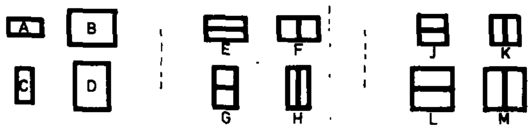
PERCEPTION OF A VISUAL STIMULUS IN A SELECTIVE ATTENTION PARADIGM



L.C. BOER

VRIJE UNIVERSITEIT TE AMSTERDAM

PERCEPTION OF A VISUAL STIMULUS IN A SELECTIVE ATTENTION PARADIGM

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor in de sociale wetenschappen
aan de Vrije Universiteit te Amsterdam,
op gezag van de rector magnificus
dr. H. Verheul,
hoogleraar in de faculteit der wiskunde en natuurwetenschappen,
in het openbaar te verdedigen
op donderdag 11 november 1982 te 15.30 uur
in het hoofdgebouw der universiteit, De Boelelaan 1105

door

LOUIS CAREL BOER

geboren te Schipluiden

Sneldruk
Boulevard, Enschede

Promotor : Prof. dr. S.D. Fokkema
Copromotor: Dr. P.J.G. Keuss
Coreferent : Prof. dr. A.F. Sanders

to Minke

Acknowledgements

I wish to thank *dr. Paul Keuss* for introducing me to the area of perception and performance. The dissertation is a continuation of the research described in our first shared publication, which appeared in Perception & Psychophysics (1979, 25, 197-204), which in turn was a continuation of an earlier report of dr. Keuss (Perception & Psychophysics, 1977, 21, 371-376). It has been a pleasure cooperating with dr. Keuss.

I also wish to thank *prof. Fokkema* for his kind supervision; *prof. Sanders* for his valuable critique on an earlier draft of the dissertation; and *Marie-José Huis in 't Veld* and *Evert Jan Stoffels* for their help in collecting the data. Further thanks go to my present employer, the *Institute for Perception TNO* at Soesterberg, for providing me with the time and the facilities to complete the dissertation. Finally, I thank those who gave their valuable editorial assistance, and I thank *Ingrid Honhoff* for her typing.

Contents

1. General introduction: Perception of a visual stimulus in a selective attention paradigm 7

2. Integrality over different paradigms: Card sorting and two-stimulus matching 18

3. Presentation rate over two different paradigms 36

4. Global precedence as a postperceptual effect: An analysis of speed-accuracy tradeoff functions 56

5. Summary, and speculations on the nature of global dominance 82

6. Samenvatting van "Waarneming van een visuele stimulus in een selectieve-aandacht taak" 92

Note—Chapters 2 and 4 have also been published as separate articles in *Perception & Psychophysics*, 1981, 29, 71 - 76; and 1982, 31, 358 - 366; respectively.

Chapter I

General introduction: Perception of a visual *stimulus in a selective attention paradigm*

Is it possible to attend selectively to one aspect of a visual stimulus? In general, the answer is "sometimes, it is; sometimes it is not". This dissertation discusses some characteristics of perception that determine whether or not selective attention is possible. Chapters 2 and 3 concentrate on a particular condition causing problems for selective attention, namely, when the aspects of the stimulus are perceived as <u>integral</u>. Chapter 4 concentrates on a condition where perception of the stimulus begins with a diffuse, global impression. This introductory chapter will discuss the main points of these two conditions. Moreover, a third condition (connected with the name of C.W. Eriksen) will be mentioned briefly because of its interrelations with the other conditions. Before elaborating the three conditions, I will start with a description of a general selective-attention paradigm, used in this dissertation.

The typical task requiring selective attention invites the subject to concentrate on some particular aspect of the visual stimulus, and to ignore all other aspects as much as possible. Generally, the measure is either the time to judge the relevant aspect (the reaction time), or the accuracy of that judgment. It is clear that the subject had selective attention problems if the judgments on relevant aspects show an influence due to the irrelevant (to be ignored) aspects. Usually, this influence is detrimental and is denoted as interference. We may term this a failure of selective attention. However, such cases should not be judged too harshly. In fact, selective attention instructions led to near perfect assesments, but at a cost, such as an increase in reaction time. Perfect selective attention, by contrast, would mean that no costs could be measured.

Eriksen has studied selective attention with letters as relevant and irrelevant aspects. The relevant letter is called the target and the irrelevant letters are termed noise letters or flanking letters, since they usually appear on one or both sides of the target letter. The location of the target is known in advance. Since the target appears in the centre of the visual field, little if any limits of the visual system will play a role. Greater difficulty of recognizing the target due to presence of flankers operates mainly outside the fovea. Moreover, this "lateral interference" (see Bouma, 1978, for a review) is due to the simple presence of flankers, while the selective attention problem reported by Eriksen depends critically on the identity of the flankers; interference is only obtained when flanker identity conflicts with target identity (e.g. Eriksen & Eriksen, 1974, 1979; Eriksen & Schultz, 1979). For example, with two possible target letters, H and S, interference is present when the H is flanked by "conflicting" Ss (SHS), while interference is absent when the H is flanked by "consistent" Hs (HHH). The explanation is that the flankers are processed to the level of incipient response activation. Note that perception of the irrelevant flankers is not always detrimental, unlike lateral interference. The point is that the subject is unable to prevent the flankers from evoking incipient responses. This is sometimes innocent, sometimes harmful.

Again, it should be stressed that the failure of selectivity is only limited. After all, the subject can manage to do the task; it only needs some extra time. Moreover, other evidence suggests that subjects are selective; they can and do direct their attention towards the spatial position reserved for the target letter (Bashinski & Bacharach, 1980; Posner, Snyder, & Davidson, 1980) thereby, "amplifying" the perceptual information arriving from that position. The failure of perfect selectivity only shows that not all of the information stemming from irrelevant positions is ignored.

The degree of interference, or selective attention failure, decreases when the separation between flankers and target is increased. Good selective attention is, generally speaking, possible when the flanking "noise" is over one degree of visual angle removed from the target (Eriksen & Hoffman, 1972, 1974). The interference increases when the incompatibility, or "conflict", between flankers and target is more pronounced. This explains why Gatti and Egeth (1978) obtained interference even when the distance between target and noise was as great as 5°. They used the Stroop Task (named after Stroop, who reported the phenomenon in 1935) famous for its extreme incompatibility. Further, the interference is influenced by the relative "clarity", or "conspicuity", of flankers and target, as for example shown by Eriksen and Schultz's (1979) manipulation of contrast and size.

To sum up the findings for the Eriksen paradigm: Irrelevant flanking noise is registered and processed along with the relevant target. For foveally presented targets, the interference does not stem from lateral interference, but from conflicting responses activated by the noise. Perceptual input of the flanking noise is decreased (hence a decrease in interference) by (1) attending to the target position (2) presenting the flankers farther away from the target. Invoking Posner's notion of psychological pathways (Posner, 1978) one could say that the noise interferes more when it travels along well-paved pathways, whether the paving was done by perceptual (retinal) factors, attentional strategies, instructions (such as defining the response set), previous experience, or innate tendencies.

The second situation in which selective attention has been studied systematically capitalizes on stimulus factors. Garner proposes excluding noise types that run the risk of eliciting conflicting response tendencies (e.g. Garner, 1976, p. 103). He has also little interest in retinal factors, though it seems possible that they play a role here too. Another difference between this and the Eriksen paradigm is that relevant and irrelevant aspects together constitute one and the same object; for example, the relevant aspect of a rectangle is its size, and the irrelevant aspect is its form. The basic theme that Garner develops can be considered as a differentiation of the old Gestalt tenet that the whole stimulus ocnsists of more than a summation of isolated aspects. This "more" causes selective attention failures.

Garner aims at defining which aspects, when combined, will form an integrated whole, this being indicated by a failure of selective attention. The point is that integral aspects are just one unitary aspect to the perceiver, while separable aspects are perceived as two separate aspects. Selective attention to separable aspects is, of course, good. It is not clear what causes the interference due to integrality. Admittedly, the irrelevant aspect is perceived together with the relevant aspect, but this fact in itself does not explain the interference, especially since the aspects are not conflicting. Felfoldy (1974) suggested that sequential effects are the cause of interference, but this account was shown to be incomplete. Certainly sequential effects do play some role, but the interference remains, even when they are adequately controlled for (see especially chapter 3 of this dissertation; see also King Gruenewald, & Lockhead, 1978; and Dykes & Cooper, 1978). Lockhead, Gruenewald, and King (1978) suggested that the increased variability due to the irrelevant aspect increases classification times. Redding and Tharp (1981) suggested that it is a matter of response conflict, just like in the Eriksen paradigm. The issue is still unresolved.

A further problem with Garner's system is that the conclusions are so dependent on the set of stimuli used. This severely limits the generality of the conclusions. Lockhead has demonstrated this point several times (e.g. King, Crist, & Lockhead, 1979) by showing that the rated similarity between integral stimuli gives a very good prediction of the speeded classification tasks used by Garner. This similarity, in turn, can sometimes be changed dramatically by a small physical change in one of the aspects (Lockhead & King, 1977), so as to result in a very different pattern of data for Garner's classification tasks.

Garner tried to overcome the problem by looking for a physical definition of integrality. One such a definition (Garner & Felfoldy, 1970) was, that aspects should be integral if one aspect cannot exist without the other (as size and shape of an object; or pitch and intensity of a tone). Such a definition would greatly increase the predictive power of the integrality concept. Unfortunately, the attempt has not been much of a succes and was not pursued further. However, the possibility of a physical definition should not be excluded altogether.

Lacking a physical definition, the definition of integrality runs the risk of circularity. If integrality can only be detected from selective attention failures then integrality is only a restatement of that experimental result--not an explanation. For this reason, Garner was careful to use as many other tasks as possible. In addition to selective attention studies, he also used tasks without time pressure, namely, similarity judgments and free classifications (e.g. Garner, 1974); and tried to touch also on concept learning and choice tasks (Garner, 1976). The underlying rationale is that a concept is useful when several qualitatively different paradigms all converge on that same concept. (The formal treatment of the idea of converging operations has been given by Garner, Hake, & Eriksen, 1956). Based on such convergent evidence it seems plausible to conclude that integrality exists--two aspects can be one unitary aspect to the perceiver. This serves as an assumption in the present dissertation, where the next two chapters use speeded classification tasks (mainly selective attention tasks) only, and therefore can not provide further evidence of the value of the integrality concept for other tasks.

The third situation of a deficit in selective attention concentrates on the relatively greater globality of one aspect over the other. Navon (1977) initiated many research attempts by contending that perception begins with a global impression to which detail, or local, information is subsequently added. His global-to-local model of perceptual development predicts that selective attention to global aspects will be perfect. The local information can be ignored completely, since the subject taps the developing perceptual information at the moment that only global aspects are represented. The global aspect, on the other hand, is impossible to ignore, and selective attention to local aspects will thus fail. The result has been obtained several times: good selective attention to global, poor selective attention to local aspects (Miller, 1981; Martin, 1979; Navon, 1981). Somewhat more controversial than the result, is the interpretation in terms of the global-to-local model of perceptual development. Chapter 4 and the last part of chapter 5 give a more extensive treatment of the "global dominance" results. In this introduction, I will outline how the global-to-local model relates to the paradigms of Eriksen and Garner, and how the model relates to Gestalt Psychology.

The interference due to failing selectivity appears only when global and local aspects are in conflict. This is the same as for the Eriksen paradigm. The supposed precedence of global information is, in fact, tantamount to an Eriksen task in which targets and flankers are presented in succession (Eriksen & Hoffman, 1972). Both the Eriksen and the Navon situation differ from Garner's paradigm in which response conflict is deliberately avoided. It is possible that the aspects in both response-conflict situations are separable, despite their interference. Separability even seems likely for Eriksen's situation and may also apply to Navon's global and local aspects. On the other hand, if Navon is right, and if global precedes local, there is an early perceptual stage during which only the global aspect is represented. At that point in time it does not make sense to discuss the way in which aspects relate--there is simply no possibility for a relation.

The global-to-local model ascribes the impossibility of ignoring the global aspect to the ontogenesis of the percept. The problem of Aktualgenese (or microgenesis of percepts) has been studied by Gestalt psychologists. In particular, Sander and his students concentrated on "das Werden von Gestalten" (Undeutsch, 1942, p. 39). They assumed that presenting the stimulus under poor viewing conditions (in extreme miniature, very briefly, or peripherally) delayed Aktualgenese to such an extent that the process became accessible to consciousness. However, the conceived Aktualgenese as a warfare between "psychodispositional constants" or "structural tendencies" on the one hand, and the claims of the stimulus pattern on the other hand (Sander, 1930). Is was not temporal arrival of levels of stimulus information which had the interest, but the endogeneous forces of the observer who, for example, tried to make a good Gestalt. To the subjects of those days, the task was emotionally charged, and to no small extent. For example, violating the structural tendencies of the subject induced "dissatisfactions, torturing tensions, and repudiations" (Sander, 1930, p. 195), and observers report "a veritable fear of dissolution", "a mood to presage disaster" (p. 201) just before the tilt of one picture in the stereoscope becomes so deviant that binocular fusion fails.

The brief introduction illustrates some problematic aspects of the Gestalt results. The assumption that poor viewing conditions served only to delay Aktualgenese seems risky, to say the least. For example, it is possible that the subjects did not report what they saw, but which interpretation they preferred. In particular, the intense emotionality (strange to modern experiments) should make one aware of the possibility of unveridical report. Secondly, some ways of stimulus presentation have the effect of selectively removing the local details (pheripheral presentation; presentation in extreme miniature). Such presentations are ill-suited to study the global-to-local issue. Flavell and Draguns (1957, p. 200) summarized the status of the Gestalt studies on microgenesis: "many of these studies would be considered quite poor by present-day methodological standards".

Navon (1977) was the first, but not the last, of recent authors, who theorized on the potential relevance of microgenesis. Other recent interest in microgenesis came from the continuous-flow model of Eriksen and Schultz (1978, 1979). They draw an analogy between microgenesis and a photographic film immersed in a developer. However, the predictions of this model are much less clear-cut than for the global-to-local model. A third recent report that considers microgenesis as a good explanation for some results comes from Calis and Leeuwenberg (1981). As in Gestalt Psychology, they equate microgenesis with the development of a perceptual structure (p. 1395), and not with an order of availability of perceptual information. This viewpoint will be considered again in chapter 5.

References

Bashinski, H.S., & Bacharach, V.R. Enhancement of perceptual sensitivity as the result of selectively attending to spatial locations. Perception & Psychophysics, 1980, 28, 241 - 248.

Bouma, H. Visual search and reading: Eye movements and functional visual field: A tutorial review. In J. Requin (Ed.), Attention and performance VII. Hillsdale, N.J.: Erlbaum, 1978.

Calis, G., & Leeuwenberg, E. Grounding the figure. Journal of Experimental Psychology: Human Perception and Performance, 1981, 7, 1386 - 1397.

Dykes, J.R. & Cooper, R.G. An investigation of the perceptual basis of redundancy gain and orthogonal interference for integral dimension. Perception & Psychophysics, 1978, 23, 36 - 42.

Eriksen, B.A., & Eriksen, C.W. Effects of noise letters upon the identification of a target letter in a nonsearch task. Perception & Psychophysics, 1974, 16, 143 - 149.

Eriksen, C.W., & Eriksen, B.A. Target redundancy in visual search: Do repetitions of the target within the display impair processing? Perception & Psychophysics, 1979, 26, 195 - 205.

Eriksen, C.W., & Hoffman, J.E. Temporal and spatial characteristics of selective encoding from visual displays. Perception & Psychophysics, 1972, 12, 201 - 204.

Eriksen, C.W. & Hoffman, J.E. Selective attention: Noise suppression on signal enhancement? Bulletin of the Psychonomic Society, 1974, 4, 587 - 589.

Eriksen, C.W. & Schultz, D.W. Temporal factors in visual information processing: A tutorial review. In J. Requin (Ed.), Attention and performance VII. Hillsdale, N.J.: Erlbaum, 1978.

Eriksen, C.W., & Schultz, D.W. Information processing in visual search: A continuous flow conception and experimental results. Perception & Psychophysics, 1979, 25, 249 - 263.

Felfoldy, G.L. Repetition effects in choice reaction time to multidimensional stimuli. Perception & Psychophysics, 1974, 15, 453 - 459.

Flavell, J.H., & Draguns, J. A microgenetic approach to perception and thought. Psychological Bulletin, 1957, 54, 197-217.

Garner, W.R. The processing of information and structure. Potomac, M.D.: Erlbaum, 1974.

Garner, W.R. Interaction of stimulus dimensions in concept and choice processes. Cognitive Psychology, 1976, 8, 98 - 123.

Garner, W.R., & Felfoldy, G.L. Integrality of stimulus dimenensions in various types of information processing. Cognitive Psychology, 1970, 1, 225 - 241.

Garner, W.R., Hake, H.W., & Eriksen, C.W. Operationism and the concept of perception. Psychological Review, 1956, 63, 149 - 159.

Gatti, S.V., & Egeth, H.E. Failure of spatial selectivity in vision. Bulletin of the Psychonomic Society, 1978, 11, 181 - 184.

King, M.C., Crist, W.B., & Lockhead, G.R. Context and goodness in a focusing task. Perception & Psychophysics, 1979, 26, 305 - 311.

King, M.C., Gruenewald, P., & Lockhead, G.R. Classifying related stimuli. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 417 - 427.

Lockhead, G.R., Gruenewald, P., & King, M.C. Holistic vs. attribute repetition effects in classifying stimuli. Memory & Cognition, 1978, 6, 438 - 445.

Lockhead, G.R., & King, M.C. Classifying integral stimuli. Journal of Experimental Psychology: Human Perception and Performance, 1977, 3, 436 - 443.

Martin, M. Local and global processing: The role of sparsity. Memory & Cognition, 1979, 7, 476 - 484.

Miller, J. Global precedence in attention and decision. Journal of Experimental Psychology: Human Perception and Performance, 1981, 7, 1161 - 1174.

Navon, D. Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 1977, 9, 353 - 383.

Navon, D. The forest revisited: More on global precedence. Psychological Research, 1981, 43, 1 - 32.

Posner, M.I. Chronometric explorations of mind. Hillsdale, N.J.: Erlbaum, 1978.

Posner, M.I., Snyder, C.R.R., & Davidson, B.J. Attention and the detection of signals. Journal of Experimental Psychology: General, 1980, 2, 160 - 174.

Stroop, J.R. Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 1935, 18, 643 - 662.

Sander, F. Structure, totality of experience, and Gestalt. In C. Murchison (Ed.), Psychologies of 1930. Worcester, Mass.: Clark University Press, 1930.

Redding, G.M., & Tharp, D.A. Processing line location and orientation. Journal of Experimental Psychology: Human Perception and Performance, 1981, 7, 115 - 129.

Undeutsch, U. Die Aktualgenese in ihrer allgemeinpsychologischen und ihrer charakterologischen Bedeutung. Scientia, 1942, 72, 37 - 42; 95 - 98.

Chapter II

Integrality over different paradigms: Card sorting and two-stimulus matching

Orthogonal interference--indicating the cohesiveness between geometrical dimensions--was examined using two separate tasks: (1) card sorting and (2) two-stimulus matching requiring same/different responses. The card-sorting results of the present experiment were contrasted with the results of previous research (Boer & Keuss, 1979; Keuss, 1977) which used the two-stimulus matching task. Results were generally similar in that the orthogonal interference and, consequently, the degree of integrality/separability were the same for both tasks. Evidence was found for the emergence of a new nominal dimension. This and other results are only compatible with a weaker form of the global-to-local hypothesis of perceptual processing.

The study of the perceptual relationship between the "attributes," or "dimensions," that constitute a stimulus has led to the concepts of integrality and separability (e.g., Garner & Felfoldy, 1970; Lockhead, 1972). The typical test that reveals these concepts invites the observer to focus his attention on the dimension that determines category membership--this dimension is termed the relevant dimension--and, if possible, *not* to attend to any other (irrelevant) dimension. This report examines whether these concepts are equally valid for two separate tasks. The first task, used widely in this field, requires the subject to sort a pile of cards, one stimulus per card. The deck contains, say, 25 cards, and the subject speed-sorts them into two piles or categories. Studies with more technical sophistication do not use actual cards, but, for historical reasons, we prefer the term "card sorting" (cf. Felfoldy, 1974). The second task studied here is known as the two-stimulus matching task. Stimuli are presented in pairs and the subject bases his response on a comparison, or a match, between the stimuli of a pair. We will discuss these two tasks in order.

In card sorting, performance with a critical series of stimuli is contrasted with performance in a baseline-condition series of stimuli. The critical series requires the observer to treat stimuli that differ on the irrelevant dimension as identical. This secondary dimension varies orthogonally; that is, it is not possible to predict the state of the secondary dimension from the state of the relevant dimension, or vice versa. Orthogonal performance--the adjective "orthogonal" will be used to denote the critical series of stimuli in the two-stimulus matching task as well--would be best when variations in the irrelevant attribute are simply not perceived. The ideal subject would simply focus on the relevant dimension, exclude the rest of the stimulus, and directly filter out the relevant from the whole. Bivalued dimensions reduce the number of effective stimuli with a factor two, since stimuli differing on the irrelevant dimension are then perceived as identical. This reduction in stimulus uncertainty improves performance, and the expectation is that the sorting times are identical to the baseline series in which the irrelevant dimension was kept fixed.

When, however, the subject fails to consistently focus on the relevant dimension, he can still perform the task, since the attention failure is compensated for by additional processing. It is commonly supposed that the subject is highly motivated to adopt the *optimal strategy of focusing on the relevant dimension. But whether* or not he will be *able* to do so depends on the perceptual relationship between the dimensions or attributes. Separable dimensions do permit a focusing strategy. They have no "cohesive forces" between them, and the subject can filter out at will. If, on the other hand, the dimensions are integral, the stimulus is initially perceived as a whole (a Gestalt, or a blob; Lockhead, 1972) and the subject must resort to additional processing to overcome the cohesive forces between the dimensions.

It has to be kept in mind that the baseline, or unidimensional, condition with which the orthogonal performance is contrasted, is *not* supposed to be sensitive to the between-dimension relation; in this condition, within a series of stimuli, only the relevant dimension varies and the other dimension is in a fixed state throughout. (It is therefore called a univariate or unidimensional series.) The unidimensional series has thus a smaller number of actual stimuli than the orthogonal series, and the strategy of focusing on the relevant dimension does not reduce the number of effective stimuli. Unidimensional performance will consequently always be at its optimum, whether focusing is possible or not.

Now we turn to the two-stimulus matching task, in which every trial presents two stimuli instead of one. Same/different matchings (are the two stimuli similar on the relevant dimension or not?) are used widely, but other matchings exist as well (for example, Dykes & Cooper, 1978). The use of same/different judgments has the advantage that there is a growing body of knowledge about the additional processing resorted to when integrality disables the use of the focusing strategy for "same" responses. Dixon and Just (1978) and others (Besner & Coltheart, 1975, 1976; Bundesen & Larsen, 1975; Larsen & Bundesen, 1978) present evidence that a to-be-matched stimulus pair that is "same" on the relevant dimension but different on the irrelevant dimension—we call this an *orthogonal* "same" pair —is *normalized* before being compared. This process, which compensates for irrelevant disparity, can be considered a form of mental transformation (cf. Shepard, 1975).

From these considerations, it follows that the orthogonal series should have an irrelevant disparity (i.e., the irrelevant dimension is "different"), while the unidimensional series should be without an irrelevant disparity. Orthogonal "same" pairs can thus be judged as "same" only when the subject normalizes the irrelevant disparity. The increased processing of the orthogonal series, or the orthogonal interference, within the "same" response of a two-stimulus matching task can thus be considered as an indication of whether the very "cohesive forces" supposed to hamper orthogonal card sorting are operative in opposition to a dimension-wise analysis in two-stimulus matching.

It must be mentioned that in previous research (Boer & Keuss, 1979; Keuss, 1977) we had the irrelevant level fixed for a particular stimulus within the pair. For example, in the orthogonal series, the *left* stimulus of the pair always had irrelevant level x1, while the right stimulus always had irrelevant level x2. Consequently, the irrelevant level for a particular stimulus was completely known in advance of all trials. Fixed presentation of the irrelevant level, rather than nonfixed or varied presentation of the irrelevant dimension, might have prompted selective attention. If so, this procedural detail should actually cause an underestimation of the integrality between relevant and irrelevant dimensions.

By contrast, somewhat less is known about the compensatory processes resorted to in an orthogonal card-sort task. Lockhead and King (1977) have shown that, on first sighting, the stimulus is recognized in terms of similarity to other potential stimuli (or, to use their terms, that the stimulus is located in a psychological, or similarity, space). It is not clear which processing ensues if stimuli occupying different positions in similarity space are assigned the same response. "There must be additional internal processing to map two (or more) objects into a common response" (Lockhead & King, 1977, p. 442), but the nature of this process is as yet unknown. Comparing results from the card-sort task with results from the two-stimulus matching task might reveal whether the same sort of additional processing for integral dimensions is used in both tasks.

An additional point in need of clarification is that of the fixed serial availability of the dimensions that constitute a particular stimulus, that is, that perceptual processing of one particular dimension is always faster than the perceptual processing of the other dimension. Within the Garnerian system (Garner, 1976), based on card-sorting tasks, there is no provision for this situation, but that this state of affairs seemed to exist was the conclusion of our previous research (Boer & Keuss, 1979; Keuss, 1977). Judging an outline rectangle (the fastest dimension) was *not* interfered with by an inserted line (the slower dimension), while judging an inserted line was interfered with by the outline. The implication is thus an asymmetry in orthogonal interference: The slower dimension can be filtered out when judgment is of the faster dimension, but the faster dimension cannot be filtered out when judgment is of the slower dimension.

A fixed serial availability of dimensions has also some implications for *correlated* card-sort series. The dimensions of such a correlated series are combined with 100% redundancy. This leaves it to the subject to decide how to categorize: by dimension x, by dimension y, or by both. A redundancy gain relative to the unidimensional series is taken as another sign of integrality. Only if the dimensions cannot be used simultaneously will the subject fail to profit by redundancy in the correlated series.[1] This is the case when the dimensions are separable and also when one dimension is always faster than the other dimension, as in a situation of fixed serial availability. This leads to two predictions: (1) a redundancy gain relative to unidimensional series when judging is by the inserted line, and (2) no redundancy gain when judging is by the outline form.

The experiment uses a card-sort task, correlated series included. The results can be compared with the results of previous work in which the to-be-matched pair was presented simultaneously (Keuss, 1977; and the simultaneous condition of Boer & Keuss, 1979). Stimuli are, of course, the same in both paradigms.

Method

Subjects

Six university students (one female) participated as paid volunteers.

Stimuli and Apparatus

The subject sat at approximately 50 cm from the screen of a Tectronix 611 display unit, which, except for a 4 x 5 cm space, was covered. The display (P31 coated) was slightly below eye level and was used in nonstore mode. Stimuli appeared as yellowish-green outlines on a dark-gray background. A stimulus subtended a visual angle of about 1 deg 2 min. Its construction time and refresh rate were 6 msec.

Responses were made by using two conventional response buttons that were connected to microswitches. The buttons were mounted on a panel below the display unit. Depression of either button stopped stimulus presentation. Reaction time was recorded with millisecond accuracy by means of a KW8IE real-time clock. A PDP-8/i computer controlled the experiment.

All stimuli were rectangles varying dichotomously within any 240-trial series in either one or both dimensions (see Figure 1). During a stimulus series, the upper left corner of the display held the stimulus exemplar(s) belonging to the left-response category. Similarly, the upper-right corner of the display held the exemplar(s) belonging to the right-response category. The exemplars were drawn as black outlines on white index cards and were six times larger than the actual stimuli.

<u>Conditions</u>

The dichotomic dimensions used were size and form of an outline rectangle and orientation of a line inserted in the rectangle. The two levels of the size dimension were small/large, and the two levels of form and orientation were, in order, lying/standing and horizontal/vertical. There were three main conditions: SF (stimulus set: size and form), OF (orientation and form), and OS (orientation and size). Each set consisted of four stimuli. Figure 1 shows them in 2 by 2 matrices. The four stimuli of SF were: small, lying (A); large, lying (B); small, standing (C); and large,standing (D) (the letters A-D refer to the identification labels in Figure 1). The four stimuli of OF were: horizontal, lying (E); vertical, lying (F); horizontal, standing (G); and vertical, standing (H). The four stimuli of OS were: horizontal, small (J); vertical, small (K); horizontal, large (L); and vertical, large (M).

Sorting the stimuli of any main condition could be done by each of the constituent dimensions. Stimuli in a different *column* of a 2 by 2 matrix could be mapped to different responses (e.g., A and C vs. B and D) or stimuli in a different *row* could be mapped to different responses (e.g., A and B vs. C and D). Sorting was by size in condition SF and by orientation in conditions OF and OS when *column* membership was critical. Sorting was by form in conditions SF and OF and by size in condition OS when *row* membership was critical.

Any stimulus of a 2 by 2 set for a particular main condition could occur from trial to trial in the orthogonal series of that condition. Sorting was by one of the constituent dimensions, as indicated by the instructions. Only *two* of the set of four stimuli could occur in a particular unidimensional or correlated series. In a unidimensional series, one of the dimensions was held constant while the other dimension was varied. (This excluded one row or one column of the matrix, and sorting was, of course, by the dimension that varied.) There were thus four unidimensional series in each main condition: In condition SF there was an A vs. B series and a C vs. D series (both sorted by size) and an A vs. C series and a B vs. D series (both sorted by form). In a correlated series, both dimensions varied again, but in a perfectly correlated fashion. This excluded either the major or the minor diagonal of the matrix. There were thus two correlated series in each main condition: for example an A vs. D series and a B vs. C series. Sorting was by either dimension or by both, as the subject preferred.

Procedure

All subjects were presented all series of the main conditions in different random orders. Each subject ran through nine 1.5-h individual sessions, three per main condition. A three-session block for a particular main condition was completed before another block for another condition was run. The first session of a three-session block was used to familiarize the subject and was not further analyzed.

Each series consisted of 240 trials. A programming device se-

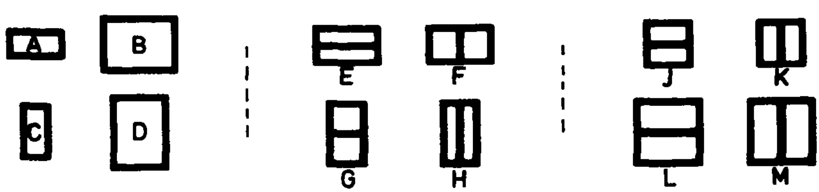


Figure 1. *The three groups of four stimuli in the card-sort task.* In left-to-right order, the groups were used in conditions SF, OF, and OS. (The labels have been added for identification. All stimuli are drawn on the same scale. The actual sizes of the stimuli were as follows: A and C measure 4.9×7.3 mm; B and D, 7.3×10.8 mm; E-H, 6.0×9.0 mm; J and K, 6.0×6.0 mm; and L and M, 9.0×9.0 mm.)

lected the stimuli in a completely random fashion. The least significant two bits of the reaction time (msec) determined the next stimulus. Depression of either button stopped stimulus presentation. The interval between the response and the construction of the next stimulus was .5 sec. This was lengthened to 1.5 sec when an error was made. The lenghtened interval began with the sounding of a 200-msec buzzer and ended with an erase-the-screen flash.

The subject was instructed to avoid errors and to react as quickly as possible. Each session began with two warm-up series that were randomly selected from the experimental series. After a 5-min break, the subject began with the eight experimental series (two correlated, four unidimensional, and two orthogonal). One series of 240 items lasted about 3-5 min, on the average. Between series there was 2-min rest. After four experimental series, the rest was lengthened to 20 min. Stimulus-to-response mapping--e.g. press left for the small stimulus and press right for the large stimulus--was reversed for the remaining four series.

Results

Error responses were few: 2.1%. Incidence of errors was tested separately and in parallel with RT. Figure 2 shows, for each main conditions (SF, OF, and OS), mean RTs and percent errors of the two correlated, four unidimensional, and two orthogonal series. Within a main condition, there was no RT/error difference between any pair of unidimensional series that were sorted by the same dimension [largest $t(5) = .438$]; neither was there a difference between any pair of correlated series [largest $t(5) = 1.710$]. Data were consequently collapsed across such pairs.

Redundancy Gains

Per main condition, the superiority of correlated xy sorting over unidimensional sorting (or the redundancy gain) was tested twice--once relative to the x-sorted unidimensional data and once relative to the y-sorted unidimensional data. In condition SF, both tests reached significance in the predicted direction [smallest $t(5) = 3.219$, $p < .02$], but in condition OF, both tests failed to reach significance. Correlated sorting even tended to be inferior to sort-by-form unidimensional performance [$t(5) = -1.684$, $p < .15$]. In condition OS, there was a redundancy gain relative to the orientation-sorted unidimensional series [$t(5) = 4.422$, $p < .01$]. The gain relative to the size-sorted series was apparent only in the error frequency, which was significantly less in the correlated series [$t(5) = 3.341$, $p < .02$].

Orthogonal Interferences

Within a main condition, the x-sorted orthogonal series was com-

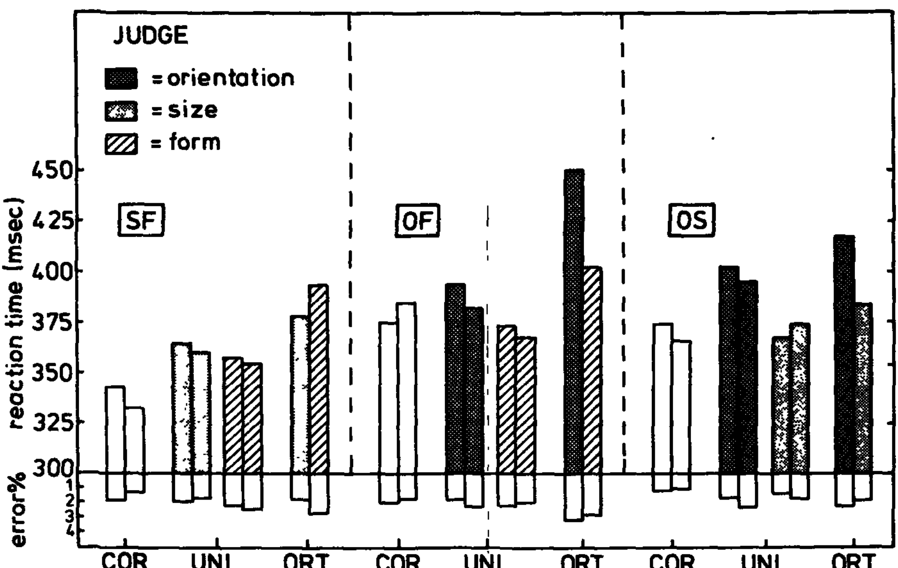


Figure 2. Reaction time and percent error as a function of the way in which the dimensions of a particular main condition were combined (correlated, unidimensional, or orthogonal).

pared with the two x-sorted unidimensional series, and the y-sorted orthogonal series was compared with the two y-sorted unidimensional series. All six such tests, two per main condition, showed significant interference [smallest $t(5) = 2.153$, $p < .05$]. In general, more errors were observed in the orthogonal than in the unidimensional series, although significance was reached only in condition OF [smallest $t(5) = 2.162$, $p < .025$]. It appears that in condition SF orthogonal interference was strongest when form instead of size had to be judged [$F(1,5) = 8.17$, $p < .05$]. In condition OF, orthogonal interference was strongest when orientation, rather than form, was to be judged [$F(1,5) = 10.39$, $p < .025$]. In condition OS, orthogonal interference did not depend on the dimension of relevance ($F < 1$).

For both OF and OS, sorting by outline—either size or form—was faster than sorting by orientation [$Fs(1,5) = 37.93$ and 29.27, respectively; $p < .005$].

Card Sorting vs. Two-Stimulus Matching

Table 1, last column, shows all six orthogonal interferences. They can be compared with previous two-stimulus matching tasks, the results of which are given in the first two columns. Note that the first two columns agree on the rank order of the interferences and not on strength per se (the probability of obtaining the same order of six combinations twice is 1:720, or less than .0014). Therefore, we prefer to compare rank orders rather than absolute results. The order of orthogonal interference of the present card-sort task was similar to the order obtained with the two-stimulus matching tasks in that the two combinations with strongest interference were, respectively, orientation with irrelevant form and form with irrelevant size (the probability of this agreement is 1:30, which is less than .04). The difference between tasks is that the two combinations of relevant outline (size or form) and irrelevant orientation showed interference only in the card-sort task.

Table 1
Orthogonal Interferences (in Milliseconds) Measured in the "Same" Response of Two-Stimulus Matching Tasks (Boer & Keuss, 1979; Keuss, 1977) and in the Card-Sort Task of the Present Experiment

	Dimension		Two-Stimulus Matching		Card Sorting
Main Condition	Rele-vant	Irrele-vant	Keuss	Boer & Keuss	Present Experiment
SF	S	F	65	30	16
	F	S	76	49	40
OF	O	F	79	73	64
	F	O	11	5	34
OS	O	S	26	9	19
	S	O	2	0	12

Note—The stimuli of a to-be-matched pair were always presented simultaneously and side by side. S = size; F = form; O = orientation.

Discussion

There appeared to be considerable agreement between the two-stimulus matching task and the card-sort task. Mutual integrality between size and form was observed in both paradigms. The asymmetric integrality between outline (size or form) and inserted line (orientation) was, to some degree, also observed in the card-sort task. In the two-stimulus matching task, irrelevant variation in the inserted line was ignored, whereas irrelevant outline variation could not be ignored. In the card-sort task, on the other hand, this asymmetry was observed in the *amount* of interference: irrelevant variation was harder to ignore in the outline than in the inserted line. This finding could point to a greater sensitivity for interference of the card-sort test. But it could also point to slightly different modes of perceiving, implying that the "cohesive forces" between dimensions depend, to some degree, on the paradigm used. The fact that the individual trial in the one task requires a judgment about a *pair* of stimuli and that the other task requires judgments only about single stimuli may have something to do with the difference in perceptual processing. In the main, however, it can be said that the meaning of integrality is the same over different paradigms.

Condition OF offers evidence for a new nominal dimension (cf. Garner, 1976), based on the way in which orientation and form are combined. The main reason to decide upon the new nominal dimension is the "redundancy loss" observed in condition OF. Inferior correlated sorting suggests that the correlated OF stimuli are more similar and, hence, more difficult to discriminate than are unidimensional sort-by-form OF stimuli. This could be caused by the way of perceiving the inserted line. It can be seen in Figure 1, stimuli E-H, that form and inserted line have something in common inasmuch as the labels horizontal/vertical and lying/standing can, in principle, describe both the form of the rectangle and the orientation of the inserted line. For instance, the line of stimulus E can be said to be consistent with the state of the rectangle, since both dimensions are "horizontal" (or "lying"). Similarly, the line of stimulus H is consistent with the surrounding rectangle, since both are "standing" (or "vertical"). The lines of stimuli F and G are, by contrast, in conflict with their rectangles, since the position of the line is not the same as that of the rectangle.

It follows that the lines in the correlated pair E/H are similar--both consistent to the rectangle--much as the lines in the other correlated pair E/G are conflicting. This renders discrimination in the correlated series more difficult. A unidimensional pair, on the other hand, with a conflicting line in the one stimulus and a consistent line in the other stimulus, is more easy to discriminate. (An additional indication for the new nominal dimension is observed in the orthogonal OF series. In both series, sorting conflicting stimuli was significantly more difficult than sorting consistent stimuli[2]). It should be noted that we do not wish to convey the idea that the subjects actually used verbal labels. This question, interesting as it may be, is beyond the scope of the present study.

There was some evidence for an outline-first availability. Sorting by outline--orthogonal or unidimensional--was faster than sorting the same stimuli by orientation of the inserted line. There are, however, two aspects of the data that are in contrast with outline-first availability: (1) sorting by outline was interfered with by the inserted line, and (2) the emergence of the new nominal dimension, mentioned in the previous paragraph. If relevant outline is perceived first, why should it combine with the interior to form a new nominal dimension?

Boer and Keuss (1979) originally suggested that White's (1976) outside-to-inside iconic scanning might be the mechanism behind the outline-first availability. But, as Petersik (1977) suggested, an equally valid explanation is that low spatial frequencies are analyzed before higher frequencies, and an outline has a lower spatial frequency than the interior. A more general theory is that the buildup of perceptual information proceeds from global to local (Bouma, 1971; Eriksen & Schultz, 1978; Navon, 1977), and gross contour information like outline form can be perceived as being global and details such as an inserted line as being local. When judgment about a local aspect is required, the subject has to wait until the "icon" (in the sense of Eriksen & Schultz, 1978) is completed, so the globals are inevitably taken in. On the other hand, when judgment is about a global aspect only, the icon can be used as soon as the global aspects are taken in, which occurs before the moment that the locals are taken in.

Our study thus is only compatible with some weaker form of the global-to-local hypothesis; that is, the global aspects are *usually but not always* taken in before the local aspects are.

Doubts have recently arisen about the generality of the global-to-local hypothesis (Martin, 1979; Pomeranz & Sager, 1975), but caution in interpreting the negative evidence for the global-to-local hypothesis is recommended. When looking for global precedence, one often tries to show that irrelevant global variation affects local judgments (Kinchla & Wolfe, 1979; Martin, 1979; Navon, 1977). This finding, most clearly visible as an interference effect, indeed indicates that perception of the global aspect did occur. Such interference is, however, not established as the unavoidable consequence of global perception. Separability is consistent with the idea that perception of one aspect can occur without affecting the perception of other aspects. The absence of interference does not guarantee the absence of perception! The researcher who wants to test for global precedence might want to keep this thought in mind.

Notes

1. It is implied that a difference along two dimensions will be greater than a one-dimensional difference. Lockhead and King (1977) have shown that this statement is not always true and that a deliberate choice of the dimensions and their levels can result in a situation of near identity of two stimuli that differ along two dimensions. (Of course, the result will be a redundancy instead of a redundancy gain.) We think, however, that this is an exception rather than the rule.

2. Further confirmation that conflict stimuli were more difficult to classify was obtained in three follow-up experiments, described in the next chapter.

References

Besner, D., & Coltheart, M. Same-different judgements with words and nonwords: The differential effects of relative size. Memory & Cognition, 1975, 3, 673 - 677.

Besner, D., & Coltheart, M. Mental size scaling examined. Memory & Cognition, 1976, 4, 525 - 531.

Boer, L.C., & Keuss, P.J.G. Storage mode of geometrical dimensions in a two-stimulus matching paradigm. Perception & Psychophysics, 1979, 25, 197 - 204.

Bouma, H. Visual recognition of isolated lower-case letters. Vision Research, 1971, 11, 459 - 474.

Bundesen, C., & Larsen, A. Visual transformation of size. Journal of Experimental Psychology: Human Perception and Performance, 1975, 1, 214 - 220.

Dixon, P., & Just, M.A. Normalization of irrelevant dimensions in stimulus comparisons. Journal of Experimental Psychology: Human Perception and Performance, 1978, 4, 36 - 46.

Dykes, J.R., & Cooper, R.G. An investigation of the perceptual basis of redundancy gain and orthogonal interference for integral dimensions. Perception & Psychophysics, 1978, 23, 36 - 42.

Eriksen, C.W., & Schultz, D.W. Temporal factors in visual information processing: A tutorial review. In J. Requin (Ed.), Attention and performance VII. Hillsdale, N.J.: Erlbaum, 1978.

Felfoldy, G.L. Repetition effects in choice reaction time to multidimensional stimuli. Perception & Psychophysics, 1974, 15, 453 - 459.

Garner, W.R. Interaction of stimulus dimensions in concept and choice processes. Cognitive Psychology, 1976, 8, 98 - 123.

Garner, W.R., & Felfoldy, G.L. Integrality of stimulus dimensions in various types of information processing. Cognitive Psychology, 1970, 1, 225 - 241.

Keuss, P.J.G. Processing of geometrical dimensions in a binary classification task: Evidence for a dual process model. Perception & Psychophysics, 1977, 21, 371 - 376.

Kinchla, R.A., & Wolfe, J.M. The order of visual processing: "Top-down," "bottom-up," or "middle-out." Perception & Psychophysics, 1979, 25, 225 - 231.

Larsen, A., & Bundesen, C. Size scaling in visual pattern recognition. Journal of Experimental Psychology: Human Perception and Performance, 1978, 4, 1 - 20.

Lockhead, G.R. Processing dimensional stimuli: A note. Psychological Review, 1972, 79, 410 - 419.

Lockhead, G.R., & King, M.C. Classifying integral stimuli. Journal of Experimental Psychology: Human Perception and Performance, 1977, 3, 436 - 443.

Martin, M. Local and global processing: The role of sparsity. Memory & Cognition, 1979, 7, 476 - 484.

Navon, D. Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 1977, 9, 353 - 383.

Petersik, J.T. A physiological and psychophysical interpretation of the processing of geometrical dimensions in a binary classification task: Comments on Keuss (1977). Perception & Psychophysics, 1977, 22, 511 - 515.

Pomerantz, J.R., & Sager, L.C. Asymmetric integrality with dimensions of visual pattern. Perception & Psychophysics, 1975, 18, 460 - 466.

Shepard, R.N. Form, formation, and transformation of internal representations. In R.L. Solso (Ed.), Information processing and cognition: The Loyola Symposium. Hillsdale, N.J.: Erlbaum, 1975.

White, M.J. Order of processing in visual perception. Canadian Journal of Psychology, 1976, 30, 140 - 156.

Chapter III

Presentation rate over two different paradigms

> In this chapter, a particular discrepancy in amount of interference between card sorting and two-stimulus matching was pursued somewhat further. The difference disappeared in the within-subjects design of Experiment 1. Moreover, it was demonstrated that the between task variation in interference did not exceed the variation in interference observed within either task. This confirmed the conclusion of chapter 2 that the meaning of integrality is the same over different tasks, and that integrality (at least as defined from the selective attention performance) is a property of the stimulus rather than of the type of task.
>
> A significant source of variation in interference was presentation rate, probably because this manipulated sequential effects. The role of a particular type of sequential effects was discussed: the change constancy cue, reported by Fletcher and Rabbitt (1978).

In the previous chapter it was found that integrality was, by and large, the same over the two tasks: two-stimulus matching and card sorting; nevertheless, some difference in integrality was obtained. In particular, it appeared that in the two-stimulus matching task the relevant form could be analyzed from a stimulus consisting of a rectangle with an inserted line (orientation), while for the same stimulus presented in a card-sort task, it took time to get rid of the inserted line. It seemed as if integrality was absent in the former, and present in the latter task. Presentation rate, however, differed between tasks!

This chapter attemps to identify the source of the difference between the tasks. In particular, the rate of presenting consecutive trials is studied. Before systematically manipulating presentation rate, the experiments start with a comparison of the two tasks at the same presentation rate.

Experiment 1

The two-stimulus matching task had a variable of secondary interest that had nothing to do with presentation rate, namely, the relative position of the stimuli of a to-be-matched pair. Placing them side-by-side, as in Figure 1, introduces a risk that the subject decides same/different on the basis of a horizontal scan between the elements of a pair to see if they are on the same level (Dykes & Cooper, 1978). In order to examine if such had played a role in the previous two-stimulus matching experiments, two blocks of two-stimulus matching series were presented, Stimuli were placed side-by-side in one block and stimuli were placed diagonally in another block—the left stimulus positioned higher than the right stimulus.

Presentation rate. Presentation rate, defined as the time between the response to a stimulus and onset of the stimulus of the immediately following trial, was set at ½ sec for both card sorting and two-stimulus matching.

Stimuli and apparatus. In the card-sort task one stimulus (1° of visual angle) was presented per trial. In the two-stimulus matching task two stimuli, together spanning 4.3° of visual angle (see Figure 1) were presented. Construction time and refresh rate for the stimulus or the stimulus pair was 12 msec. Further details are given in chapter 2.

Subjects. Eight paid university students (one female) served as subjects.

<u>Conditions</u>. The two tasks were card sorting and two-stimulus matching. In both, form was the relevant dimension and the inserted line was the irrelevant dimension. This particular combination of dimensions was selected because the difference in interference was maximal here (see Table 1 of chapter 2). The card-sort task had three series: two unidimensional series (1) E vs. G (see also cover) and (2) F vs. H; and one orthogonal series, E and F vs. G and H. The two-stimulus matching task had four series. Each series had two "same" and two "different" pairs. (Figure 1 shows the four pairs within a particular series, but the inserted line is omitted in this figure.) The state of the irrelevant inserted line produced four separate series of stimuli.

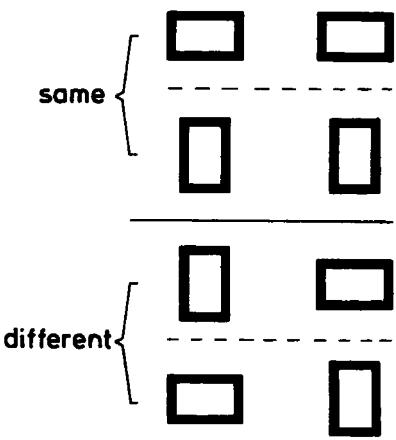


Figure 1. Stimuli for the two-stimulus matching tasks of Experiments 1 and 2a. The inserted line has been omitted for ease of exposure; it actually was never relevant for the subject.

In Series 1, all inserted lines were horizontal, and in Series 2, all inserted lines were vertical. These series did not require any selective attention since a "same" pair is "same" in all respects and this removed the necessity of any additional processing such as normalization. As these two series provide us with baseline data, they are the "unidimensional" series.

In series 3, the *left* figure's line was horizontal throughout the series, while the *right* line was vertical throughout the series. Series 4 was a reversal of left and right line, i.e., the left figure had a vertical, and the right figure had a horizontal line. These two series required attribute selection, since a "same" pair is only "same" if the inserted line is ignored. Here, dimensional inseparability necessitated additional normalization of the stimuli: Series 3 and 4 are the "orthogonal" series.

The stimuli within the two-stimulus matching task were placed in two ways: One block of series placed the stimuli of a pair along an imaginary line with a slope of -1 (diagonal position). Horizontal and vertical positioned stimulus pairs had the same midpoint-to-midpoint distance of 21 mm.

Procedure. Half of the subjects did the card-sort block first and the other half did the two-stimulus matching blocks first. Within the two-stimulus matching task, four subjects had the block of horizontal-positioned stimuli first and four subjects had the block of diagonal-positioned stimuli first. A two-stimulus matching block had four experimental series. There was only one card-sort block with three experimental series. In each block, all series were presented twice, the first time as practice and the second time as experimental series. All practice series of a block had been presented in random order before any experimental series was presented. Additionally, presentation order of experimental series was randomized over subjects. An experimental series had 200 trials and lasted 3 to 3½ min. A practice series was half as long.

A subject completed his 14 practice and 14 experimental series in one day of testing. The morning session occupied him about two hours and the afternoon session took about 1½ h. Between series, a break of minimal two minutes was inserted. It could be lengthened at the subject's will. Mapping of left/right response button to same/different (two-stimulus matching) or to lying/standing (card sorting) was assigned randomly to subjects and reversed after the first two experimental series of any block.

Data analysis. Of the two-stimulus matching task only the "same" responses were analyzed. RTs_{diff} were excluded since the process of normalization (Dixon & Just, 1978) is not always observed in the "different" responses. In an ANOVA, not given in detail here, we explored the response type (same/different) of the matching task. Significant effects were response type, i.e., the usually observed superiority of the "same" reaction (18 msec; $F (1,7) = 12.67$; $p < .01$), and its interaction with the orthogonal interference, i.e., the "same" response tended to be the more sensitive index (22 vs. 14 msec; $F (1,7) = 3.61$; $p < .10$).

Omission of the "different" reactions creates a problem for the error data since it is somewhat arbitrary which errors remain for analysis: the false "same" responses that were made on "different" stimuli, or the errors that were made on "same" stimuli (the false "different" responses). An ANOVA on all error data revealed no significant effects except for more false "different" reactions ($F (1,7) = 7.36$ $p < .05$; cf. Krueger, 1978, p. 281).

For these reasons error data were not analyzed further in the two-stimulus matching task.

Results and Discussion

Errors were few: 2.1% in card-sorting, and 2.4% in two-stimulus matching. There was a tendency toward more errors in the latter task ($F(1,7) = 1.925$; $p < .10$) and the RT results revealed clearly that the two-stimulus matching task was more difficult ($F(1,7) = 116.03$; $p < .001$); the difference was 104 msec.

The variable of secondary interest--the separation of the to-be-matched pair--was significant only as a main effect. Classifying diagonally positioned stimuli was more difficult than horizontally positioned stimuli (see Table 1; $t(7) = 5.01$; $p < .005$), but the orthogonal interference was not changed by the separation of the stimuli ($t(7) = .391$). Thus the procedure of matching a pair of stimuli was not a function of the way the stimuli were separated. This ruled out horizontal scanning as an important contributor.

The evidence of chapter 2 for a new perception of the inserted line (viz., consistent or in conflict with the state of the surrounding rectangle) was confirmed. Conflict between line orientation and rectangle slowed down the classification of orthogonal stimuli ($t(7) = 2.384$; $p < .025$). The effect was of the same order in both this and the experiment of chapter 2; 9.0 and 8.4 msec respectively. (The consistent-conflicting result will be discussed further in Experiment 2b.)

The most important point of this experiment was that once both tasks were equated over presentation rate, the amount of orthogonal interference was the same (see Table 1). The interference was 22 msec in the RT_{same} of the two-stimulus matchings [$t(7) = 4.056$; $p < .05$ and 25 msec in card sorting $t(7) = 3.650$; $p < .05$]. Error data pointed in the same direction (though significance was not reached).

Table 1

RTs (msec) of Experiment I (RSI = ½ sec)

	Card Sort	Two-Stimulus Matching only "same" reactions: horizontal stimulus pair	Two-Stimulus Matching only "same" reactions: diagonal stimulus pair
Orthogonal series	375	454	487
Unidim'1 series	350	433	463
Orthogonal interference	25	21	24

One may ask whether the results in two tasks reflect the same extent of interference: Is the card-sort index lower than normal, or is the two-stimulus matching index higher than normal? Inspection of Table 1, chapter 2, shows that both statements are probably true (the present card-sort interference was about 10 msec lower, the present two-stimulus matching interference was about 15 msec higher). Whatever the exact cause may be, the difference in interferences in integrality disappeared when the tasks had the same presentation rate. The next experiments consider some reasons why presentation rate should affect interference.

Experiment 2a

First, it will be pointed out that the so-called repetition effect can only explain different interferences within the card-sort task. Then another sequential effect is considered, one that is also sensitive to presentation rate, that may effect the interference in both tasks.

Stimulus repetitions are in general favorable: the more repetitions, the better the performance (Bertelson, 1961). In the card-sort task, each unidimensional series has 50% of repetitions, but the orthogonal series has only 25% of repetitions. The repetition effect will predict better performance for the unidimensional series. The effect favors unidimensional performance more than orthogonal performance, thus raising the estimated interference. However, the repetition effect vanishes when presentation rate is slow (e.g. Kirby, 1976). The advantage for unidimensional sorting is removed. This led Feldoldy (1974) to predict less interference for slow presentations, which prediction he confirmed.

The situation for the two-stimulus matching task is different. Every series in this task has four stimuli, so the percentage of stimulus repetitions is 25 in unidimensional as well as orthogonal series. Thus, repetition effects can never selectively favor unidimensional performance.

Fletcher and Rabbitt (1978) recently reported another type of sequential effects, that is also a function of presentation rate. It is possible that these sequential effects changed the perception of the individual stimulus, and consequently the interfering effect of the inserted line. Suppose that perception proceeds in a global-to-local fashion, as Navon assumed (1977). That means that the outline form is usually available before the inserted line, so that it is relatively easy to ignore that line. The data of chapter 2 are compatible with this model: The asymmetric integrality between form and inserted line meant that it was relatively easy to ignore the line. However, the global-to-local model is a description of microgenesis, or the ontogenesis of the percept, and applies only for early perceptual stages. There is a reason to believe that the early perceptual stages are changed for fast presentations; that the percept is no longer built up anew for every stimulus, and that ignoring the inserted line is no longer relatively easy.

Suppose a fast presentation rate in which the stimulus is replaced by the next one 300 msec after the subject's reaction (we consider only the situation that the stimulus remains <u>on</u> until the subject gives a response). Using this response-stimulus interval (RSI) Fletcher and Rabbitt showed that the first impression of the stimulus conveyed the idea of a change or a constancy relative to the immediate preceding stimulus; change or constancy depending on whether or not the stimulus differed from the predecessor. Global-to-local microgenesis may not occur in this situation. Instead, the change-constancy impression leads the development of the percept. Greater ease of ignoring the inserted line would, therefore, only be observed for slow presentations. In that case, every individual stimulus stands alone and is perceived as a separate event with an invidual microgenesis. In other words, if the case of ignoring the inserted line is critically dependent on global-to-local microgenesis, presentation rate could have suggested different degrees of separability due to the fact that global-to-local microgenesis occurred only for slow presentations.

Experiment 2a will use the two-stimulus matching task; Experiment 2b the card-sorting task. Presentation rate is varied in both.

Method of the Two-Stimulus Matchings

Most details are similar to the two-stimulus matchings of Experiment 1.

Subjects. Twelve paid university students (four males) served as subjects.

Presentation rate. There were three presentation rates, defined in terms of response-stimulus intervals. These intervals were ½, 1½, and 3 sec. Each interval had four separate series. The inserted line was always "same" in the unidimensional Series 1 and 2, and the inserted line was always "different" in the orthogonal Series 3 and 4. All stimuli were placed side by side, as in Figure 1.

Procedure. Intervals were presented block-wise, i.e., all series with a particular interval were completed before a series with another interval began. The blocks were presented in a different random order to each subject. Presentation order for the four series within a block as well as selection of the stimuli within a series were random too. A series was terminated after 37 "same" stimuli had been presented. (The number of trials follows a Pascal distribution with an average of 2 x 37 trials.

The actual number of trials per series in the experiment ranged between 60 and 109).

Each subject participated in two individual test sessions, about ½ an 1¾ hour respectively. The first session served for practice. It was a shorthand of the second, experimental session. The experimental session began with two warm-up series randomly taken from the first block. Each new block was introduced by one warm-up series. Breaks were inserted whenever subject or experimenter desired.

Results and Discussion

Errors were few, 3.0%. Presentation rate had no effect on the reaction times ($F(2,22) < 1$). More importantly, the variation in orthogonal interference of the "same" reactions ($F(1,11) = 18.75$; $p < .005$) did not vary over the three presentation rates, as shown in Table 2 ($F(2,22) < 1$). Integrality, as measured in a two-stimulus matching task, is not a function of presentation rate.

Table 2

The "same" reaction times (msec) of Experiment 2a

	Response-Stimulus Interval (sec)		
	½	1½	3
Orthogonal series	437	437	443
Unidim'l series	426	418	431
Orthogonal interference	11	19	12

Either the interference was not related to the supposed prior availability of outline form (as predicted from the global-to-local model), or the serial availability was not affected by presentation rate.

Experiment 2b

This experiment manipulated presentation rate of a card-sort task. It was already discussed in the introduction of Experiment 2a that presenting stimuli in rapid succession makes them appear as either changes or constancies. Fletcher and Rabbitt (1978) demonstrated moreover that the change-constancy impression actually determined responding when the impression could be used as a basis for responding. This is only the case when the two alternative stimuli are mapped in a one-to-one fashion onto responses. The subject simply repeats the response when the stimulus appears as a constancy, and gives the other response if the stimulus appears as a change. Note that this strategy can only be applied when two stimuli are mapped one-to-one onto responses. As soon as many-to-one mapping is employed, the change impression is unreliable. For example, if stimuli E and F are mapped onto the same response--see front cover--, an F after an E gives the impression of change, but no change in the response is required.

The change-constancy cue selectively favors unidimensional card sorting, since this series has only two stimuli, mapped one-to-one onto responses. Note that, again, the selective favoring of unidimensional performance only applies to card-sorting, and not to two-stimulus matching which has always 2 : 1 mappings. Experiment 2b tries to find out whether presentation rate interacts in this way with unidimensional card sorting: It expects superior unidimensional performance for fast presentations.

Card-Sorting Method

Unless otherwise mentioned, all details are identical to Experiment 1.

Subjects. Five laboratory-staff members and three university students participated in the experiment.

Stimuli and presentation rates. The rectangles, labeled E-H on front cover, were used as stimuli in a card-sort task. In all series (one orthogonal and two unidimensional) the subjects form-sorted the stimuli: "lying" rectangles left, "standing" rectangles right (this was reversed for the even numbered subjects). The interval between the response on trial *i* and the construction of the stimulus on trial *i* + 1 was ½ sec in the fast-presentation block (as in chapter 2) and was two sec in the slow-presentation block. These were the only presentation rates.

Procedure. The first four subjects commenced with the fast block while the last four subjects did the slow block first. A block consisted of six series; the first three were given as practice. The duration of a fast-presentation series of 120 trials was averaged 1.7 minutes; the duration of a slow-presentation series of 60 trials was averaged 2.4 minutes.

Results and Discussion

Errors were few, 2.0%. Presentation rate, as a main effect, was not significant (F's < 1 in RTs and error%); however, it seemed to interact with the orthogonal interference ($F(1,7) = 8.70$; $p < .025$), as shown in Table 3. There was a little interference in the slow-presentation condition (10 msec; $t(7) = 1.390$; $p < .11$), but interference was substantial in the fast-presentation condition (30 msec; $t(7) = 3.645$; $p < .005$). (In both conditions there were .4% more errors in the orthogonal series--n.s.).

However, interpretation in terms of orthogonal interference

Card-Sorting Method

Unless otherwise mentioned, all details are identical to Experiment 1.

Subjects. Five laboratory-staff members and three university students participated in the experiment.

Stimuli and presentation rates. The rectangles, labeled E-H on front cover, were used as stimuli in a card-sort task. In all series (one orthogonal and two unidimensional) the subjects form-sorted the stimuli: "lying" rectangles left, "standing" rectangles right (this was reversed for the even numbered subjects). The interval between the response on trial i and the construction of the stimulus on trial $i + 1$ was ½ sec in the fast-presentation block (as in chapter 2) and was two sec in the slow-presentation block. These were the only presentation rates.

Procedure. The first four subjects commenced with the fast block while the last four subjects did the slow block first. A block consisted of six series; the first three were given as practice. The duration of a fast-presentation series of 120 trials was averaged 1.7 minutes; the duration of a slow-presentation series of 60 trials was averaged 2.4 minutes.

Results and Discussion

Errors were few, 2.0%. Presentation rate, as a main effect, was not significant (F's < 1 in RTs and error%); however, it seemed to interact with the orthogonal interference ($F(1,7) = 8.70$; $p < .025$), as shown in Table 3. There was a little interference in the slow-presentation condition (10 msec; $t(7) = 1.390$; $p < .11$), but interference was substantial in the fast-presentation condition (30 msec; $t(7) = 3.645$; $p < .005$). (In both conditions there were .4% more errors in the orthogonal series--n.s.).

However, interpretation in terms of orthogonal interference is somewhat deceptive here. At first sight, it seems suggested indeed that the inserted line was more easily ignored (hence less interference) when presentation rate was slow; however two other findings show that unidimensional, and not orthogonal, processing

Table 3

Card-sort results of Experiment 1 and 2b. The numbers give the RTs in msec; the first number of a pair gives the RT for sorting consistent, the second number the RT for sorting conflict stimuli.

	Exp. 1 (card-sort)	Exp. 2 (card-sort)	
	fast	fast	slow
	RSI = ½ sec	RSI = ½ sec	RSI = 2 sec
orthogonal series	371;380	371;383	376;390
unidim'l series	352;347	351;344	370;377
orthogonal interference	25	30	10

was modified by slow presentations. The first finding was that presentation rate did *not* change the influence of the state of the inserted line (consistent vs. conflict). The effect, 12 msec in the fast-presentation block and 14 msec in the slow-presentation block, strongly suggests (together with results of similar magnitude found in Experiment 1) that the inserted line in the orthogonal series was processed identically over presentation rate. The second finding was, that orthogonal processing was unmodified by presentation rate. Together, these findings show that only undidmensional processing was affected by presentation rate; its efficiency being increased for fast presentations.

In a card-sort task, the traditional method of assessing the orthogonal interference as the orthogonal-unidimensional difference turns out to be a presentation-rate dependent measure. The experiment shows that an apparent decrement in interference over presentation rate can be observed while actually only unidimensional, not orthogonal, performance was changed. Unidimensional efficiency was increased for fast presentations (responding based on change-constancy) or, to state it the other way around, unidimensional efficiency was decreased for slow presentations, thus underestimating the orthogonal interference in card-sorting (cf. Felfoldy, 1974).

Was the effect of presentation rate mediated by the change-constancy cue that guided response selection, or was the effect mediated (see introduction of Experiment 2a) by the higher incidence of stimulus repetitions? No direct answer is possible, since both mechanisms give rise to similar predictions. However, since both are types of sequential effects, we can say at least that sequential effects decreased unidimensional efficiency of a card-sort task when presentations are fast.

General Discussion

Is integrality the same over different tasks? In answering the question, the fact of variability within tasks should be taken into account. The card-sorting experiment 2b failed to reveal integrality for slow presentations, but showed significant interference for fast presentations (thus pointing to integrality). So, here we have a variability of interference within one and the same task. Within-task variability was also indicated for two-stimulus matchings when we list all interferences of this and the previous chapter (that also includes the result of Keuss, 1977). The interference due to integrality between (relevant) form and (irrelevant) inserted line was 11 (n.s.), 5 (n.s.), 22, and 14 msec. So, for this task we have also within-task variability (though it cannot be ascribed here to presentation rate). Considering the fact that there is within-task variation, the between-task variation becomes only of importance as far as it exceeds the within-task variation. This was not obtained; Experiment 1 even showed highly similar interference over tasks when subjects did them both.

The conclusion of chapter 2 is thus confirmed. Integrality is the same over different tasks. The theoretical implication is, that selective attention is a matter of the stimulus. The stimulus limits the possibilities for selective attention—not the type of task. A further comment is that integrality, as the alleged source for poor selective attention, was treated as a quantitative stimulus property and not as an all-or-none phenomenon. For example, asymmetric integrality meant in these chapters, that the coherence of dimension a to dimension b was stronger than the b-to-a coherence, and not absence of b-to-a coherence. This viewpoint has also been suggested by Nickerson (1978) who states that integrality and separability should be conceived of as endpoints of a continuum. Thus, integrality is a quantifyable stimulus property.

The experiments of this chapter focussed especially on sequential effects, assumed to be manipulated by presentation rate. It is very likely that the strong effects of presentation rate on card-sorting interference were mediated by these effects, that have full strength only for fast presentations. Two comments should be interference for fast presentations (thus pointing to integrality). So, here we have a variability of interference within one and the same task. Within-task variability was also indicated for two-stimulus matchings when we list all interferences of this and the previous chapter (that also includes the result of Keuss, 1977). The interference due to integrality between (relevant) form and (irrelevant) inserted line was 11 (n.s.), 5 (n.s.), 22, and 14 msec. So, for this task we have also within-task variability (though it cannot be ascribed here to presentation rate). Considering the fact that there is within-task variation, the between-task variation becomes only of importance as far as it exceeds the within-task variation. This was not obtained; Experiment 1 even showed highly similar interference over tasks when subjects did them both.

The conclusion of chapter 2 is thus confirmed. Integrality is the same over different tasks. The theoretical implication is, that selective attention is a matter of the stimulus. The stimulus limits the possibilities for selective attention—not the type of task. A further comment is that integrality, as the alleged source for poor selective attention, was treated as a quantitative stimulus property and not as an all-or-none phenomenon. For example, asymmetric integrality meant in these chapters, that the coherence of dimension a to dimension b was stronger than the b-to-a coherence, and not absence of b-to-a coherence. This viewpoint has also been suggested by Nickerson (1978) who states that integrality and separability should be conceived of as endpoints of a continuum. Thus, integrality is a quantifyable stimulus property.

The experiments of this chapter focussed especially on sequential effects, assumed to be manipulated by presentation rate. It is very likely that the strong effects of presentation rate on card-sorting interference were mediated by these effects, that have full strength only for fast presentations. Two comments should be added. (1) Contrary to Felfoldy's suggestion (1974), sequential effects can not explain all of the interference. Interference was also obtained in the two-stimulus matchings, in which unidimensional and orthogonal series are equally affected by sequential effects. Other studies corroborate this conclusion: Interference is observed even when sequential effects are adequately controlled for (Dykes & Cooper, 1978; King, Gruenewald, & Lockhead, 1978). (2) The second comment is that integrality is the cause that orthogonal card sorting does not profit from sequential effects as much as unidimensional card-sorting. This is because the definition of what is, and what is not, a stimulus repetition (or a constancy) depends on the separability/integrality of the stimulus. Had the irrelevant line been completely separable, a repetition of the outline form would have been perceived as a stimulus repetition.[1] Orthogonal sorting would, then, profit just as much from sequential effects as unidimensional sorting, so that fast presentations would not show a greater orthogonal interference. The recommendation that can be given is the following. Once it has been decided to use the card-sort task, presentation rate should be fast, because this enhances the sensitivity of the test to detect selective attention problems associated with integrality. The finding of Santee and Egeth (1980) that card-sorting is the less sensitive task probably stems from the use of slow presentations.

It remains to be ascertained to what extent a fixed serial availability of dimensions explains the asymmetric integrality between outline form and inserted line. There is the by now well-established fact that the line is either consistent to or in conflict with the outline form. This was also observed when the dimension of supposedly prior availability was relevant (viz., outline form), implying that the two dimensions were integrated to some extent. However, availability differences cannot be ruled out solely by this result. First, there is the observation that a conflicting noise element (see chapter 1) interferes with judgment on the target letter, even when the target preceded the noise by 50 msec (Hoffman, 1975). Apparently, prior availability does not exclude some interaction. Secondly, the position can be defended that outline form was available first on most, but not all, occasions (see the similar conclusion of chapter 2). Thus, the data do not refute the global-to-local model as a possible explanation of better selective attention to outline form. The next chapter puts the model more directly to test, in which the consistent-conflict state of the inserted line gives an indication of the effect of this irrelevant line on form judgment.

Note

1. That repetition of outline form only was not perceived as identical to repetition of both outline and inserted line, was apparent from the significant shorter RT, and the significant decrease in errors for complete repetitions. The difference in RT was 28 msec for the experiment reported in chapter 2, and 13 and 22 msec for the card-sort experiments of this chapter. This sequential effect, observed within the orthogonal card sortings, correlated .62, .62, and .66 with integrality, as measured from the increased difficulty of orthogonal, as opposed to unidimensional, card sorting.

References

Bertelson, P. Sequential redundancy and speed in a serial two-choice responding task. Quarterly Journal of Experimental Psychology, 1961, 13, 90 - 102.

Dixon, P. & Just, M.A. Normalization of irrelevant dimensions in stimulus comparisons. Journal of Experimental Psychology: Human Perception and Performance, 1978, 4, 36 - 46.

Dykes, J.R. & Cooper, R.G. An investigation of the perceptual basis of redundancy gain and orthogonal interference for integral dimensions. Perception & Psychophysics, 1978, 23, 36 - 42.

Fletcher, B.C. & Rabbitt, P.M.A. The changing pattern of perceptual analytic strategies and response selection with practice in a two choice reaction time task. Quarterly Journal of Experimental Psychology, 1978, 30, 417 - 427.

Felfoldy, G.L. Repetition effects in choice reaction time to multidimensional stimuli. Perception & Psychophysics, 1974, 15, 453 - 459.

Hoffman, J. Hierarchical stages in the processing of visual information. Perception & Psychophysics, 1975, 18, 348 - 354.

Keuss, P.J.G. Processing of geometrical dimensions in a binary classification task: Evidence for a dual process model. Perception & Psychophysics, 1977, 21, 371 - 376.

King, M.C., Gruenewald, P., & Lockhead, G.R. Classifying related stimuli. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 417 - 427.

Kirby, N.H. Sequential effects in two-choice reaction time: Automatic facilitation or subjective expectancy? Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 567 - 577.

Krueger, L.E. A theory of perceptual matching. _Psychological Review_, 1978, _85_, 278 - 304.

Navon, D. Forest before trees: The precedence of global features in visual perception. _Cognitive Psychology_, 1977, _9_, 353 - 383.

Nickerson, R.S. Comments on W.R. Garner's "Selective attention to attributes and to stimuli". _Journal of Experimental Psychology General_, 1978, 107, 452 - 456.

Santee, J.L., & Egeth, H.E. Selective attention in the speeded classification and comparison of mulidimensional stimuli. _Perception & Psychophysics_, 1980, _28_, 191 - 204.

Chapter IV

Global precedence as a postperceptual effect: An analysis of speed-accuracy tradeoff functions

Two experiments examined the speed-accuracy tradeoff for stimuli used by Martin (1979), some of which have a Stroop-like conflict between the relevant (to-be-judged) and the irrelevant aspect. Speed of transmitting information about a local aspect was significantly reduced when the irrelevant global aspect conflicted with the relevant local aspect, while speed of transmitting information about the global aspect was not affected when the irrelevant local aspect conflicted with the relevant global aspect. This result, when extrapolated to the accuracy level of an ordinary reaction-time task, fitted very well the reaction-time predictions of the global precedence model proposed by Navon (1977). However, other results were incongruent with the fundamental assumption of that model: that global features are accumulated with temporal priority over local features. The finding that, independently of speed, information transmission of the global aspect started later when the irrelevant local aspect was conflicting, corroborates Miller's (1981a) conclusion that global and local features are available with a similar time course. Global precedence is therefore a postperceptual effect; absence of interaction with S-R compatibility suggested that it operated before the response selection stage. The term global dominance may be preferred, because it avoids the implication of prior availability for the global aspect. Furthermore, the possibility of whether Stroop conflict should be considered a necessary condition for global dominance is discussed.

The chapter is concerned with the accumulation of information of a visual form and, in particular, with whether transmission of global information precedes transmission of local (detail) information. Within the present chapter, we conceive of perception as a process of gradual feature accumulation. Furthermore, in line with the continuous-flow model of Eriksen and Schultz (1978, 1979), we assume that a subject's response is based upon the amount of information accumulated at that particular instant. The ontogenesis of the percept ("Aktualgenese" in terms of the Leipzig School of Gestalt Psychology) will therefore be reflected by the response of the moment.

For the global-to-local hypothesis, the distinction between global and local features is a basic one. As opposed to feature models in which global features are composites of local features (Gibson, 1969; Selfridge, 1959; Treisman & Gelade, 1980), the global-to-local hypothesis states that perception begins with a global whole to which local details are gradually added. According to the global precedence model, global and local features denote separate sets of features. Thus, global feature availability is not dependent on the accumulation of a sufficient number of local features; on the contrary, the model implies that global feature sampling precedes local feature sampling or that global feature sampling is faster than local feature sampling. Some predictions from the global precedence model are: (1) it is easier to judge a form on its global characteristics than on its local characteristics; and (2) global characteristics are difficult to ignore, while local ones are easy to ignore--that is, interference from irrelevant (to-be-ignored) global aspects exceeds interference from irrelevant aspects.

What is meant by the global-local distinction is rather obvious in everyday language. A more formal definition can be attempted using the concept of spatial frequency. A visual form can be described as a mixture of different spatial frequencies (Campbell, 1974). A way of eliminating high spatial frequencies is to defocus the image, as, for example, the image from a projector can easily be defocused. Local or detailed information contained in the high frequencies is lost, while gross, global shapes contained in the low frequencies are preserved. High spatial frequencies in isolation (i.e., without low frequencies) are exemplified by a bad quality Xerox copy. Details are preserved, but global, uniform surfaces seem to have brightness differences. Another formal definition assumes that the outer contour is the global aspect; Bouma (1971, p. 463) called this contour, formed by the smallest polygon enclosing the whole, the "envelope." Which definition is more useful is not clear. Moreover, the choice of one definition over the other does not seem to be of consequence for the research of this chapter.

One line of evidence for the global precedence model is obtained from the analysis of confusion matrices. Frequently, briefly flashed letters and letterlike symbols are confused with each other if similar in global characteristics, as defined by contour similarity (Bouma, 1971; Lupker, 1979). Of special interest for the present study is another line of evidence that focuses on Stroop interference in letter stimuli. The interference is between global shape and the elements making up that shape. For example, H and S are presented as global shapes in Figure 1, in which the component elements are either small capital Hs or Ss (or Os). When the response set consists of H and S, an H consisting of many small Hs is said to be consistent, while an H consisting of small Ss is said to be conflicting (as is an S consisting of small Hs). The typical task requires observers to classify according to a particular level and to ignore the other level as much as possible. It follows that a performance difference between consistent and conflict stimuli indicates a failure to ignore the irrelevant level.

Navon (1977, 1981a) found clear support for the global precedence model. Irrelevant local letters were easily ignored, while global shape was impossible to ignore. The result was replicated in part by Kinchla and Wolfe (1979) in a different paradigm. These in-

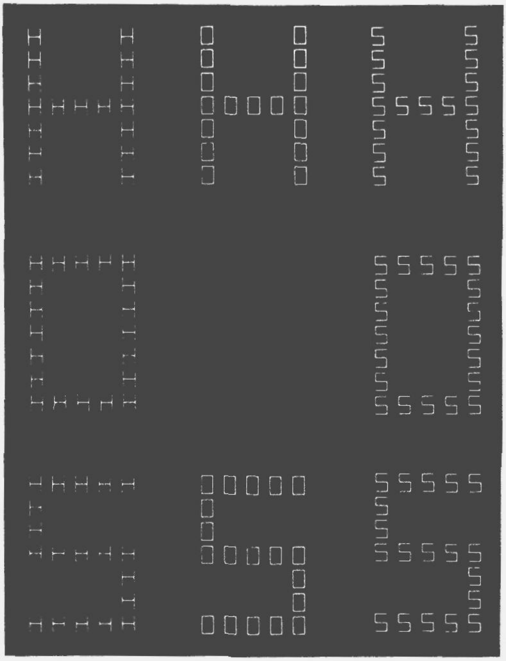


Figure 1. Global letters consisting of many local letters. (These letters were used by Martin, 1979, and in Experiment 2.)

vestigators used a target search task in which the subject detected whether or not the auditory target letter was present on the display. They demonstrated global precedence provided that the large letter subsumed less than 8 deg of visual angle. Martin (1979) also obtained similar results and showed as an additional requirement that the number of elements constituting the global shape should not be too low. Essentially, her point related to the fact that legibility of letters formed by filling in the appropriate positions of an r x c matrix is decreased with lower values of r and c (Vartabedian, 1971). She found global precedence for stimuli built on a 7 x 5 matrix; Navon (1979, 1981a) and Kinchla and Wolfe (1979) used approximately the same matrix (7 x 6).

A study by Hoffman (1980) raises doubt about the global precedence model. Hoffman reports similar speed of recognition for "judge global" and "judge local" (attentional task instructions to subject) conditions. In addition, he reports that it is just as difficult to ignore the global level as it is to ignore the local level. It is not clear to us how this result was obtained or how it can be reconciled with other studies, especially that by Kinchla and Wolfe (1979), who used a similar paradigm. Hoffman refers tentatively to "a host of ill-defined (stimulus) factors" (p. 233). This is in line with Navon's (1981a, p. 7) argument that global precedence can be overridden by other factors. One of these factors could be the use of matrices with rather sparse points to construct the letters (5 x 5 for global and 6 x 5 for local letters. Another factor may be due to stimulus presentation--the oscilloscope built the stimulus in such a way that the first small element was finished some 23 msec before the last element (and, therefore, also the global shape) was finished. This difference is small, but if it had any effect it would undoubtedly tend to favor local over global aspects.[1] (In pilot work, we found another demonstration that global precedence can be overridden--namely, the presentation of a few of the local letters at a higher brightness. A Tektronix 611 oscilloscope constructed the stimuli of Figure 1. When the completed image was shown to the subject, the last small letter to be plotted had a 300-mlx intensity, while the first letters to be plotted were already at the storage level of 6 mlx. It took another 75 msec for the last element to reach storage level. The data, depicted in the left part of Figure 2, show no global precedence. When the same stimuli were presented later by a slide projector, the clear precedence result depicted in the right part of Figure 2 was obtained.[2])

In the studies considered above, reaction time (RT) is the principal dependent variable, while proportion of errors is a variable of secondary interest; an alternative method is one that combines these two variables into one measurement--namely, a speed-accuracy function (Schouten & Bekker, 1967). According to the continuous-flow model, the initial region of the speed-accuracy function

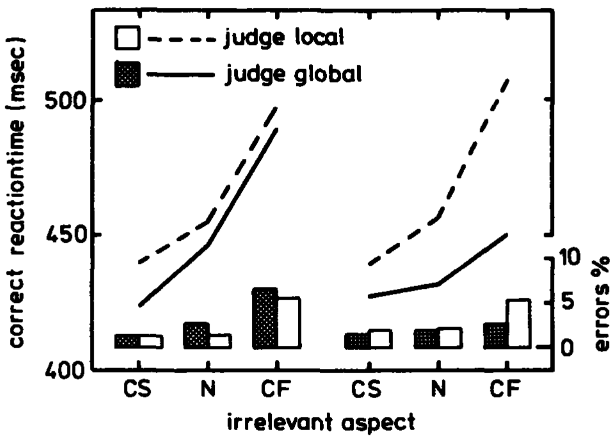


Figure 2. A demonstration that global precedence can be overridden, in this case by presenting a few local elements at a higher brightness. Both panels show RT and error rate as a function of the to-be-ignored aspect, which is consistent with (CS), neutral to (N), or in conflict with (CF) the relevant aspect. The letters depicted in Figure 1 were used as stimuli. In the left panel, they were presented by an oscilloscope, which resulted in a between-elements difference in brightness; in the right panel, they were presented by a slide projector. Note that global precedence is obtained only in the latter situation.

reflects how the subject acts on the first bits of perceptual information (Eriksen & Schultz, 1978, p. 5). This is relevant for the global precedence model, for if global features are sampled first, they should prevail during the initial stages of perceptual processing. When the subject is forced (e.g., by imposing a deadline) to emit a very fast response, a more direct demonstration of global precedence is expected than under the usual RT instruction that warns the subject to avoid errors. In the latter case, the subject may aim at a safe response, that is, only after accumulation of sufficient global features; this increases the probability that local features are added to the sample, possibly lowering sensitivity for global precedence. Therefore, we prefer a speed-accuracy function analysis. Although in a different field, Polf (1976) also chose speed-accuracy analysis for essentially the same reason--namely, that certain representations are activated only when the subject has sufficient time.

Before proceeding with the specific predictions, some definitional framework will clarify the exposition. By the speed-accuracy function (SAF), we denote that region of the RT/accuracy curve for which RT and accuracy are positively related. The SAF describes the increases in accuracy gained by unit increases in RT. The upper bound of the function is achieved when accuracy reaches perfection; the lower bound is chance level. Expressing accuracy in bits of information transmitted between stimuli and responses (Garner, 1962), the lower bound is at the zero-bits transmitted level (i.e., when the SAF intersects the abscissa or RT axis).

Of particular interest for the SAF analysis are those stimuli for which the local aspect has some RT effect when the subject has to react to global form only. This effect, minor as it may be relative to the complementary effect (global effects when the subject reacts to local aspects only), enables us to see at which level of accuracy local features enter the percept.

In the "judge global" condition, the global precedence model predicts the following for the SAF: (1) in the initial region of the SAF, no difference between consistent and conflict stimuli is expected; (2) as accuracy approaches perfection, a decrease in the growth rate of information per time unit is expected--caused by the interference in conflict stimuli that occurs as local features enter the picture. Thus, the conflict SAF is a two-limbed function: at first, identical to the consistent SAF (since only global features are present); later, with a smaller slope, or when there is a smooth transition between the limbs, the SAF is curvilinear. The best-fitting straight line for the conflict SAF will have a shallower slope than the consistent SAF and will intersect the RT axis at a lower RT.

Experiment 1

The goal of the first experiment was to test the "judge global" predictions. Observers classified rectangles according to position (lying/standing). Inserted in each rectangle was a lying

	stimulus type			
	consistent		conflict	
response				
""	1-p	p	1-p	p
""	p	1-p	p	1-p
sum	0.5	0.5	0.5	0.5

note: P = Proportion of errors/stimulus

Figure 3. Stimuli used in Experiment 1 and response accuracy derivation. There are two types of stimuli: consistent and conflict. Proportions of correct and error responses at a particular deadline are entered in the two 2 × 2 stimulus-to-response matrices—one matrix for consistent, the other for conflict stimuli. For each deadline, within-matrix accuracy is expressed as U (stim:resp) (Garner, 1962).

or standing line through the rectangle's midpoint (see Figure 3). Previous experiments (Boer & Keuss, 1979, 1981) have shown that classifying by the rectangular outline was easier than classifying by the inserted line that is a detail in the whole. In addition, irrelevant variation in the outline was more difficult to ignore than irrelevant variation in the inserted line. All this suggested the view that the outline rectangle is a global aspect, while the inserted line is a local aspect. This view is in agreement, both with the definition that equates contour and global aspect and with the definition that equates low spatial frequency and global aspect (see Petersik, 1977, for a more extensive discussion of our rectangles in terms of spatial frequency).

Furthermore, it appeared that the inserted line was either consistent or in conflict with the rectangle. The preceding chapter found that classification was easier when the rectangle and the line were in the same state (both standing or both lying; see the left pair of stimuli in Figure 3) than when their states were in conflict (see the right pair of stimuli in Figure 3). The present Experiment 1 derives speed-accuracy functions separately for these conflicting and consistent rectangles.

Method

Subjects. Fourteen students took part in the experiment as paid volunteers. All had participated in the chronologically earlier Experiment 2.

Stimuli and Apparatus. The subject sat in a soundproof cubicle, with hands resting on a response box that had two conventional response keys mounted on it: the left key was to be used for reacting to lying stimuli, and the right key, to react to standing stimuli. The subject faced a black projection screen 140 cm away, its center slightly below eye level. The cubicle was dimly lit, giving the white outline of the otherwise black screen an illumination of .4 cd/m^2. A feedback indicator lamp (showing whether the response was correct or not) was attached to the left of the screen, and a loudspeaker stood on the floor below the screen. All other equipment was outside the cubicle.

An electromechanical shutter (Compur M) was placed directly before the lens of a Kodak Carousel (S-RA 2000) that projected the stimuli. The shutter opened in less than 3 msec. The beam of the projector entered the cubicle through a 12 x 12 cm window and showed the stimulus as a white outline rectangle on the black screen (white=5.3 and black=.03 cd/m^2). The stimulus was a 2.52 x 1.68 cm rectangle, subtending a visual angle slightly over 1 deg. Line thickness was about 2mm.

The to-be-judged aspect of the stimulus was the position--either standing or lying. The to-be-ignored aspect was the position of an inserted line that was also either standing or lying. Figure 3 shows the set of four possible stimuli.

Procedure. A trial had a fixed duration of 4.25 sec and began with a 150-msec warning (75 dB, 1,000 Hz) delivered by the loudspeaker below the screen. This was followed by the to-be-judged stimulus that was projected for 100 msec. When the deadline had elapsed, the response signal sounded, indicating that the subject should respond immediately by pressing one of the two response keys. The trial ended with a silent period of 3 sec, during which the projector searched for the next stimulus slide.

A deadline was defined as the time between stimulus onset and the response signal. The latter was a train of three pips, spaced by 75 msec, much as in the study of Schouten and Bekker (1967). Each pip lasted 20 msec and had a frequency of 2,500 Hz. The subject's instruction was to press one of the keys at the onset of the last pip. When he pressed the key more than 50 msec too early or too late, a buzzer sounded for 200 msec (61 Hz, square wave). The subject was instructed to aim at the buzzer-free period of 100 msec. (For the experimental sessions, an average of 77% of the reactions were within the desired time-band.)

Time between warning tone and last pip was always 650 msec (offset to onset), while the moment of stimulus presentation varied as required by the deadline. Time elapsed since warning tone was therefore an additional cue for the subject when the response was due. The interval between warning tone and stimulus presentation was, of course, always 650 msec minus the deadline (msec).

A feedback indicator lamp lit a 2 x 4 cm area during the time a key was down. A green light indicated a correct response, and a red light indicated an incorrect response. Deadlines were presented in blocks of 120 trials each. Deadlines were chosen in such a way that correct stimulus judgments for the individual subject should not be under 60% or over 95%. Selection of deadlines was random with this constraint.

After a 120-trial block, the performance was discussed with the subject on the basis of a computer printout indicating percentage responses made too early or too late and percentage of correct responses.

Data from the first session were considered as practice. In the second session, scheduled on another day, the experimental data were collected.

Results and Discussion

Only the last eight blocks were entered in the analysis. Blocks with less than 55% correct responses were discarded (two blocks over all subjects). For each 110-trial block (first 10 trials discarded as warm ups), two RT-accuracy points were derived: one for consistent and the other for conflict stimuli (see Figure 3). Garner's (1962) information transmission index, U, was used as a measure of accuracy. For the present two-choice task, this U ranges between zero and one bit of transmitted information. Median reaction time was used as a measure of speed. The last eight blocks for each subject were thereby reduced to a group of eight RT-accuracy points for consistent stimuli, and another eight RT-accuracy points, for conflict stimuli. Points with accuracy under .01 or over .94 bits were discarded. This resulted in an average loss of .4 points per subject; the speed-accuracy function was thus estimated on an average of 7.6 points.

The SAF was calculated as the line best fitting the above-mentioned data. In view of the fact that both the RT and accuracy variables are subject to error (cf. Salthouse, 1981), Brace's method for best-fitting lines was adopted (Brace, 1977). Using this method, two speed-accuracy functions were derived for each individual subject: one for consistent, the other for conflict, stimuli.

To test whether the consistent SAF differed from the conflict SAF, two ANOVAs were employed. One ANOVA tested for slope differences; the other tested for intercept differences. In order to provide a more meaningful interpretation for the intercept, the latter was defined as the point of intersection with the abscissa, which can be interpreted as the moment that accuracy begins to improve from chance level.

The slope ANOVA revealed only a trend toward faster information transmission for consistent stimuli ($F(1,13)=3.28$, $p < .10$). The intercept ANOVA showed a significant effect of stimulus type: the moment that information transmission started occurred earlier for consistent stimuli (239 vs. 252 msec; $F(1,13)=11.05$, $p < .01$). Figure 4 shows the SAFs, with slope and intercept averaged over the 14 subjects.

The global precedence prediction--no difference due to details in the initial part of the SAF--was disconfirmed. In the absence of a clear difference in slope, the two SAFs are best considered as parallel lines, with the entire conflict SAF displaced somewhat to the right (or slower/inaccurate range). This means that information about stimulus detail had an approximately equal effect over the whole speed-accuracy range studied. Anyway, there was no clear indication that the effect of irrelevant stimulus detail was increased from initial to later stages, as predicted by the idea of global precedence. The data suggested, rather, that local features had already been sampled by the time information about global features could be passed on. In that case, the slope of the SAF would vary only under the influence of postperceptual processes and would thus fail to reveal a differential time course of global and local features. However, it is possible that the differential time course might show as an intercept effect, if it is correct to suppose that

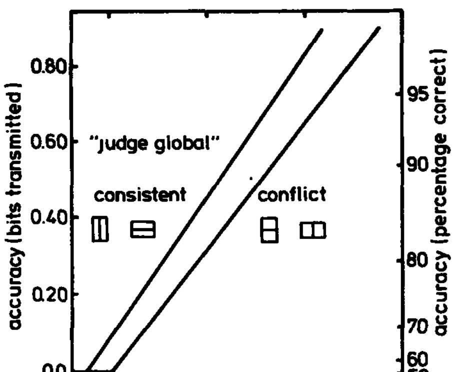


Figure 4. Speed-accuracy functions for the geometrical stimuli used in Experiment 1 for each stimulus type (consistent/conflict). Accuracy is expressed as bits of information transmitted. To illustrate the relation with percentage correct reactions, percentage correct is shown on the right-hand scale of the figure. This relationship holds only when percentage correct is distributed evenly over stimuli, since uneven distribution raises the bits transmitted for a given percentage correct. (The eight symbols along the abscissa show the average deadlines used in the eight experimental blocks.)

the start of information transmission occurs as soon as sufficient features have been sampled. One of the aims of Experiment 2 was to see whether global precedence was indeed reflected in the intercept of the speed-accuracy functions.

Experiment 2

The stimuli of Experiment 1 are not very typical in studies of global precedence. To avoid the possibility that the geometric stimuli failed to capture the global-local distinction, the letter stimuli of Figure 1 were used in Experiment 2. All research of global precedence has so far used this type of material, in which many small letters constitute the global form (Hoffman, 1980; Martin, 1979; Miller, 1981a; Navon, 1977, 1981a).

In order to test the global precedence model further, the experiment was extended to include a judge-global group of subjects as well as a judge-local group. The global precedence model predicts that the moment at which information transmission can start will occur later in time for the judge-local group, because local features are sampled later, or, in a weaker version of the model, because the rate of sampling local features is relatively slow. The moment at which sufficient features have been sampled for a better-than-chance impression of the stimulus will consequently be later.

A further prediction of the model is that global precedence will be obtained from the beginning of the SAF, observed as a sizable interference when global features are in conflict with local judgment. The weak form of global precedence implies that the momentary sample contains more global than local features during the initial stages. It follows that conflict in the stimulus (top-right and bottom-left in Figure 1) will be most interfering when the local features, assumed to be underrepresented, have to be judged, compared with when the overrepresented global features have to be judged.

In addition to these points, we examined the role of stimulus-response *compatibility. Navon (1977, 1981a) did not analyze* this factor, although it has some theoretical importance: interaction between the global precedence result and S-R compatibility would suggest that global precedence was caused at a postperceptual stage--namely, at response selection. This is especially relevant because of Miller's (1981a) contention that a global precedence result has a postperceptual locus.

In these related studies, the stimulus could appear in any one of the four quadrants of an area about twice the size of the global form. Although not explicitly stated, the likely reason for introducing this positional uncertainty is to prevent the subject from limiting his attention to a particular spot--a strategy that would be very useful, especially in the judge-local condition. (However, Ward, in press, compared positional certainty and uncertainty and found no difference whatever.) Martin (1979) also randomized stimulus position, but, due to the fact that her subjects named the stimuli, there were no consequences for S-R compatibility. We, like Navon (1977, 1981a), used two different response keys: one on the left and one on the right. It is in this particular situation that a left-right variation in stimulus position works as an irrelevant *directional* cue for responding with the left vs. the right key. Simon has studied the effect extensively and has shown that this compatibility is located at the response selection stage (Simon, in press; Simon, Acosta, Mewaldt, & Speidel, 1976). Applying Sternberg's (1969) additive-factor logic, interaction of Factor x with S-R compatibility implies that Factor x has its effect also at the response selection stage. The logic thus enables us to see whether global precedence is (in part) located at this postperceptual stage.

Method

Subjects. Thirty four students were tested; all were paid volunteers with normal or fully corrected vision. Seventeen subjects were assigned to each of the two attention conditions--judge local and judge global. However, two judge-global subjects and one judge-local subject had to be eliminated from the final analysis since their performance deteriorated during the first session, while accuracy was hardly related to the particular deadline. Discarding randomly another subject from the judge-local group made for a balanced design of 15 judge-global and 15 judge-local subjects.

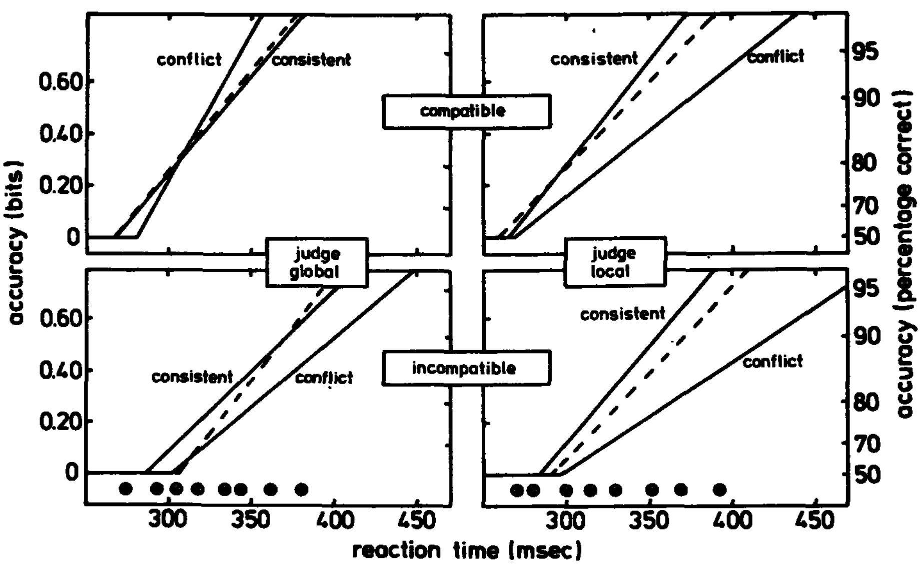


Figure 5. Speed-accuracy functions for the letter stimuli used in Experiment 2 for each stimulus type: the broken line represents neutral stimuli; the solid lines show consistent and conflict stimuli, as indicated. The eight symbols along the abscissa show the average deadlines (The left part of the figure shows the data of the 15 judge-global subjects; the right part shows the data for the 15 judge-local subjects. Each top panel shows data for which the stimulus required a compatible reaction; each bottom panel shows data for which the stimulus required an incompatible reaction.)

Stimuli. The stimuli, their positions on the display, exposure time, and visual angle were very much the same as the many-element stimuli in Martin's (1979) first experiment. The global letter was 9.9 x 6.3 cm or 2.6 x 4.0 deg of visual angle at a 140-cm viewing distance. The local letters were 8.5 x 11.2 mm, which is the line thickness of the global letter; line thickness of the local letters was less than 2 mm. The stimulus appeared randomly in one of the four quadrants of the visible area immediately adjacent to the area's central and vertical axes. Thus, half of the stimuli were presented on the left side of the screen (a quarter at top left, a quarter at bottom left), and half of the stimuli were presented on the right side of the screen (a quarter at top right, a quarter at bottom right). Half of the stimuli required a compatible reaction (stimulus left, response left; stimulus right, response right), and half required an incompatible reaction. Furthermore, in addition to the consistent and conflict stimuli, a neutral type was used in which the irrelevant level was a rectangle not connected to any to-be-judged aspect (see Figure 1).

Procedure. The procedure was the same as in Experiment 1.

Results

Data analysis was similar to Experiment 1, but compatibility was also analyzed. For a particular subject, six speed-accuracy functions were derived (3 stimulus types x 2 levels of compatibility), based on RT-accuracy points that were between .01 and .94 bits of information transmitted. (Due to the greater number of SAFs and the consequently lower number of observations per point, the criterion was in fact between .01 and .76 bits.) The criterion removed, on the average, 1.5 points per subject. Each SAF was thus based on 6.5 points.

Figure 5 shows the average SAFs for each stimulus type. The left part of the figure shows the judge-global group of subjects;

the right part shows the judge-local group of subjects. The top panel within each part shows the compatible condition, and the bottom panel shows the incompatible condition.

Compatibility had an effect on the slope ($F(1,28)=4.59$, $p < .05$) and on the intercept ($F(1,28)=51$, $p < .01$); that is, incompatible S-R mappings delay by 24 msec the moment that information transmission is begun and subsequently slow down the transmission itself so as to predict another 24-msec delay under perfect accuracy performance. Compatibility did not interact with other factors except for a trend toward interaction with stimulus type ($Fs(2,56)=2.30$ and 2.49, $ps < .11$; for slopes and intercepts, respectively).

Stimulus type tended to affect the intercept ($F(2,56)=3.03$, $p < .06$), pointing to the finding that transmission may start a little earlier for consistent stimuli (but see also the General Discussion). Global subjects tended toward greater speed of information transmission than local subjects ($F(1,28)=3.68$, $p < .07$), while information transmission started at the same time for both groups of subjects ($F < 1$). More important, the interfering effect of stimulus type on speed of information transmission (i.e., the slope of the SAF) was greater for the judge-local group ($F(2,56)=5.34$, $p < .01$). No other interactions with global/local subjects were observed.

On inspection of Figure 5, it is clear that the bulk of the effects, trends, and interactions related to stimulus type were accounted for by the shallow conflict SAF in the judge-local group. Information transmission was apparently very difficult in this condition.

General Discussion

The typical global precedence result was obtained, insofar as the speed of information transmission was slowed down only when global features interfered with local judgment, and not when local features interfered with global judgment. Closer inspection of the data suggested a postperceptual basis for the results. The argument is mainly based on how the details interfered when the subject judged the stimuli on global form.

The first experiment revealed an effect of irrelevant local detail on the intercept of the SAF, while no clear evidence was observed for a slope difference. The second experiment confirmed the impression: the intercept effect--even the size of it--was replicated (13 msec; $F(2,14)=4.68$, $p < .05$; $F < 1$ for the judge-local group), while irrelevant local features had absolutely no effect on slope. Consequently, the effect of to-be-ignored detail must have been present in full from the very beginning of the SAF, while the effect was not further increased in the late part of the SAF. Thus, it is very likely that global and local features had already been sampled exhaustively before any information could be passed on.[3] This was also suggested by the observation that information transmission for the judge-local group started just as early as for the judge-global group; in fact, it was 10 msec earlier.

We now consider <u>when</u> global precedence was obtained. No global precedence was found at the intercept; the different SAFs for different stimulus types lie very closely together, to diverge substantially only in the late part of the SAF. If perception (or feature accumulation) was already complete at the intercept, the absence of an initial global precedence result argues against any <u>perceptual</u> locus for global precedence. When, later on, a global precedence result was obtained, its locus was consequently postperceptual. Miller (1981a) similarly argues for postperceptual global precedence. He showed that local information becomes available to decision processes with a time course similar to that of global information and that subjects can integrate global and local information into a single decision. His conclusion may have been dependent on the specific task: he used a target-search in which the target could be located at either or both levels. This paradigm more or less forced the subject to divide his attention over global and local aspects. The present task, by contrast, motivated the subject to lock his attention onto one aspect exclusively. (Moreover, we used a between-subjects design.) Our result is thus an even stronger argument in favor of similar time courses for the availability of local and global aspects in perception.

The evidence for similar time courses in perception does not question the phenomenon itself--namely, that it is impossible to ignore the global aspect. The phenomenon was observed in this and other studies and appears to be mandatory, in the sense that subjects were unable to ignore the global aspect in spite of their intentions. It is only the interpretation in terms of <u>perception</u> that is probably incorrect. Global precedence is a matter of differential use of global and local information, not a matter of differential availability of global and local information (see the discussion between Miller, 1981b, and Navon, 1981b). The term <u>global dominance</u> may be preferred, because it avoids the implication of differential availability.

In fact, when it comes to perceptual availability, the data of the present paper are even compatible with the opposite building order of the percept: local before global, or at least, local as the faster information. If we are right in interpreting the intercept as reflecting an early stage of perception determined by data limitations rather than processing limitations, the intercept data reveal that the local, and not the global, aspect is most difficult to ignore. The irrelevant global aspect had no effect on the intercept for the judge-local group (Eperiment 2), but the irrelevant local aspect had a significant effect on the intercept, both in Experiment 1 and in Experiment 2 (the judge-global group).

At what stage of processing does global dominance come into being? The position seems defendable that stimulus preprocessing and encoding were either very fast relative to subsequent stages or that they were unitary processes in the sense that they did not pass information to subsequent stages unless they were completed.[4] There was no indication that the result of global dominance had something to do with response selection (Fs < 1 for the interaction with S-R compatibility). The most tenable interpretation of the present results seems to be that global dominance (or precedence) is located somewhere between perception and response selection.

Miller (1981a) argues for greater ease of directing attention to the global aspect and deciding accordingly. Ward (in press) similarly invokes an attentional account when ascribing global dominance to the greater conspicuity of the global aspect because he leaves the precise definition of conspicuity to Engel (1971), who defines conspicuity as "that combination of properties in a visible object in its background by which it attracts attention" (p. 536). Unfortunately, attentional accounts are of little help in identifying which processing stages are involved in global dominance.

Finally, we briefly consider a finding of <u>local</u> precedence, which may suggest a condition necessary to obtain global dominance. The particular result was obtained in the card-sort tasks of Pomerantz and Sager (1975). The stimuli in their last two experiments were very similar to our letter stimuli: large forms (2.5 deg) made up of many small letters (.2 deg each). They found that the local letters were most difficult to ignore.

The first consideration is the difference in methods used to assess the interference of the to-be-ignored aspect. The card-sort task investigates the effect of random variation in the irrelevant aspect compared with a condition without this irrelevant variation. The task in the present report investigates the effect of a particular state of the irrelevant aspect compared with the effect of other states of that aspect. For example, we were interested in the effect of conflict due to the irrelevant aspect compared with the effect of other states (neutral and consistent) of the aspect. In assessing such effects, we used trial blocks in which the state of the irrelevant aspect varied unpredictably from trial to trial, but we did not use trial blocks with the irrelevant aspect fixed in a particular state. There is, however, some counterevidence for the idea that the different result of Pomerantz and Sager (1975) was due to their different method. We previously examined the rectangular stimuli of Experiment 1 in a card-sort task and found a global dominance result. Navon (1981a) also used the two methods (even in a within-subjects design) and also found global dominance in both methods.

The difference in stimuli suggests a more likely hypothesis to account for the absence of global dominance in the results of Pomerantz and Sager (1975)--viz., that the compatibility between the value of the global aspect and the particular value of the local aspect is very important. Pomerantz and Sager choose letters for the local aspect and geometric configurations for the global aspect, thereby avoiding conflict across aspects. On the other hand, in those studies in which global dominance was found, the levels within a particular aspect were selected in such a way as to contradict or to confirm the levels selected for the other aspect. This suggests that global dominance is only observed when the levels across aspects are sometimes in conflict; in other words, that the consistent/conflict relation across aspects is a necessary condition for global dominance. The global aspect must have some bearing on the judgment the subject tries to make--only then is it impossible to ignore the suggestion offered by the global aspect.

Notes

1. According to a reviewer of this chapter, the plotting order in Hoffman's second experiment was random. It was not made clear whether this refers to the order of plotting the small letters or to the order of plotting each point over the whole stimulus. Only in the latter case is our objection met, but see our incidental finding that brightness differences due to oscilloscope presentation can override global precedence (see Figure 2).

2. The data of the left and right panels of Figure 2 were based on one group of 18, and another group of 11, subjects, respectively, none of whom participated in the other experiments reported in this research. Each subject did 150-200 judge-local trials and 150-200 judge-global trials, with order of global-local attention counterbalanced between subjects.

3. At first sight an alternative explanation may be suggested, namely, that the slope of the SAF reflects feature accumulation. However, this explanation cannot account for the different interference in the judge-local and the judge-global group.

Interference for the judge-local group (cf. also Experiment 1) was constant over the whole range of the SAF. This would necessitate the assumption that interference is a function of the <u>ratio</u> of local and (irrelevant) global features, and that this ratio is constant during feature accumulation. Interference for the judge-global group did, however, increase towards later stages of the SAF, which would necessitate the assumption that the ratio of (irrelevant) local and global features <u>changes</u> during feature accumulation.

4. The result that the slope of the speed-accuracy function does not reflect perceptual processes argues against the applicability of the continuous-flow model of Eriksen and Schultz (1978, 1979). The result is in line with Pachella's (1974) idea that the slope reflects only process limitations--not data limitations.

References

Boer, L.C. & Keuss, P.J.G. Storage mode of geometrical dimensions in a two-stimulus matching paradigm. Perception & Psychophysics, 1979, 25, 197 - 204.

Boer, L.C. & Keuss, P.J.G. Integrality over different paradigms: (1) card sorting and (2) two-stimulus matching. Perception & Psychophysics, 1981, 29, 71-76; Chapter 2 of this dissertation.

Bouma, H. Visual recognition of isolated lower-case letters. Vision Research, 1971, 11, 459 - 474.

Brace, R.A. Fitting straight lines to experimental data. American Journal of Physiology, 1977, 233, R94 - R99.

Campbell, F.W. The transmission of spatial information through the visual system. In F.O. Schmitt & F.G. Worden (Eds.), The neurosciences third study program. Cambridge, Mass: M.I.T. Press, 1974.

Engel, F.L. Visual conspicuity, directed attention and retinal locus. Vision Research, 1971, 11, 563 - 576.

Eriksen, C.W., & Schultz, D.W. Temporal factors in visual information processing: A tutorial review. In J. Requin (Ed.), Attention and performance VII. Hillsdale, N.J: Erlbaum, 1978.

Eriksen, C.W., & Schultz, D.W. Information processing in visual search: A continuous flow conception and experimental results. Perception & Psychophysics, 1979, 25, 249 - 263.

Garner, W.R. Uncertainty and structure as psychological concepts. New York: Wiley, 1962.

Gibson, E.J. Principles of perceptual learning and development. New York: Appleton, 1969.

Hoffman, J.E. Interaction between global and local levels of a form. Journal of Experimental Psychology: Human Perception and Performance, 1980, 6, 222 - 234.

Kinchla, R.A., & Wolfe, J.M. The order of visual processing: "Top-down," "bottom-up," or "middle-out." Perception & Psychophysics, 1979, 25, 225 - 231.

Lupker, S.J. On the nature of perceptual information during letter perception. Perception & Psychophysics, 1979, 25, 303 - 312.

Martin, M. Local and global processing: The role of sparsity. Memory & Cognition, 1979, 7, 476 - 484.

Miller, J. Global precedence in attention and decision. Journal of Experimental Psychology: Human Perception and Performance, 1981, 7, 1161 - 1174.(a)

Miller, J. Global precedence: Information availability or use? Reply to Navon. Journal of Experimental Psychology: Human Perception and Performance, 1981, 7, 1183 - 1185.(b)

Navon, D. Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 1977, 9, 353 - 383.

Navon, D. The forest revisited: More on global precedence. Psychological Research, 1981, 43, 1 - 32.(a)

Navon, D. Do attention and decision follow perception? Comment on Miller. Journal of Experimental Psychology: Human Perception and Performance, 1981, 7, 1175 - 1182.(b)

Pachella, R.G. The interpretation of reaction time in information-processing research. In B.H. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition. Hillsdale, N.J.: Erlbaum, 1974.

Petersik, J.T. A physiological and psychophysical interpretation of geometrical dimensions in a binary classification task: Comments on Keuss (1977). Perception & Psychophysics, 1977, 22, 511 - 515.

Polf, J. The word superiority effect: A speed accuracy analysis and test of a decoding hypothesis. Unpublished doctoral dissertation, University of Oregon, 1976.

Pomerantz, J.R., & Sager, L.C. Asymmetric integrality with dimensions of visual pattern. Perception & Psychophysics, 1975, 18, 460 - 466.

Salthouse, T.A. Converging evidence for information-processing stages: A comparative-influence stage-analysis method. Acta Psychologica, 1981, 47, 39 - 61.

Schouten, J.F., & Bekker, J.A.M. Reaction time and accuracy. In A.F. Sanders (Ed.), Attention and performance I. Amsterdam: North-Holland, 1967. (Reprinted from Acta Psychologica, 1967, 27.)

Selfridge, O. Pandemonium: A paradigm for learning. In Symposium on the mechanization of thought processes. London: Her Majesty's Stationery Office, 1959.

Simon, J.R. Effect of an auditory stimulus on the processing of a visual stimulus under single- and dual-tasks conditions. Acta Psychologica, in press.

Simon, J.R., Acosta, E., Mewaldt, S.P., & Speidel, C.R. The effect of an irrelevant directional cue on choice reaction time: Duration of the phenomenon and its relation to stages of processing. Perception & Psychophysics, 1976, 19, 16 - 22.

Sternberg, S. The discovery of processing stages: Extensions of Donder's method. In W.G. Koster (Ed.), Attention and performance II. Amsterdam: North-Holland, 1969. (Reprinted from Acta Psychologica, 1969, 30.)

Treisman, A.M., & Gelade, G. A feature-integration theory of attention. Cognitive Psychology, 1980, 12, 97 - 136.

Vartabedian, A.G. Legibility of symbols on CRT displays. Applied Ergonomics, 1971, 2, 130 - 132.

Ward, L.M. Determinants of attention to local and global features of visual forms. Journal of Experimental Psychology: Human Perception and Performance, in press.

Chapter V

Summary, and speculations on the nature of global dominance

A summary of the findings is presented: Problems for selective attention can, among others, be due to (1) integrality as a stimulus property and (2) global dominance caused by a postperceptual process.

The remainder of the chapter concentrates on the process giving rise to global dominance. First, two implications of the forest-trees terminology (denoting global and local aspects) are pointed out, one of which leads us to consider the confounding between relative size and globality. Some evidence is reviewed indicating that size alone is insufficient as an explanation. Then, it is discussed whether global dominance can, in principle, be ascribed to a reflex-like rechecking of a specific aspect of the percept; and how such a recheck relates to perception itself. Finally, the functional use of global dominance is considered. One such use of global dominance is, that global aspects are more resistant to frequently occurring decrements in acuity.

The original question of the dissertation was: To what extent is it possible to attend to only one aspect of a visual stimulus. Chapter 2 and 3 showed that the limits on selective attention stemming from integrality were not dependent on the specific task used. This is compatible with Garner's contention that integrality is a property of the stimulus, and this adds to other evidence that integrality between, or "unitary perception" of two stimulus aspects can be listed as one of the causes of selective attention problems.

Chapter 4 addressed another source of problems for selective attention, stemming from the alleged global-to-local development of perceptual information (Navon, 1977). Chapter 2 and 3 referred already to this model as a possible explanation for particular aspects of the data. Chapter 4 showed that the global-to-local model was incorrect as a model of perceptual availability. On the other hand, existence of global dominance was indicated. Global dominance certainly should be considered as an explanation for the asymmetric integrality between outline form and inserted detail, established in earlier chapters. However, integrality, when applied to this situation, is no longer a pure stimulus aspect, since the selective attention problem is due not to perception of one unitary aspect instead of two distinct aspects, but rather to a postperceptual dominance of one aspect over the other. (Maybe it should be made explicit that the assumption of unitary perception does not exclude an underlying process of feature accumulation, which process played a central role in chapter 4's treatment of microgenesis as a feature accumulation process. For example, the idea of integrality is in good agreement with a feature accumulation model, in which the features convey only combined information about both aspects.)

The remainder of this chapter will address the exact nature of global dominance. In particular, it considers the possibility of whether global dominance can be conceived of as a reflex-like operation on the percept, to be bypassed only by extreme measures.

To begin with, I will discuss the connotations implied by the forest-trees terminology used by Navon (1977, 1981, in press) as a colorful shorthand for global and local aspects. First, the terminology implies a natural relation between global and local aspects—an implication not borne out in a global letter consisting of many local letters, nor in a triangle consisting of three local elements (Navon, 1977; in press). There are two plausible arguments why to use this material. (1) Global and local aspects can be chosen in such a way that the aspects are sometimes in conflict, which makes the paradigm extremely sensitive in detecting interference and (2) Global and local aspects, once perceived, are equally codable. This avoids a confound between codability and globality; that is, when global shape is easier to judge, it cannot be ascribed to the greater ease of matching that shape to the feature list (or scheme) necessary for identification (or coding). These advantages seem rather indispensable for a test of global dominance, and it would be very difficult; not to say impossible, to select natural stimuli having these same advantages.

A second connotation of the forest-trees terminology is that the global shape is built from many local elements. This is, of course, the gist of the whole global-local distinction and was also borne out in the stimulus material. But what would the results be if the global shape is not built of many local elements. As when, for example, the global shape stands beside the set of many local elements. If similar global dominance data were to be observed, the principle of parsimony argues for an interpretation in terms of size alone, discarding global and local terms as superfluous concepts. However, some findings are to be reported showing that size alone provides an insufficient explanation and that the global-local distinction is a meaningful one. Schultz and Eriksen (1978) studied the effect of letter size on speed of recognition, height of letters varying between .14 and 2.14^{o} of visual angle. They found most of the effect at the small end of the scale, probably because of the limited resolution capacity of the visual system. Based on these results, the size effect to be expected for the global and local letters of chapter 4 is small. The best estimate for recognizing the local letter of chapter 4 is 395 msec; the best estimate for recognizing a 2.14^{o}

global letter is 380 msec. Schultz and Eriksen used no letters bigger than that, but express their conviction of finding decreasing performance for letters of greater size. This they would certainly expect for global letters 4^{o} in height. Accepting the logic, it is unlikely that dominance of global shape could have been caused by relative size.

More pertinent evidence for the inadequacy of the size explanation comes from Experiment 2 of Eriksen and Schultz (1979). The target letter, appearing directly above the fixation point, was flanked on both sides by noise letters that could be consistent to, or in conflict with, target identity (see chapter 1 for a further discussion of the Eriksen paradigm). They found more pervasive interference when noise exceeded target size by a factor 2. This seems like global dominance. However, this effect was eliminated when the size of the noise letter was further increased (1.12^{o} while the target was $.25^{o}$, which gives a size ratio of 4½ : 1). Considering that in chapter 4 the global-local size ratio was still greater (10 : 1), it seems unlikely again that size alone was responsible for global dominance.

In fact, the results of Experiment 2 in chapter 4 are additional evidence that more than size is involved in global dominance. Size effects are assumed to operate early in the visual tract. For example, according to the continuous-flow model of Eriksen and Schultz (1979), the visual system needs less stimulus energy if the stimulus appears with good acuity. Size is one of the factors that improve acuity, but only up to a certain point, after which a further increase in size has the negative effect of projecting the outer edges of the stimulus onto more eccentric retinal positions, where acuity suffers. All size effects, whether degrading or improving acuity, are thus located in an early perceptual stage. However, chapter 4 showed that global dominance occurred, but only after the early stages. This result additionally refutes a size-alone explanation. Global and local aspects deserve to be treated in their own right, and not as simple size differences. The situation that global consists of many local elements (as implied by forest-trees terms) should be considered as a special situation, in which more than size is involved.

Before speculating on the relation between perception and global dominance, let us briefly sum up the relevant results. The speed-accuracy functions revealed significantly less global dominance (even absence of it) when the subject performed under rather extreme time pressure, while the usual global dominance effect was observed as soon as he performed under a less extreme time pressure. Further, it should be noted that global dominance was not under voluntary control. Global dominance emerged irresistably, despite the subject's intention to ignore the global shape. (And note what excellent opportunity he had for selective attention: He went throug a lot of training, and moreover, this training was very consistent; relevant and irrelevant aspects were never interchanged.)

A possible way in which perception and global dominance could be related is that global dominance is the result of a secondary reflex-like operation on the percept. The operation follows mandatorily after perception, unless extreme time pressure prevents the operation to occur. Several possible conceptions suggest themselves here. The operation can be conceived as a transformation of the percept, or (in terms of Treisman, 1960) as the application of an attentional filter that puts through some aspects in attenuated form and amplifies others. Or, alternatively, the idea of a recheck on the input can be invoked, as for example Bamber (1969) and Krueger suggested (Krueger, 1978; Krueger & Shapiro, 1981); the recheck in point addressing a particular aspect of the input—the global shape. As long as the idea is conveyed that the process is directed towards a specific aspect, the particular term is of no importance; it could be variously called recheck, filtering, transformation, or "inquiry" (as Navon probably would have preferred, 1981).

Could these rechecks be considered as part of perception? The answer for the supposed global dominance recheck was <u>no</u> (chapter 4). However, recent discussions have considered rechecking as part of perception. For example, McClelland and Miller assume that in perception the input is checked for "structural relevance". They propose the existence of "heuristics to direct processing to aspects of the input that are potentially important for determining the final figure" (1979, p. 221). Calis and Leeuwenberg assume a test phase, in which tests are made in a hierarchical order; "specific information is asked for at specific moments" (1981, p. 1396). They call this whole process, including tests, microgenesis. The Gestalt view of perception as microgenesis or Aktualgenese is very close indeed to the conception of input, followed by specific rechecks. The Gestalt observer trying to impose his "structural rendencies" (Sander, 1930, p. 194) on the registered information is reminiscent at least, of our present-day subject checking the presence of a particular "structure" suggested by the input. Until now, it seems a matter of personal preference or tradition how to define perception. However, I think that a merit of the methodology of chapter 4 is, that it can help in setting limits on the definition of perception, for example, by saying: "All rechecks that can be bypassed under extreme time pressure do not belong to perception proper".

A recheck on global aspects will restrict the possibilities for selective attention, probably in all tasks without extreme time pressure. This should not be taken to imply that selective attention is of no consequence for the global recheck, (it may, or may not, have some effect). The result of chapter 4 only demonstrates that selective attention is hampered by the recheck. Similar problems for selective attention will probably arise from other rechecks.

I will conclude this chapter with some remarks about the ecological validity of global dominance. The reasoning presupposes that most mechanisms with which the human being is equipped make sense, that is, are useful in real-life circumstances. Whether this is derived from the viewpoint that God created harmony (and not disconnectedness) between organism and environment, or to the viewpoint that evaluation was at work has lead to hot debates (Science, 1982, 215, 33-39 and 142-146). However, there is a general consensus that most functions serve a useful purpose. A reason, then, to prefer global over local aspects is revealed when taking into account the limited acuity of the visual system. When acuity deteriorates the finest discriminations suffer most, while more crude aspects are still discernable. This is, for example, the case when an object is seen at a long distance. Global characteristics survive greater acuity decrements than local characteristics. The advantage of basing object identity on global characteristics is that object identification is maintained over a large range of acuity levels. Several situations in which acuity suffers do occur frequently. In addition to long-distance viewing, the object is often perceived peripherally (Westheimer, 1972), or in semi-darkness (Westheimer, 1972, or with inadequate accommodated eyes, or when moving across the retina. Substantial experience with such situations designates local aspects as unreliable information: global aspects are available more often than local aspects. Moreover, the acuity of the human infant is very poor, especially in the first six months (e.g. Werner & Lipsitt, 1981). The fact that local aspects are even less reliable for the infant, could well be an extra reason to weigh these aspects much less in postperceptual processing. In addition, this could reinforce the use of a global dominance strategy, which the infant may retain through later stages of development.

References

Bamber, D. Reaction times and error rates for "same"-"different" judgments of multidimensional stimuli. Perception & Psychophysics, 1969, 6, 169 - 174.

Calis, G., & Leeuwenberg, E. Grounding the figure. Journal of Experimental Psychology: Human Perception and Performance, 1981, 7, 1386 - 1397.

Eriksen, C.W., & Schultz, D.W. Information processing in visual search: A continuous flow conception and experimental results. Perception & Psychophysics, 1979, 25, 249 - 263.

Krueger, L.E. A theory of perceptual matching. Psychological Review, 1978, 85, 278 - 304.

Krueger, L.E., & Shapiro, R.G. A reformulation of Proctor's unified theory for matching-task phenomena. Psychological Review, 1981, 88, 573 - 581.

McClelland, J.L., & Miller, J. Structural factors in figure perception. Perception & Psychophysics, 1979, 26, 221 - 229.

Navon, D. How many trees does it take to make a forest? Manuscript in preparation.

Navon, D. Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 1977, 9, 353 - 383.

Navon, D. The forest revisited: More on global precedence. Psychological Research, 1981, 43, 1 - 32.

Sander, F. Structure, totality of experience, and Gestalt. In C. Murchison (Ed.), Psychologies of 1930. Worcester, Mass.: Clark University Press, 1930.

Schultz, D.W., & Eriksen, C.W. Stimulus size and acuity in information processing. Bulletin of the Psychonomic Society, 1978, 12, 397 - 399.

Treisman, A.M. Contextual cues in selective listening. Quarterly Journal of Experimental Psychology, 1960, 12, 242-248.

Werner, J.S., & Lipsitt, L.P. The infancy of human sensory systems. In E.S. Gollins (Ed.), Developmental plasticity: Behavioral and biological aspects of variation in development. New York: Academic Press, 1981.

Westheimer, G. Visual acuity and spatial modulation thresholds. In D. Jameson and L.M. Hurrich (Eds.), Handbook of Sensory Psychology, VII/4, Visual Psychophysics. Berlin: Springer, 1972.

Chapter VI

Samenvatting van
"Waarneming van een visuele stimulus
in een selectieve-aandacht taak"

Hoofdstuk 1 introduceert een veel gebruikte selectieve-aandacht taak waarmee in de dissertatie enkele facetten van de waarneming zijn onderzocht. De proefpersoon moet een uit meerdere aspecten bestaande visuele stimulus beoordelen op één aspect, terwijl andere aspecten zoveel mogelijk genegeerd moeten worden. Uit de resultaten blijkt in hoeverre de proefpersonen tot de geïnstrueerde selectieve aandacht in staat waren. Het succes waarmee iemand zijn aandacht selectief op een bepaald aspect kan richten hangt af van twee belangrijke perceptuele factoren, t.w. *integraliteit* en *de voorrang waarmee globale stimulusaspecten worden waargenomen* (global precedence).

Integraliteit betekent dat de verschillende aspecten van de stimulus als een integraal geheel worden waargenomen. Selectieve aandacht voor één aspect wordt daardoor belemmerd. De tweede factor, de voorrang voor globale stimulusaspecten, veronderstelt een waarnemingsfase waarin nog geen details (of locale aspecten) zijn geregistreerd maar alleen globale aspecten. Deze theorie voorspelt dat selectieve aandacht voor globale aspecten zeer goed mogelijk is, maar dat aandacht voor locale aspecten moeilijker zal zijn. Het idee van globale voorrang voorspelt dus een asymmetrie van selectieve aandacht: Globale aspecten kunnen gemakkelijk los van locale aspecten beoordeeld worden, maar locale aspecten niet los van globale aspecten.

Hoofdstuk 2 gaat na of de betekenis van het begrip integraliteit beperkt is tot de op dit terrein gebruikelijke kaart-sorteer taken. Resultaten van deze taak worden vergeleken met resultaten van een taak waar de proefpersoon steeds twee stimuli moet beoordelen als "gelijk" of "verschillend", de zg. matching taak. In het algemeen geven beide taken dezelfde resultaten--reden om te besluiten dat integrale waarneming van twee aspecten niet verandert wanneer de taak verandert.

Hoofdstuk 3 onderzoekt of presentatietempo van invloed is op het succes van selectieve aandacht. Dit blijkt niet het geval. Het waarnemen van integraliteit wordt dus evenmin beïnvloed door de specifieke taakconfiguratie. (Overigens is het wel handiger om kaartsorteertaken in snel tempo af te nemen, daar dit de gevoeligheid van de taak vergroot.)

Hoofdstuk 4 gaat verder in op het idee dat globale aspecten voorrang hebben. Dit idee werd in de vorige hoofdstukken gebruikt ter verklaring van een bepaalde asymmetrie in integraliteit. Analyse van snelheid-versus-nauwkeurigheidsfuncties laat zien dat globale aspecten inderdaad domineren, maar dat dit resultaat niet kan worden toegeschreven aan hun vroegere registratie in de waarneming.

Hoofdstuk 5 geeft een korte samenvatting van het geheel, nl. dat integraliteit van de stimulus en globale dominantie beperkende factoren zijn voor selectieve aandacht. Vervolgens wordt betoogd dat "globale" aspecten niet te herleiden zijn tot "grote" aspecten; verder dat globale dominantie tot stand komt tijdens "recheck"-procedures *na* informatieregistratie. Tenslotte wordt ingegaan op de functionele betekenis van globale dominantie.