session. But the differences were slight, and not consistent between sessions. If there was an effect of prior experience with a single selective task it was extremely subtle and may have varied over time. The difference in conclusions drawn in Experiments 7 and 8 regarding the effects of prior experience indicates that further research is necessary to resolve this question. It may be that prior experience with both tasks does differ in its effects from prior experience with a single selective task, which was statistically equivalent to no prior experience. The failure of prior experience to reliably influence OR task performance in Experiment 8 does not require the rejection of the attentional approach. But nor can the two alternatives be distinguished by means of this factor.

Since neither practice nor prior experience reliably influenced the OR task pattern, some other means of discriminating between the perceptual and attentional alternatives is needed. The actual attentional strategy employed, as inferred from the pattern of RTs, might permit such a discrimination to be made. Combined across groups and sessions, the mean RT for PI matches was 976 msec, the mean RT for P matches was 1168 msec, and the mean RT for I matches was 1353 msec. P matches were almost exactly intermediate to the other two types, being 202 msec slower than PI matches and 185 msec faster than I matches. The perceptual view predicts that PI and P matches would be made equally rapidly, and I matches slowly, because OR task performance should represent the most efficient conjoining of selective task processing. The data do not support this prediction and so the perceptual viewpoint can be shelved.

The data do fit nicely with the attentional viewpoint which argues that attentional allocations alter in the OR task, with the speed of P matches (relative to PI and I matches) reflecting the relative weightings of the identity and position dimensions. In Experiment 7 an absence of prior selective task experience produced P matches that were as slow as I matches, whereas prior experience with both selective tasks produced P matches that were nearly as fast as PI matches. Here, an intermediate amount of prior selective task experience resulted in P matches that were intermediate in speed to PI and I matches.

Experiments 7 and 8 are consistent in showing that attentional or strategic factors must be invoked to account for the patterns of performance in the OR task. Attentional factors seem to have their greatest impact on the speed of position matches. Fast PI matches and slow I matches are stable attributes of OR task performance and it is the level of P matches that fluctuates as attentional strategy varies.

Selective Task Performance.

An asymmetric effect of irrelevant dimension consistency was found both before and after execution of the OR task. The magnitude of the asymmetry was reduced, however, by intervening OR task performance. When the selective tasks preceded the OR task both main effects and their interaction were significant at the .01 level. When the selective tasks followed the OR task both main effects and their interaction were significant at the .05 level.

Figure 19 shows that this reduction in asymmetry occurred because of an improvement in the overall level of Identity matching and a decrease in the advantage for consistent matches. Such a conclusion should be tempered with caution however, because although the advantage for consistent matches in the Identity task was 306 msec before the OR task and 202 msec after the OR task, both values were unduly influenced by a single subject. If the subject with the largest consistency effect before the OR task and the subject with the smallest consistency effect after the OR task are eliminated, then the consistency effects are almost identical: 248 msec before the OR task and 253 msec after the OR task.

A separate ANOVA on Identity task performance, with time of performance a between-subjects factor and consistency a within-subjects factor, confirmed this point. Consistent matches were reliably faster than inconsistent [$F(1,6) = 31.58$, $p < .01$], but time of performance (before or after the OR task) did not influence RT ($F < 1$), nor did it interact with consistency [$F(1,6) = 1.63$]. (A parallel ANOVA on Position task performance indicated that RT was unaffected by time of performance ($F < 1$), consistency [$F(1,6) = 1.67$], or their interaction [$F(1,6) = 2.08$].)

At first glance the present results appear to contradict those of Experiment 7, where the asymmetric effect of irrelevant dimension consistency was completely eliminated with prior shared task experience. But that prior shared attention task experience included AND task performance which probably elevated RT for PI matches -- and it was this elevation in RT (in conjunction with the decrease in RT for I matches) that eliminated the consistency effect. In Experiment 8, where there was only OR task performance, there was a slight reduction in the consistency effect arising from a greater decrease in RT for I matches (206 msec) than for PI matches (81 msec).

Furthermore, both experiments were consistent in showing that it is changes in the nature and level of Identity matching that accounts for the diminution or elimination of both the overall task difference and the asymmetrical consistency effect. I have argued that OR task performance involves the allocation of attention primarily to the identity dimension, with the position dimension given subsidiary consideration. This assertion is supported by the observation that subsequent Identity matching is enhanced, while subsequent Position matching is essentially unchanged.

In conclusion, then, the results of Experiment 8 augment our understanding of the relationship between the dimensions of position and identity under conditions of shared attention. Performance under the disjunctive requirement is not a simple combination of selective task performances, as was shown by the obtained pattern of RTs in the OR task, and the differential elevation of PI and P matches relative to the selective task levels. Both effects are robust and they replicate those found in Experiment 7. They are also similar to the findings of Hoffman

(1980) and Miller (1981), who used a different pair of asymmetrically separable dimensions.

The effects of practice and prior selective task experience are less clear-cut, aside from the finding that performance showed a general improvement with practice. The discrepancy between the findings of Experiments 7 and 8 regarding prior selective task experience may be related to the amount of experience which differed in the two experiments. But subjects with no prior selective task experience in Experiment 8 also produced the "intermediate" pattern of RTs complicating the question considerably.

It appears that prior experience may work the other way too. Selective Identity task performance is altered by prior experience in a shared attention task, although the changes were small in Experiment 8. The principal change is an improvement in the speed of I matches, which reduces the advantage held by consistent (PI) matches thereby lessening the overall asymmetry between the Position and Identity tasks.

Although neither of the main manipulations of Experiment 8 (practice in the OR task and type of prior selective task experience) were successful in clearly distinguishing the perceptual from the attentional conceptualization, the other findings -- the pattern of RTs in the OR task, the differential effect of sharing attention on matches with a positional component, and the weaker asymmetry when selective tasks follow the OR task -- are better handled by an attentional interpretation, which emphasizes processing flexibility.

SUMMARY OF EXPERIMENTS 7 AND 8

Experiments 7 and 8 reveal one of the most important determinants of performance: Whether attention is shared between the position and identity dimensions or is selectively directed to one of them. When the dimensions are selectively attended the position dimension is characterized by much more rapid performance and an insensitivity to the status of the irrelevant identity dimension. The identity dimension is characterized by slower overall performance and a marked sensitivity to the status of the irrelevant position dimension. This pattern of results characterizes a dimensional relationship of asymmetric separability.

When attention is shared between the two dimensions the pattern of performance is altered. Conjunctively sharing attention (the AND task of Experiment 7) produces performance at about the level of the selective Identity task. Disjunctively sharing attention (the OR task of Experiments 7 and 8) has two principal consequences. One is the substantial slowing of response speed for matches with a positional component, PI and P, coupled with a trivial slowing of response speed for I matches. The other is the fluctuation in the inter-relationship between the three types of matches, as the speed of P matches varies between the faster PI and slower I matches, depending upon the amount and type of prior selective task experience.

Considered in their totality, these multifaceted effects of sharing attention between the position and identity dimensions indicate that attentional strategy is paramount in determining the observed patterns of performance. A perceptual conceptualization, relying on fixed perceptual structures and/or cognitive mechanisms, can account for very few of the observed effects.

It must be said that Experiments 7 and 8 leave a number of issues unresolved, and in answering some questions, raise others. This is not surprising since they were intended as initial, exploratory studies. Nor is it undesirable as it points to future avenues of investigation. The point made abundantly clear by these two experiments is that conclusions reached on the basis of selective attention studies cannot be assumed to hold when a task requires attention to be shared. Obvious as it may be this point seems to have been often overlooked in both applied and experimental situations.

CONCLUSION

To conclude, I will summarize the main findings of these experiments, discuss the limitations and the advantages of the research, and trace the connections to established research areas.

Main Findings

Experiments 1, 2, and 3 examined performance under conditions of selective attention with only the relevant dimension represented in the comparison displays. The position task and the identity task were formally equivalent: Either four positions or four identities were successively matched. Various experimental parameters were manipulated to demonstrate the separability of the two dimensions. That is, manipulation of position information was predicted to affect performance only in the position task, and manipulation of identity information was predicted to affect performance only in the identity task.

The first and most robust finding was that the successive matching of four identities took longer than did the successive matching of four positions. Identity matching was also less accurate than position matching. Experiments 1 and 2 demonstrated that identity matching was affected by the nature of the identity information, with geometric forms matched more slowly than letters, but unaffected by variation of the position information presented in the sample displays. Position matching was largely unaffected by variation of either the identity information or the position information. Positions were successively matched as rapidly in the absence of a matrix outline as in its presence, and

variation in matrix size from nine cells (3x3) to 36 cells (6x6) did not reliably affect RT.

Experiment 3 demonstrated that the accuracy of position recall decreased as the matrix size increased and replicated the finding that position recognition was not sensitive to matrix size. This difference in results as a function of task had important implications concerning the processing of position information.

The conclusion drawn from the overall difference in speed of performance and the differing patterns of sensitivity to experimental manipulations was that fundamentally different processes were involved in the two tasks, at least under the unidimensional conditions employed. This conclusion, however, said little about the relationship between the two kinds of visual information.

Experiments 4, 5, and 6 tested the hypothesis that position and identity could be conceptualized as a pair of asymmetrically separable dimensions. This hypothesis was derived from the framework of dimensional relationships developed by Garner (1974, 1976, 1983). When a pair of dimensions is asymmetrically separable, the primary dimension may be selectively attended, but the secondary dimension cannot be. The occurrence of selective attention is shown by the absence of facilitation and interference effects when the irrelevant dimension is correlated with and orthogonal to the relevant dimension, respectively. In the successive matching procedure, correlation was achieved by making the irrelevant dimension consistent from sample to comparison display. Orthogonality was achieved by making the irrelevant dimension inconsistent from sample to comparison display.

A strongly asymmetrical effect of irrelevant dimension consistency was found in Experiment 4. Identity matching was much faster when the irrelevant position information was consistent than when it was inconsistent but position matching was unaffected by the status of the irrelevant identity information. Experiments 5 and 6 examined the effect of irrelevant dimension status in more detail by contrasting consistent, neutral, and inconsistent conditions. Substantial facilitation and interference effects occurred when identity was the relevant dimension (Experiment 5), but there was only a small (yet significant) facilitation effect when position was the relevant dimension (Experiment 6). These findings were precisely those predicted by the asymmetric separability hypothesis.

The final two experiments, 7 and 8, explored the effects of sharing attention between the dimensions. Performance under conditions of shared attention was clearly not a simple combination or extension of separate selective task performances, as a perceptual interpretation of dimensional relationships would predict. Instead, there was evidence of attentional reallocation toward the identity dimension, particularly in the absence of prior selective task experience. Experience in sharing attention between dimensions also produced some alterations in the pattern of subsequent selective task performance. These last two experiments highlighted the importance of attentional strategy when attention is shared between dimensions; by implication, attentional strategies may also be relevant when the dimensions are selectively attended.

Limitations

There are two potentially problematic aspects of the present series of experiments that should be acknowledged. The first is the inherent inequality in task difficulty, and the second is the use of the successive matching procedure. Neither aspect, in my opinion, seriously challenges the conclusions drawn, but both points require discussion.

The first two experiments established that, despite the formal equivalence of the position task and the identity task, the levels of performance were quite different. Identities were matched much more slowly than positions, particularly when forms were used. (Hence the decision to use letters in subsequent experiments, in order to minimize the difference in overall levels.) Part of the slowness of identity matching in Experiments 1 and 2 can be attributed to the use of neutral comparison displays which, as the results of Experiment 5 indicated, were functionally akin to inconsistent comparison displays, but with a slight advantage because of their predictability. However even with consistent comparison displays, RTs in the identity task were approximately 200 msec slower than those in the position task.

Garner (1983) has discussed the problem potentially created by unequally difficult tasks. A large difference in difficulty, or discriminability, will almost inevitably produce an apparent asymmetry in selective attention, since the faster dimension will exert more influence on the slower dimension than vice versa. Thus, a finding of asymmetry in selective attention cannot be unequivocally attributed to an asymmetry in processing. However, Garner also argues that a blanket requirement of equal discriminability is not appropriate, since a difference in performance levels can itself be used to infer a difference in processing levels. This is the situation in the present

experiments: The fact that position matching is markedly superior to identity matching supports the contention that for a variety of reasons position information is given precedence over identity information. To argue that the observed asymmetry is merely a reflection of the difference in task difficulty is to beg the question concerning the origin of that difference.

It is an empirical question whether changing the relative difficulties of the position and identity tasks would alter the pattern of asymmetric interference. To alter the relative difficulties of the two tasks the difficulty of the position task would need to be increased and/or the difficulty of the identity task would need to be reduced. To do this would of course abolish the formal equivalence between the two tasks.

I suspect that even with equivalently difficult position and identity tasks there would be asymmetric interference, since such asymmetry has been found in several other studies where both the overall RTs were faster and the position-identity task differential was much smaller (Logan, 1980; Logan & Zbrodoff, 1979; Paley, 1978; Paley & Olson, 1975). Furthermore, in an attempt to equate task difficulty, data from the slowest six position subjects and the fastest six identity subjects in Experiment 4 were compared. The overall mean RT was then 1064 msec in the Position task and 1013 msec in the Identity task. The advantage for consistent matches was 33 msec in the position task and 154 msec in the identity task. So even when identity matching was slightly faster than position matching, there remained a strong asymmetry.

Use of the successive matching procedure in ascertaining the dimensional relationship between position and identity represents a novel application of that procedure. Several studies have compared speeded classification, simultaneous matching, and successive matching using constant pairs of dimensions (Boer & Keuss, 1979, 1981; Garner et al., 1982; Santee & Egeth, 1980). The results have not been consistent. Some studies have found that dimensional relationships vary with procedure; others have found that they do not. One point noted by both Boer and Keuss (1979) and Garner et al. (1982) was that successive matching facilitated selective attention, since the irrelevant dimension could be filtered out during the interstimulus interval, particularly when that interval was fairly long (one second or so). That Experiments 4 and 5 should so clearly show a failure to selectively attend to identity information, using a successive matching procedure and an interstimulus interval of one second, makes the conclusion all the more robust.

Another point regarding the use of the selective matching procedure is the equating of consistent and inconsistent comparison displays with the correlated and orthogonal conditions of a speeded classification task. The original studies of dimensional relationships used the speeded classification task and bi-valued dimensions so that the values on one dimension could be correlated with, neutral to, or orthogonal to the values on the other dimension. Later studies have also used the speeded classification task and bi-valued dimensions, varying the pairing from trial to trial instead of maintaining a particular pairing for a block of trials (condition). This has produced no great difficulties, nor has it met with critical objection. When dimensions are multiply valued, as in the present experiments, the latter trial by trial approach seems the

only reasonable way of proceeding. The crucial point is that selective attention is defined as an insensitivity to variation on the irrelevant dimension, irrespective of whether that variation occurs across conditions or across individual trials. The proof that consistent and inconsistent comparison displays are analogous to correlated and orthogonal conditions lies in the results: The hypothesis of asymmetric separability, developed from the traditional comparison of correlated and orthogonal conditions, was firmly supported.

Advantages

There are a number of advantages arising from the use of multiple positions and multiple identities. First, the similarity of the conclusions reached in the present experiments using a successive matching procedure with multiple positions and identities to those arising from earlier studies using a speeded classification procedure with dichotomous positions and identities shows that the phenomenon (the relationship of asymmetric separability between position and identity) is a general one and is not limited to a specific procedure or set of stimulus materials.

Second, the use of multiple positions and identities provides a closer approximation to more complex cognitive activities. Perhaps the most obvious example is reading. Others that come to mind include scene comprehension, cognitive mapping, and driving a car.

Third, using multiple positions and multiple identities potentially permits independent manipulation of both task difficulty and degree of irrelevant dimension consistency. Some initial attempts in this direction were included in the present experiments but there is scope for much more to be done. These sorts of manipulations could be useful

in determining whether there are limits to, or changes in, the relationship of asymmetric separability.

Connections

The main conclusions reached from the results of Experiments 1 to 8 fit quite nicely with the major generalizations arising from several different areas of research. The findings of most importance are these: (1) Position information processing is more easily, and hence more rapidly, accomplished than is identity information processing under conditions of selective attention. (2) Position and identity exhibit a dimensional relationship of asymmetric separability under conditions of selective attention. (3) Sharing attention between dimensions differentially affects position processing.

The principal findings that emerged from the review of iconic memory research were: (1) a position performance superiority, (2) an advantage when position was precued but not when identity was precued, and (3) a deleterious effect of position accuracy when both types of information had to be processed. The superiority of positional cues in a partial report procedure and the impact of serial position on whole report were also noted.

The overall superiority of position performance in iconic memory studies parallels the present finding that position matching is superior to identity matching. The salience of position as a partial report cue is not surprising given that position is the primary dimension and is characterized by rapid and automatic processing. It is therefore efficient (in the sense that little additional effort is required) to use position as a cue in partial report.

The asymmetrical effect of precuing parallels the asymmetric effect of irrelevant dimension consistency: It matters little when the primary position dimension is relevant, but both precuing and consistency are beneficial when the secondary identity dimension is relevant. Reducing the effort required to initially process the position information, either by precuing or making that information consistent, frees resources for the processing of identity information. Facilitating the processing of identity information, via precuing or consistency, has little impact because that information is slower than and subsidiary to the position processing.

The selective decrement for position information when both position and identity must be reported is analogous to the effect of sharing attention between dimensions. Under conditions of shared attention, both dimensions must be attended, even if only one is reported or matched on a particular trial. As was shown in Experiments 7 and 8, this had serious consequences for position matching, but little effect on identity matching. The underlying reason for this pattern of effects is of course the differential ability to selectively attend the two dimensions. Since identity information cannot be selectively attended, making the automatically processed position information also relevant does not substantially alter the nature of the task. Because position information can be selectively attended, adding an identity processing requirement radically changes the task with a consequent cost for position processing.

The major conclusions from the short-term visual memory research that was reviewed were: (1) a difference in the coding of position and identity information, (2) automatic encoding of position but not

identity information, and (3) a general superiority for identity performance. The conclusions from the present experiments are generally consistent with these, but the connections are perhaps not as obvious nor as strong as with the iconic memory research. This is probably because much of the iconic memory research, like the present research, has been more directly concerned with the relationship between position and identity information whereas the short-term visual memory research has tended to focus on differences between the processing of position and the processing of identity information. Such differences may nevertheless be important to the relationship. Furthermore, the temporal parameters used in many of the short-term visual memory studies have been far longer than those used in the present experiments. Since one conclusion from those studies was that performance levels for the two types of information diverged over time this may be another reason why there are some discrepancies in the conclusions reached.

Several studies using the selective interference design indicated that position information was visually coded and identity information was verbally coded. The present experiments have not addressed the issue of coding differences, but the argument that position is the primary dimension, and is usually given precedence in processing, agrees with the notion of coding differences. As outlined earlier, visual coding is both a developmentally and phylogenetically earlier phenomenon than is verbal coding; visual processing seems to occur at a lower neurological level, and may well be less flexible than verbal processing. Given these assumptions, it seems only reasonable that position information is processed more rapidly than identity information, and should be less affected by experimental variation along either dimension.

Studies that have contrasted the incidental with the intentional learning of position and identity information have suggested that position information processing falls at the automatic end of the automatic-effortful continuum. This automaticity, coupled with the rapidity of position information processing, is fundamental to the asymmetrical relationship between the two dimensions. Because position information is automatically processed, variation of that information markedly affects the processing of identity information. If position information were not automatically processed then selective attention to the identity dimension would be feasible.

The short-term visual memory studies that showed a general superiority for identity information are slightly harder to reconcile with the present results. Most of these studies have used complex pictorial material and quite long retention intervals, and so probably require different processing strategies than does the almost immediate matching of four letters. Some of the studies have also used spatial relocation or reconstruction as their measure of position information processing. Experiment 3 demonstrated clear differences between position recognition and position recall. As suggested in the discussion of Experiment 3 a recognition procedure may be particularly suitable for visually coded material whereas a recall procedure may be advantageous for verbally coded material.

There is another aspect of the short-term visual memory studies that might permit a resolution, and that is the fact that typically both position and identity information have been made relevant to the task. When subjects in the present experiments were required to process both dimensions the level of position performance dropped substantially, sometimes to the level of identity performance.

Given the differences in stimulus materials, temporal framework, performance measures, and attentional conditions, the difference in patterns of results and conclusions is hardly surprising. It remains to discover the degree of overlap between the two areas.

The hypothesis of asymmetric separability stems directly from Garner's (1974, 1976, 1983) conceptualization of dimensional relationships. The original studies of dimensional relationships tended to view stimulus structure as the determining factor in such relationships and so physical dimensions were extensively studied. Later research expanded the domain of dimensional relationships by including cognitive dimensions, and by considering the interplay of stimulus, subject, and task factors. The present research falls within this wider circle, since the cognitive dimension of letter identity was used, and the interaction of task (attentional condition) and stimulus factors was a point of interest. The present research has also extended the utility of the dimensional approach by demonstrating that the use of multiply-valued dimensions produces results analogous to those obtained when bi-valued dimensions are used.

Finally, the present research has made contact with the vast body of research concerning attentional theory. Although most of the present experiments used selective attention conditions only, the final two experiments did contrast shared attention conditions with selective attention conditions. It is this contrast which brings together the dimensional and the attentional areas. Under conditions of selective attention the automaticity of position information processing is apparent whereas under conditions of shared attention attentional

strategies are seen to interact with the automatic processing of position in determining the pattern of performance. The distinction between automatic and attentional processes has been a feature of recent thinking in attentional theory (Broadbent, 1982; Hasher & Zacks, 1979; Logan, 1980; Navon & Gopher, 1979). For those dimensions that fall toward the automatic end of the continuum a consideration of the joint operation of automatic and attentional factors would be an important aspect of a dimensional analysis.

The distinction between shared and selective, or divided and focused, has a long history in attentional research. In discussing the attentional-dimensional connection, however, I am not suggesting that a dimensional analysis ought always to contrast the two. The schema of dimensional relationships was designed with reference to selective attention. It remains to be seen to what extent dimensional relationships can be used to account for shared attention performance -- if, indeed, they ought to do so. The purpose of the contrast in Experiments 7 and 8 was to distinguish between the perceptual and attentional interpretations of the particular dimensional relationship involved, that of asymmetric separability.

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APPENDIX

Before running Experiments 1 through 8 a pilot study was conducted in which the temporal parameters of sample display duration and interstimulus interval were manipulated. This appendix describes the method and results of the pilot study.

Method

Stimulus Materials. The set of 30 PI Sample displays containing four forms in the cells of a 3x3 matrix were used in the pilot study. Two sets of comparison displays were used: The set of 60 P Comparison displays for the 3x3 matrix size, and the set of 60 I Comparison displays containing four forms. (See Method section of Experiment 1 for details.)

Procedure. Each of three experimental sessions had 30 practice trials followed by 60 experimental trials. The successive matching procedure described in the General Method section was used in the pilot study, but sample display duration and interstimulus interval were varied rather than fixed. The three sample display durations were .5, 1, and 2 sec, and these values were blocked within sessions. The three interstimulus intervals were 1, 5, and 10 sec, and these values were blocked between sessions.

Each of the six possible orders of sample display durations was paired once with an ascending order of interstimulus intervals and once with a descending order of interstimulus intervals for a total of 12

duration by interval combinations. Subjects were assigned alternately to the Position task and the Identity task in the order of their first appearance at the laboratory. Within each task subjects were randomly assigned to one of the 12 duration by interval combinations.

Each of the PI Sample displays appeared once during the practice trials and twice during the experimental trials, and was followed by a matching comparison display on half the number of trials and a mismatching comparison display on the other half. Within each block of 10 practice trials and each block of 20 experimental trials there were equal number of matches and mismatches.

Subjects. Nine male and 15 female psychology student volunteers served as subjects.

Results

Two three-way mixed ANOVAs were conducted, one using the RT data and the other using the percentage correct data. In both analyses task was a between-subjects factor, and sample display duration and interstimulus interval were within-subjects factors.

Figure 20 shows the mean correct RTs for the Position task and the Identity task. Position matches were faster than Identity matches [$F(1,22) = 198.81$, $p < .001$]. Longer sample display durations were associated with slower RTs [$F(2,44) = 10.08$, $p < .001$], as were increases in interstimulus interval [$F(2,44) = 41.44$, $p < .001$]. The task by interval interaction was significant [$F(2,44) = 6.32$, $p < .01$], with RTs showing a relatively greater increase as a function of interstimulus interval in the Identity task.

PILOT STUDY:
MEAN RTs

Figure 21 shows mean percentage correct responses in the two tasks. Accuracy was higher in the Position task than in the Identity task [$F(1,22) = 124.61, p < .001$]. There was a main effect of sample display duration [$F(2,44) = 25.50, p < .001$], and a task by duration interaction [$F(2,44) = 26.56, p < .001$]. Analysis of the simple main effects of the interaction showed no effect of sample display duration in the Position task ($F < 1$) but a substantial effect in the Identity task [$F(2,22) = 27.90, p < .01$]. The only other reliable effect was the interaction of duration and interval [$F(4,88) = 2.65, p < .05$]. This appeared to be largely confined to the Identity task.

Across all sample display durations and interstimulus intervals mean RT was 750 msec in the Position task and 1946 msec in the Identity task. Mean accuracy rates were 98.7% and 83.3% respectively. For ease of comparison with the results of Experiments 1 to 8, Table 1 gives mean RTs for each duration by interval combination in the two tasks.

TABLE 1
PILOT STUDY DATA

Position Task

ISI (Sec)	Sample Display Duration (Sec)		
	.5	1	2
1	611	645	694
5	705	728	846
10	809	813	902

Identity Task

ISI (Sec)	Sample Display Duration (Sec)		
	.5	1	2
1	1626	1670	1832
5	1940	2058	2082
10	1997	2121	2189