OPTICAL REVIEW Vol. 2, No. 1 (1995) 72–80

Learning to Recognize Patterns: Changes in the Visual Field with Familiarity

James M. BEBKO, Keiji UCHIKAWA, Shinya SAIDA and Mitsuo IKEDA

Department of Information Processing, Tokyo Institute of Technology Graduate School, 4259, Nagatsuta, Midori-ku, Yokohama, 226 Japan

(Received July 6, 1994; Accepted October 27, 1994)

Two studies were conducted to investigate changes which take place in the visual information processing of novel stimuli as they become familiar. Japanese writing characters (Hiragana and Kanji) which were unfamiliar to two native English speaking subjects were presented using a moving window technique to restrict their visual fields. Study time for visual recognition was recorded across repeated sessions, and with varying visual field restrictions. The critical visual field was defined as the size of the visual field beyond which further increases did not improve the speed of recognition performance. In the first study, when the Hiragana patterns were novel, subjects needed to see about half of the entire pattern simultaneously to maintain optimal performance. However, the critical visual field size decreased as familiarity with the patterns increased. These results were replicated in the second study with more complex Kanji characters. In addition, the critical field size decreased as pattern complexity decreased. We propose a three component model of pattern perception. In the first stage a representation of the stimulus must be constructed by the subject, and restricting of the visual field interferes dramatically with this component when stimuli are unfamiliar. With increased familiarity, subjects become able to reconstruct a previous representation from very small, unique segments of the pattern, analogous to the informativeness areas hypothesized by Loftus and Mackworth [J. Exp. Psychol., 4 (1978) 565].

Key words: learning, familiarity, visual field, pattern recognition, eye movement

These studies were conducted to investigate the changes which take place in the visual information processing of novel stimuli as they become familiar. The literature is very sparse on the processing of truly novel patterns where both the stimulus and the stimulus class are unfamiliar. There seem to be no previous studies which have systematically examined the effects of varying degrees of familiarity on visual parameters, with the exception of studies of reading and eye movements.[1)] This is surprising, given the models suggesting that subjects hypothesize and test critical areas of information when attempting to recognize patterns.[2–4)] These small areas of the patterns are fixated on more intensively, and are reported by subjects to be the determining components which can assure recognition. This visual scanning strategy implies at least a general familiarity with the picture type, yet little is known of how this end point is reached. In the following studies we examined visual parameters associated with the process of learning to recognize an unfamiliar stimulus with repeated exposure to it.

In scanning visual patterns, a series of brief fixations are used to extract relevant information for further processing of the pattern. These fixations seem directed towards the supplying of new information to foveal vision. A number of researchers have demonstrated, however, that information outside the 2° or so of foveal vision is processed during fixations, and is important for the perception of pictures,[5–7)] the comparison of line lengths[8)] and in reading tasks.[9–12)]

A variety of terms have been used to represent this visual field, depending on the phenomena being investigated. "Conspicuity area"[13)] and "functional visual field"[14)] were used to refer to the retinal area about the fixation point within which a target could be detected on a single exposure of 75 ms or 250 ms, respectively. "Perceptual span"[10,12)] or "effective visual field" has been used to refer to the region around the fixation point from which information is extracted during fixation in reading. Saida and Ikeda[5)] used the terms "useful" or "critical visual field size" to refer to the size of the visual field beyond which further increases did not improve picture recognition performance. In each case, at issue is the minimum visual field size which results in optimal performance by the subject. In this paper, we will use the term critical visual field size.

The size of the critical visual field seems to depend on the nature of the stimuli provided and the task being studied. For example, Ikeda and Takeuchi[14)] found that the greater the complexity of the central (foveal) information in a stimulus pattern, the greater was the shrinkage of the visual field for peripheral target detection. Varying critical field sizes have been found for reading[15)] vs pattern or picture perception[5,6)] suggesting that somewhat different

---

Inquiries or requests for reprints may be directed to any of the authors. Authors' current addresses are: James M. Bebko, Department of Psychology, York University, 4700 Keele Street, North York, Ontario, Canada M3J 1P3; Keiji Uchikawa, Imaging Science and Engineering Laboratory, Tokyo Institute of Technology, 4259 Nagatsuta, Midori-ku, Yokohama 226 Japan; Shinya Saida, Biosignaling Department, National Institute of Bioscience and Human-Technology, 1-1 Higashi, Tsukuba, Ibaraki 305 Japan; Mitsuo Ikeda, Department of Architecture, Kyoto University, Sakyo-ku, Kyoto 606 Japan.

This research was conducted while the first author was supported by a Government of Japan Monbusho Research Fellowship at Tokyo Institute of Technology.

processes may be involved in reading than in pattern perception.

Engel[13] indirectly suggested that the critical visual field size may become larger with training on a stimulus set, but the effect of familiarity has yet to be directly examined. Most work in the area has been with stimuli whose general classes (text, pictures, etc.), at least, are already familiar to subjects. Indeed, this familiarity is assumed to play a large role in the planning of eye movements. Several two stage models have been proposed, assuming a basic familiarity with stimulus type. In the initial stage of these models, typically on the first fixation, general, global information about a picture is extracted, from which predictions are made about where potentially informative specific information might be for subsequent fixations. In the second stage, these identified areas are scanned to evaluate the accuracy of the initial response.

Loftus and Bell[2] proposed such a model, suggesting that on initial viewing of pictures, general visual information accrues about the scene, and the subject sets up expectations about potentially informative details (uniquenesses). Subjects then fixate on these "informative areas"[3] to search for critical details which might verify the recognition of the picture. Morris *et al.*[12] recently proposed a analogous view for reading. They argued that there is a perceptual parser that on the first fixation rapidly processes global information such as word units, spaces, etc., enabling predictions to be made of where important information will likely be found for subsequent fixations. In both views, the basic parameters of the visual displays are known, enabling rapid predictions to be made for further processing, although in the case of reading it is lower-level visual cues such as word length information that is influencing where to search next. Thus, critical visual field size differences found, for example, for reading and for picture recognition, are interpretable within the relative parameters of the type of stimulus presented.

In contrast, little is known of the processing of truly novel patterns, where potentially critical aspects of the stimulus are unknown. In such cases, information about important areas cannot be retrieved, but must be constructed gradually with increasing familiarity with the stimulus. We know from the learning literature that with increased familiarity, response time to recognition decreases systematically. But little research has been done on potential changes in visual information processing characteristics which may be associated with early increases in familiarity with novel stimuli. While information in the periphery is important in planning saccades to scan patterns,[7] it is likely that the size of the critical visual field from which this information is obtained is different when a stimulus is novel vs familiar. An example of such a difference was reported by Ikeda *et al.*,[1] but for a subject reading in her native vs foreign language.

Two models of potential change with familiarity could be hypothesized (see Fig. 1). The top line in each panel represents hypothetical performance on the first session when the stimuli are truly novel; the bottom lines represent a late session, with the middle line representing performance part way through the study, after some familiarity with the stimuli has accrued. In each case, the study time required to recognize the stimuli for a subsequent recognition test decreases with increased number of presentations of the stimulus.

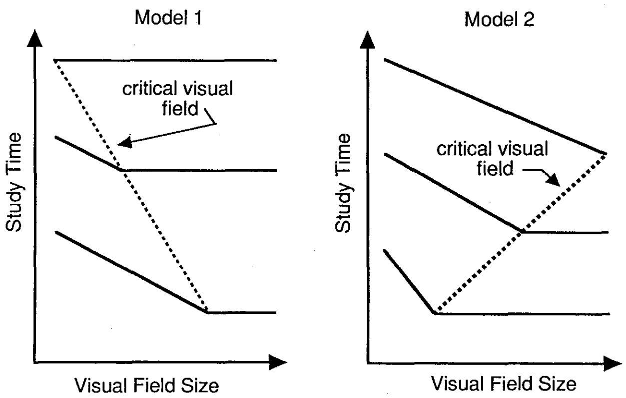

Fig. 1. Two models of potential changes in critical visual field size with increased familiarity.

In Model 1, on the first exposures to the stimuli, the subject is only able to make us of a small visual field size; providing a larger field for scanning does not result in a further lessening of study time. As the stimuli become familiar, the subject learns to make use of an increasingly larger visual field, increasing the critical field size. Providing a larger field would thus optimize performance; a more restricted field would result in increased study times. Engel's[13] training effect in a peripheral target detection task is an exemplar of this model. Another is Ikeda *et al.*'s[1] report of reading patterns in a native vs foreign language.

In Model 2, the opposite prediction is made for the critical visual field size. In this case, on initial experience with the stimuli, the subject needs a large visual field to be able to construct an initial representation of the stimulus. Restricting the visual field necessitates increased study time to enable a complete representation to be constructed internally from partial displays. But with repeated displays, the task becomes more of a recognition task, in which the subject comes to be able to identify the stimuli from much smaller views. In this case, then, the critical visual field decreases with increased familiarity across trials. Providing larger visual fields would not further enhance performance. The two-component picture recognition and reading models outlined earlier would be consistent with performance on the later sessions in Model 2.

We conducted the present studies to examine these models. In the first study, we used restricted visual fields in a moving window technique to examine whether there were systematic changes in the critical visual field size which occur with increasing stimulus familiarity. The second study was designed to determine whether observed changes in Study 1 were dependent on the complexity of the stimuli presented or were consistent across complexity level. The task for our subjects differed from previous studies, because the initial learning of unfamiliar stimuli was the focus.

Study 1: Hiragana Characters

In this study, visual stimuli which were from a novel class of patterns (Japanese writing characters presented to English speaking adults) were presented in restricted visual fields using the moving window method. The patterns were presented for five sessions to assess changes in the critical visual field size as stimuli become familiar.

Method

Subjects. The subjects were two 28 year old adults, one male and one female with normal (female) or normally-corrected visual acuity. Both had been in Japan approximately three months and could not read any of the three Japanese writing systems. While the male subject (J.B.) was aware in general terms of the models being tested, results did not differ appreciably between subjects.

Apparatus. The apparatus used has been described in detail in Saida and Ikeda[5)] for the presentation of eye-contingent artificially restricted foveal windows. A schematic diagram appears in Fig. 2. The major components included two video cameras, a corneal reflection eye movement detection apparatus, and a specially designed montage circuit to superimpose the selected window size on the subject's current eye position.

The display screen was viewed with the right eye; the other eye was occluded by a black shield approximately 2 cm in front of the eye. The subject's head was stabilized by a bite board positioned so that the distance between the CRT display screen and the subject's cornea was 105 cm. At this distance, the display screen subtended a maximum visual angle of 20.4° horizontally, and 16.5° vertically. The stimuli were centered on the screen, enlarged to 14° on a side. The subject's actual visual field, however, could be reduced from the full screen size to a square 2° on a side.

The visual field was calibrated so that the center of the square coincided with the subject's fixation point. When the subject's eyes moved, the field moved to coincide with the new fixation point. A simulation with an 8° visual field size appears in Fig. 3a. In each frame, the subject's fixation point is the center of the window. Subjects could not see anything outside the windows.

In this way, visual field size was controlled while the display was scanned at will with normal eye movements.

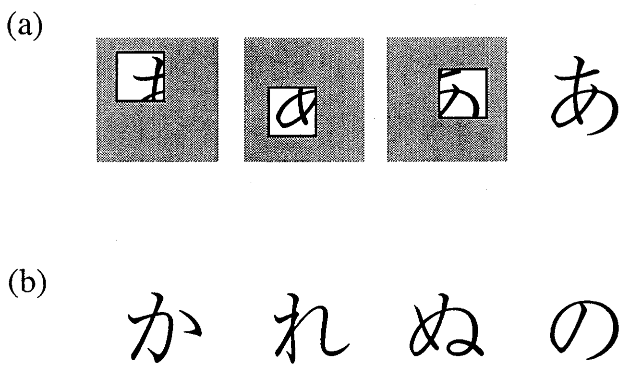

Fig. 3. Examples of Japanese Hiragana characters used in Study 1. An example of the subject's view on successive fixations with an 8° window appears in (a).

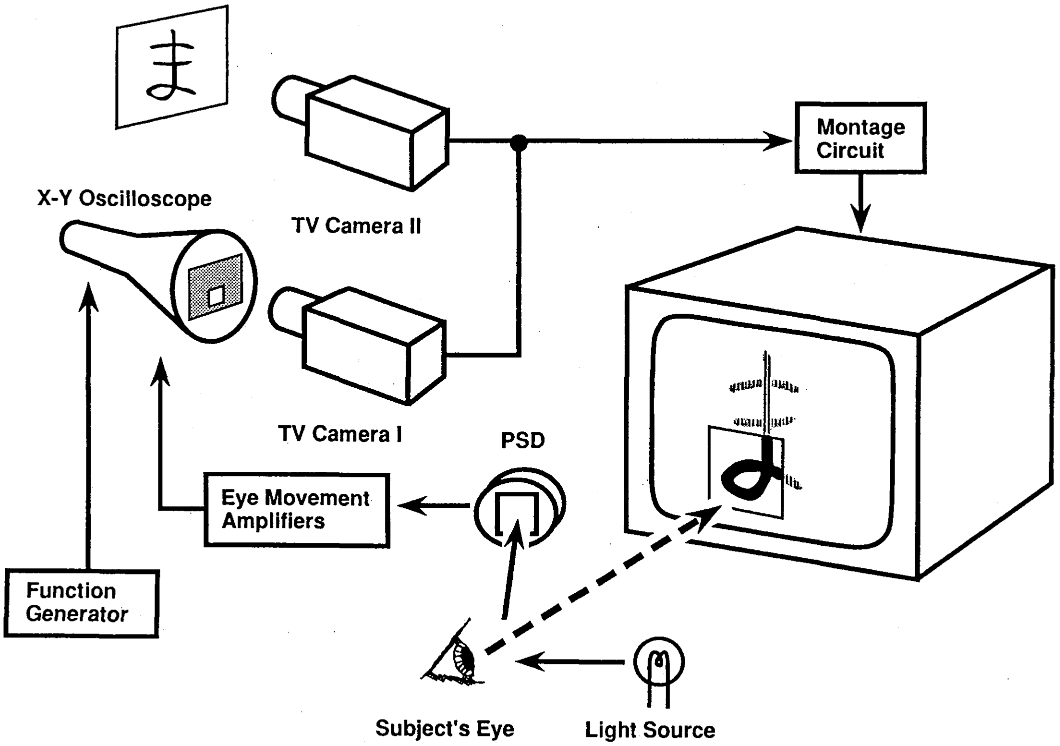

Fig. 2. Schematic diagram of the apparatus used to produce a moving restricted visual window centered on the subject's fixation point.

A data recorder recorded eye movements directly from the X-Y amplifiers. A button was pushed by the subject to initiate and terminate the display, and a digital timer recorded the study time.

Stimuli. The visual patterns presented to the subjects in this study were characters from the Japanese Hiragana syllabary. The Japanese writing system is a combination of three types of characters. Two of these types, Hiragana and Katakana, are phonetic symbols, mapping single syllables to single characters. These are arranged in most books as syllabaries (alphabets). Hiragana characters are cursive and are typically used for Japanese words and morphemes; Katakana are abbreviated Chinese characters, and are typically used to write foreign words. (Kanji, the third type of writing symbol, are described in the next study.) A total of 46 stimuli were selected from the Hiragana syllabary; examples appear in Fig. 3b. These represented meaningless visual patterns to the subjects.

Design. Five visual field sizes were used in this study: 3.5° × 3.5°, 5.5° × 5.5°, 9° × 9°, 14° × 14°, and the unrestricted field. Subjects were tested in each visual field size in each session in a counterbalanced design. During odd numbered testing sessions, the order was from the smallest to the largest field size, then from the largest to the smallest. During even numbered sessions, the order was the reverse. At the beginning of each session, the 46 stimuli were randomly split into two equal subsets (A and B) of 23 each. In the first series of visual field conditions (ascending in odd numbered sessions, descending in even), subsets A and B were alternated across the 5 visual field sizes. Then in the second series, the complementary subset was shown for each field size. Thus, each stimulus was presented once in each visual field size in each session, for a total of 230 trials per session. There were a total of 5 sessions per subject.

Procedure. Prior to each session, the subjects were asked to sort, as rapidly as possible, a deck of cards containing individual stimuli into groups of stimuli which seemed related to each other. This served a general orienting purpose to help the subjects define some of the general characteristics of the stimulus set.

Each session then began with calibration of the equipment using practice stimuli, followed by a short rest, during which the first visual field size was selected. For each stimulus, the subject was signaled with a buzzer when the display was ready, and he/she pushed a button to begin the display on the monitor. The task was to study the display and make a Yes-No button press response, corresponding to whether or not the subject could identify the stimulus in a recognition task. There was no time limit for study; pressing the Yes or No button terminated the display. After the subset of 23 stimuli were shown, there was a brief rest while the next visual field size was selected.

As a check on the accuracy of the subjects' judgments, Yes responses were intermittently tested with a three choice recognition task, with the subject asked to select the preceding stimulus. Testing was conducted on an average of every second Yes response for the first two sessions. Accuracy was 100% for both subjects, so recognition testing was discontinued to save time. Study time was recorded for each stimulus for subsequent analysis. Only Yes responses were included in analyses.

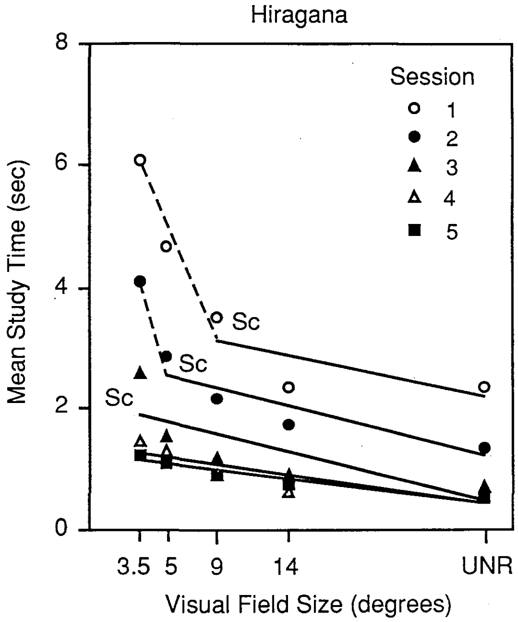

Fig. 4. Mean study times for Hiragana characters at various visual field sizes across five sessions. Critical visual field size (s_C) decreased with increasing familiarity.

Results

Since the results for the two subjects were similar, they were combined to increase precision. Mean response times per stimulus pattern are shown in Fig. 4 by visual field size and session. The unrestricted visual field was plotted at 28° on the abscissa, which is double the height and width of the actual stimuli. This assumes that if the subject fixated on an extreme part of the pattern, the view of the entire stimulus would still have been unrestricted.

The figure clearly shows that as the characters became more familiar across sessions, the response times decreased. Multiple comparisons (Newman-Keuls procedure) among the mean study times across the various visual field sizes were undertaken within each session's data. A solid regression line was fitted to those means which did not differ significantly from one another. Visual field sizes which differed significantly were connected by a broken line. The result for Sessions 1 and 2 were two lines whose intersecting point was taken to be the smallest visual field size for which optimal performance was observed. This was termed the critical visual field size (s_C) for that session. The s_C clearly decreases with increasing familiarity of the stimuli, reaching a floor effect by Session 3.

Discussion

The results of this study provide clear support for Model 2 in Fig. 1. The absolute values of s_C are not important, as they are in part a function of the parameters of the experiment; larger and smaller stimuli would likely result in larger and smaller absolute s_C values. What is important here is the decrease in s_C across sessions, with the minimum being reached by Session 3.

It appears that on initial exposure to a novel stimulus, a large visual field is required as the subject constructs an initial representation of the pattern displayed. With narrowly restricted visual fields, a longer study time is required, as the task of constructing a coherent representation becomes very difficult without significant overlap between fixations.

A similar finding with a different methodology was reported in Ikeda *et al.*,[1] where subjects were shown pictures divided into 100 units (a 10 × 10 grid). The subject could display any one unit at a time repeatedly for as long as desired and in any order. Even after 5 min of study, the subject could not identify the picture, although a meaningful partial drawing of the picture could be made by the subject afterwards. Only on viewing his own drawing did the subject then identify the picture.

Our subjects reported exactly such difficulties in the first session, in trying to construct internal representations of the stimuli with restricted visual fields. With the larger fields, approximating 50% of the display, the task was a much easier one. In later sessions, subjects reported that seeing only a small part of the stimulus was now sufficient to trigger their entire internal representation.

In Study 1 the stimuli varied unsystematically in complexity, some characters consisting of two nearly parallel simple strokes, others having several crossed strokes or cursive loops. In Study 2 we examined whether the results from the first study are consistent across levels of complexity of the stimuli. Several studies have reported a narrowing of the peripheral field with increased complexity of a foveal display.[14,16] In Study 2 the complexity of the entire pattern is systematically varied.

Study 2: Kanji Characters

If subjects have difficulty constructing a representation of a novel stimulus with a narrowed visual field, then increasing the complexity of the stimulus pattern should correspondingly increase the difficulty of constructing an image of it. The two models in Fig. 1 can be used to represent alternative views of the effect of complexity on visual field size, if the three lines are labeled from top to bottom as High, Medium and Low Complexity, respectively. Less study time should be required to process a less complex stimulus, which is consistent across both models. The predictions from Model 1 are that as complexity increases, a progressively smaller visual field is usable. With low complexity, the subject can make use of a larger visual field, and restricting it beyond the critical size results in an increase in processing time.

The alternative view in Model 2, is that as complexity increases, the subject needs a progressively larger visual field to be able to construct a meaningful representation of the stimulus. For high complexity stimuli, any restriction of the visual field beyond the critical size will increase processing time. For low complexity stimuli, the critical field size is smaller; restriction of the field makes little difference as the subject only needs a relatively narrow view to accurately process the stimuli. However, if the visual field is further restricted, then performance suffers.

These models were tested in the present study, together with replicating the familiarity effect. Novel stimuli, varying systematically in complexity were shown across 10 testing sessions.

Method

Subjects. The two subjects from study one also participated in this study. They had been in Japan for six months and at the time of this study could read the Hiragana and Katakana syllabaries, but could not read Kanji.

Apparatus and Stimuli. The apparatus from Study 1 was also used in this study. The visual patterns presented to the subjects were Kanji—one form of Japanese writing characters. These characters are Chinese in origin and were initially similar to abstract pictographs, but have since been modified by standardization, simplification and reproportioning so that each is about the same size and fits into a square. While there are an estimated 48,000 Kanji characters, 1,850 have been designated in Japan for general use. One means of classifying Kanji is by the number of strokes the character contains, and tables so-arranged appear in the front of most Japanese dictionaries.

Stimuli for this experiment were selected to form three levels of complexity (see Fig. 5). Three groups of 50 stimuli each were ultimately selected from characters consisting of: 4-6 strokes (Complexity level 1), 10-12 strokes (Complexity level 2), and 18-22 strokes (Complexity level 3). First a larger pool of potential stimuli were selected from the last two of three series of a set of commonly used character cards, resulting in characters of low frequency of use.

Both subjects then looked through a listing of the total set of characters and rejected any which they felt they might have seen before. From these remaining characters, 150 were selected at random and were grouped into appro-

Kanji Study

Complexity level	No. of strokes	Examples		
Low	4 - 6 strokes	史	甘	央
Middle	10 - 12 strokes	造	般	答
High	18 - 22 strokes	懸	離	議

Fig. 5. Samples of Japanese Kanji characters from three complexity levels used in Study 2.

priate levels. Thus, meaningless (to these subjects) visual patterns which varied systematically in complexity were used as stimuli. Examples of Kanji from the three levels are given in Fig. 5. The 50 stimuli at each complexity level were divided randomly into 5 sets of 10 each. Each set was shown at one visual field size throughout the study. No stimulus was shown twice in the same session.

Design. Five visual field sizes were used in this study: 5° × 5°, 8° × 8°, 11° × 11°, 14° × 14° (the size of the stimuli on the CRT), and the unrestricted condition. In the first session, subjects were tested in a counterbalanced design from the smallest to the largest, then from the largest to the smallest field size. In the ascending series, five of the stimuli in each of the three complexity levels (thus, 15 stimuli in all) were shown for each visual field size. The remaining five in each level were shown in the descending series. In this way, 30 different stimuli were shown at each of the five visual field sizes, resulting in the total 150 stimuli being shown per session.

In the second session, the same procedure was followed except that the counterbalanced order of visual field sizes was large to small, then small to large. There were a total of 10 sessions, the procedure for the odd numbered sessions repeating Session 1's, that of the even numbered repeating Session 2's. The same random set of 10 stimuli was used throughout for each visual field size.

Procedure. Prior to each session the equipment was calibrated, which also served to refamiliarize the subjects with the apparatus. After a short rest, the experimenter selected the beginning visual field size, inserted a practice stimulus into the card holder, and signaled the subject with a buzzer to begin the trial. When ready, the subject pushed a button to display the stimulus and restricted field on the monitor. The task was to study the pattern as long as necessary, until he or she felt that it could be positively recognized if a recognition memory test were given after that visual field size. As these were now trained subjects (from the previous study), and to keep the testing sessions within reasonable time limits, no recognition test was actually given.

After three practice trials the session was begun. Each session lasted approximately two hours, including short rests between each field size. Each subject took part in 10 sessions. The study time was recorded for each stimulus; data were averaged across the two subjects for analyses.

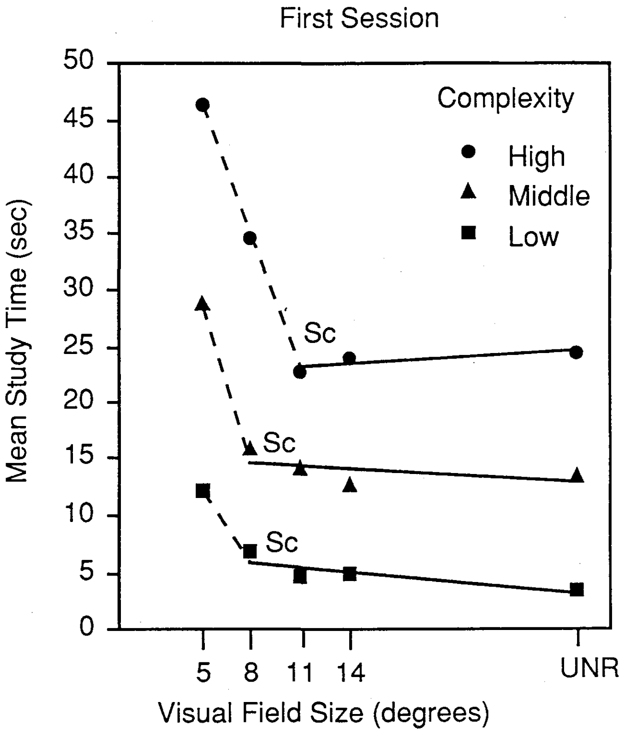

Fig. 6. Study time results for the first session of Study 2 by visual field size and complexity of the stimuli.

Results

Complexity. The study times per stimulus were summed for each visual field in each session and were averaged across the two subjects. Study time data are presented by visual field size in Fig. 6 for the first session only. It is clear that the more complex the stimuli, the greater the study time required at all visual field sizes.

The same procedure as in Study 1 was used to determine the critical visual field sizes for each complexity level. A solid regression line was fitted in Fig. 6 to points which did not differ significantly from one another for each complexity level. Visual field sizes which differed significantly were connected by a broken line. The intersecting point of the lines was taken to be the critical visual field size (s_C) for that level of complexity. As complexity decreased, s_C also tended to decrease, supporting the second model for complexity outlined earlier.

Familiarity Effects. The study time data are plotted across sessions by complexity level in Fig. 7. Typical learning curves result, with the least complex stimuli

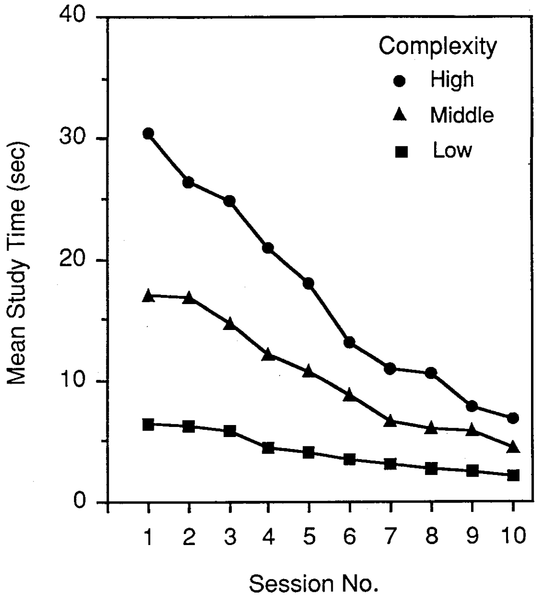

Fig. 7. Study time results across sessions for high, middle and low complexity stimuli (all visual fields combined).

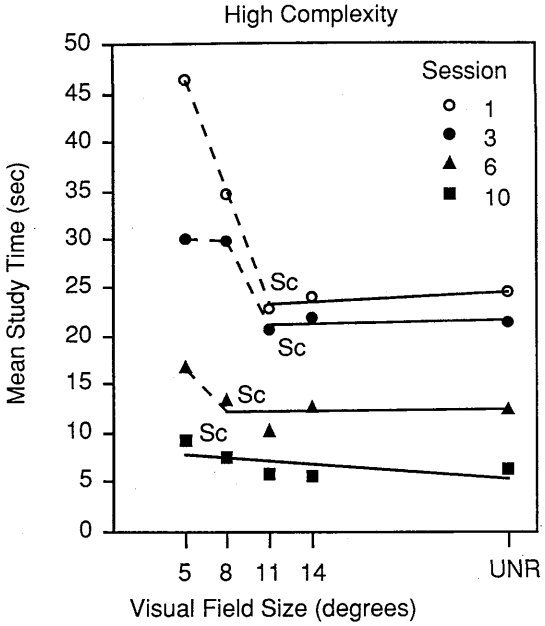

Fig. 8. Mean study times for high complexity Kanji characters in Study 2 at various visual field sizes during representative sessions.

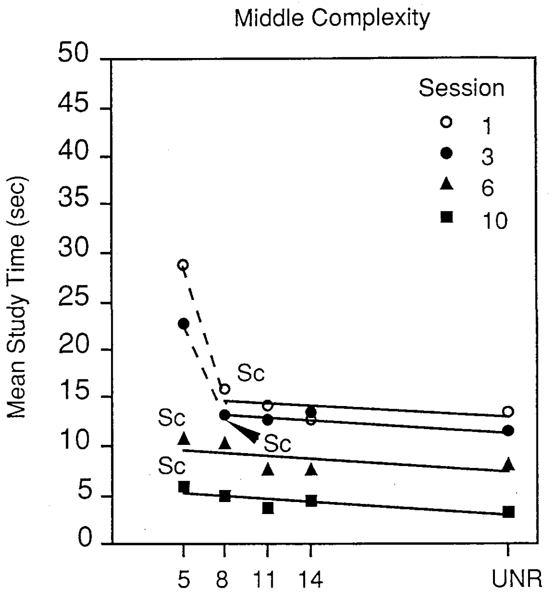

Fig. 9. Mean study times for middle complexity Kanji characters in Study 2 at various visual field sizes during representative sessions.

requiring the least study time initially, and with steady decreases in study times across sessions for all complexity levels.

In Figs. 8, 9 and 10 the study time data are plotted separately for each complexity level, by visual field size for representative sessions (the first and last, plus Sessions 3 and 6, which, together with Session 10, show apparent shifts in critical field size). The solid and broken lines were fitted as for the previous figures. For the high complexity stimuli (Fig. 8), the critical visual field decreases as the stimuli become increasingly familiar, reaching the minimum level by Session 10. Corresponding shifts occur at the other complexity levels, but with the minimum visual field size reached more rapidly in the middle (Fig. 9) and low (Fig. 10) complexity stimuli by Sessions 6 and 3, respectively. Thus, as learning of new stimuli occurs, the critical visual field size is seen to decrease correspondingly.

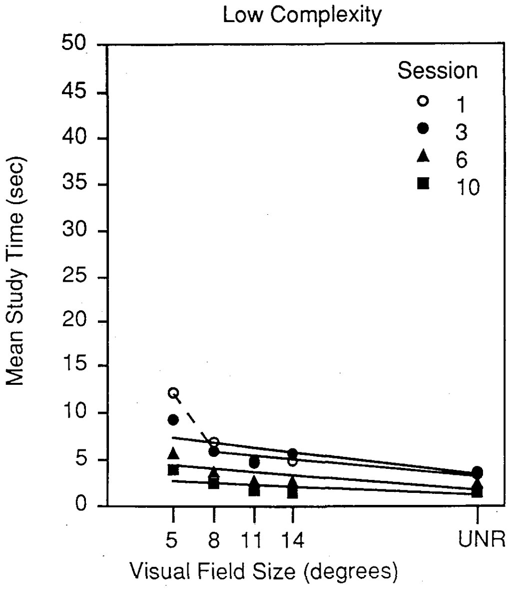

Fig. 10. Mean study times for low complexity Kanji characters in Study 2 at various visual field sizes during representative sessions.

Discussion

The familiarity findings here replicated the Study 1 findings, providing additional support for Model 2 in Fig. 1. Subject reports were consistent with the previous study. In Session 1 they reported great difficulty in constructing an initial representation of what they were viewing under the narrowest visual fields, particularly for the most complex stimuli, which is reflected in their increased study times. They reported having been able to process many of the small parts of the Kanji characters, but being unable to organize the pieces easily into a coherent image. This was less problematic for the largest visual field sizes. The very similar pattern of results for the other complexity levels suggests that the task was much the same for the initial presentation of all novel stimuli, regardless of its complexity.

The differences in critical visual field sizes with complexity level in the first session were consistent with the second of the complexity models presented. With increasing complexity, a larger visual field size was needed for optimal performance. The similarity in the patterns of outcomes for the familiarity and the complexity data is probably more than coincidental. One of the major effects of familiarity with a display may be the construction of a representation in which certain unique features, analogous to Loftus and Mackworth's[3] informative areas, are then highlighted to facilitate future recognition. Thus a complex pattern with many components can be reduced to a pattern with several essential recognition components, serving to reduce the subjective complexity of the stimulus as it becomes more familiar.

General Discussion

Both studies provided strong support for the view that an unfamiliar stimulus requires a large visual field for optimal processing, but that with practice, less and less of the stimulus is needed for optimal recognition performance to occur. This view is seemingly at odds with earlier reports that the effect of practice is to increase the size of the visual field from which information is extracted. The contradiction is only apparent, however, and can be reduced to the difference between what subjects "need" and what they can "make use of." In previous work[13,17] subjects were reported to be able to make use of larger visual fields with practice, and this was indirectly corroborated in the difference between trained and untrained subjects in the Ikeda and Takeuchi[14] study. In our studies, we have little doubt that the subjects were able to make use of visual field sizes larger than the critical sizes, even on the first experiences with a stimulus. They performed at optimal levels at the larger visual field sizes. As they became more practiced with the stimuli, they may well have been able to make use of increasing areas, if "making use of" larger areas means obtaining information from the patterns at increasing distances from the fixation point. Our data simply did not address this issue.

Our studies identified the visual area needed to attain optimal performance, and how these needs are affected by learning. We interpret the data as showing that when confronted with a pattern from a novel class of stimuli, the subject's visual needs are great. For optimal performance, a visual field size corresponding to approximately 50% of the entire pattern (11° × 11°) is needed for complex patterns, perhaps somewhat less (8° × 8°) for less complex stimuli. With practice, however, subjects reach optimal levels when seeing much smaller segments of the stimuli, performance having been limited in these studies by the window sizes used in the experiments, rather than by reaching information processing limits.

As a result of these data with unfamiliar patterns, a reinterpretation and expansion of the two-component view of pattern recognition[2] seems possible. We propose a prior, basic learning or *constructive* component from which the two recognition components derive. In this view, when a subject is confronted with a truly novel pattern, the first task is to construct an internal representation or memory trace of that pattern. To accomplish this task, the simultaneous availability of a large proportion of the entire pattern is needed. Our studies here suggest approximately 50% of the pattern, and similar findings were reported in Saida and Ikeda.[5] Once this initial representation has been formed, the mechanisms suggested in the two-component models begin to apply. However, the identification of unique, potential areas of informativeness seems to accrue gradually across trials, with increased practice with the stimuli. One of the tasks was identifying the range of possible variants in the entire stimulus class. Even in the later sessions the subjects were defining characteristics of the general class to which the stimuli belonged, as well as identifying unique aspects of individual stimuli. For example, in one of the last sessions one subject became aware of the possibility of "radicals" (i.e., miniaturized Kanji segments) being nested in the stimuli, a characteristic of many of the most complex stimuli. When the class variants are established, the subject's cognitive task becomes less open-ended. Once initial representations had been stored for the individual stimuli, the task would have gradually evolved for the subjects into more of the recognition task described by Loftus and Bell. On subsequent early sessions, when a pattern was displayed, a representation is reconstructed, and general, global information is extracted, resulting in hypotheses of where unique information may be contained which would verify the representation. In these intermediate stages of familiarity, the process of reconstructing the internal representation continues to be interfered with when the visual field is restricted, resulting in the longer study times for narrow visual fields. With wider fields, the representations are readily reconstructed, resulting in rapid recognition. Finally, as a stimulus class becomes very familiar, subjects need only to see small segments of an exemplar to reconstruct a potential representation, leading to an active search of the potentially unique areas which will confirm identification of the pattern. As these areas are small in relation to the overall stimulus, restriction of the visual field is of less consequence when a stimulus is familiar, than when it is not. In this way, the relative contribution of the constructive component comes to be less, with the global and search components taking on predominant roles.

In everyday situations, a change in processing needs, parallel to what is being proposed here, can be seen in a variety of contexts. For a traveler who is unfamiliar with a large foreign city, providing a series of details (perhaps small maps) about small segments of the city do not usually assist in building a cognitive map that is useful in understanding the layout of the city. It is rather like trying to construct a new jigsaw puzzle without the picture on the box. However, once an overall view of the area is generally understood (or the puzzle has been constructed several times), small local parts can be more easily placed in the larger picture. Indeed, a city can often then be identified from only a partial map.

The three component model and the changes in the visual field found in our studies are most appropriate to describe the processing of patterns and pictures; the process is probably somewhat different for reading. In our view, the perceptual parser proposed for reading by Morris *et al.*[12] would be subdivided into constructive and global processing components. Whereas the general class of stimuli (text) is familiar, the actual patterns scanned may be continuously novel. In this case, the construction of representations remains important, with a wide visual field essential. The Ikeda *et al.*[1] study implies that for familiar types of text, the critical visual field size may be larger than for less familiar types.

Finally, these studies serve to emphasize that in studies of visual pattern processing, it is essential to evaluate how familiar the patterns are to subjects. Degree of familiarity has been shown here to affect processing parameters, and it should, therefore, be directly considered in interpreting outcomes.

References

1) M. Ikeda, K. Uchikawa and S. Saida: Opt. Acta **26** (1979) 1103.
2) G.R. Loftus and S.M. Bell: J. Exp. Psychol.: Human Leaning Mem. **1** (1975) 103.
3) G.R. Loftus and N.H. Mackworth: J. Exp. Psychol.: Human Percep. Performance **4** (1978) 565.
4) N.H. Mackworth and J.S. Bruner: Human Dev. **13** (1970) 149.
5) S. Saida and M. Ikeda: Percept. Psychophys. **25** (1979) 119.
6) W.W. Nelson and G.R. Loftus: J. Exp. Psychol.: Human Leaning Mem. **6** (1980) 391.
7) S. Shioiri and M. Ikeda: Perception **18** (1989) 347.
8) M. Ikeda, S. Saida and T. Sugiyama: Percept. Psychophys. **22** (1977) 165.
9) M. Ikeda and S. Saida: Vision Res. **18** (1978) 83.
10) G.W. McConkie and K. Rayner: Percept. Psychophys. **17** (1975) 573.
11) K. Rayner, A.D. Well, A. Pollatsek and J.H. Bertera: Percept. Psychophys. **31** (1982) 537.
12) R.K. Morris, K. Rayner and A. Pollatsek: J. Exp. Psychol.: Human Percept. Performance **16** (1990) 268.
13) F.L. Engel: Vision Res. **11** (1971) 563.
14) M. Ikeda and T. Takeuchi: Percept. Psychophys. 18 (1975) 255.
15) K. Rayner: Psychol. Bull. 85 (1978) 618.
16) M. Voss: *Manned Systems Design: NATO Conference Series III*, eds. J. Moraal and K.F. Kraiss (Plenum, New York, 1981) Vol. 17, p. 235.
17) F.L. Engel: Vision Res. **17** (1977) 95.