The Roles of Endpoints and Closures in a Detection Task

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The purpose of this study is to investigate the relative detectability of endpoints and closures in a given random figure. A new detection task is introduced in which participants were requested to judge the state (i.e., presence or absence) of a pre-designated endpoint or a closure in a singly presented random figure. Rigorous control was exerted over the selection of stimulus figures possessing these features. The results seem somewhat confusing: the presence of closures and the absence of endpoints were identical in terms of stimulus states but elicited different levels of detectability depending upon the designated target feature (i.e., an asymmetry in detectability), the mental set for closure detection seemed to be more efficient than the mental set for endpoint detection, and the assumption of feature detection via feature search did not appear viable. To comprehensively account for these results, this paper proposes an explanation that assumes a default decision state (i.e., the presence of closures when the target feature is closures, and the absence of an endpoint when the target feature is an endpoint) and quick responses for situations that deviate from the default state.

Key words: endpoints, closures, feature detection task

Although the elusiveness of the status of shape features has been argued (e.g., Pomerantz & Pristach, 1989; Wolfe, 1998), endpoints and closures are the most frequently studied candidates for the features detected at an early stage of visual processing. Many experimental tasks have been devised to investigate the roles of endpoints and closures in the visual perception of figures.

With the use of texture segregation tasks, Julesz persistently reported that the region containing endpoints were segregated (e.g., Julesz, 1984, 1986). Here, if a region in a stimulus display consisting of certain element figures is automatically distinguishable from a neighboring region of other element figures, texture segregation is said to occur. Feature search tasks have also been employed to diagnose the automatic detections of a specific feature in a wide visual field. Its basic procedure is to judge the presence or absence of a pre-designated target figure in an array of non-target figures. If the time to detect a target is fast and independent of the number of non-targets in an array, the phenomenon is called a pop-out. If a certain target figure pops out, the feature contained in that figure would constitute a basic, preattentively detected feature. Treisman and Souther (1985) reported that a target consisting of a circle with an intersecting line popped out from the non-targets consisting of complete circles. Thus they considered that the presence of an intersecting line (i.e., the presence of endpoints) could be preattentively detected. They also found that a triangle target popped out from right angled line junctions and diagonal lines and to a lesser degree right angled line junctions popped out from triangle distractors. They considered that a closure implied by a triangle and endpoints implied by an angle are different and complementary primitive features. A related phenomenon to feature search paradigm is an illusory conjunction, which indicates an erroneous combination of preattentively detected features that results in the perception of a nonexistent derivative property (Treisman & Gelade, 1980; Treisman & Schmidt, 1982). Conversely, the derivative property emerged from an illusory-
ry conjunction is considered not to be basic. Treisman and Paterson (1984) reported that illusory conjunction of an arrow occurred from a properly oriented diagonal line and a right angle for some participants but illusory conjunctions of a triangle rarely occurred from a diagonal line and a right angle. The results would be favorable to the superiority of closure detection hypothesis.

When a holistic configuration of a figure is perceived faster than its component parts, configurational superiority effect is said to occur. According to Garner (1974), stimuli redundantly specified by separable dimensions should show no gain in the speed of their classifications while stimuli redundantly specified by integral dimensions should facilitate their classifications. In other words, if closures are directly perceived and constitute an integral dimension, configurational superiority effect would occur, whereas, if no such redundancy gain exists, componential information like respective points of line connections would be perceived one by one. On this point, Kimchi and Bloch (1998) indicated that closures dominated both discrimination and classification performance. It could thus be considered that a closure constitutes an integral dimension. In other words, a closure is automatically perceived rather than perceived through separate detections of connecting points.

To sum up, these results indicate that endpoints and/or closures are critical in early processing of figural cognition. At present, neither the questions of which feature, endpoints or closures, is more quickly detected in early perception, nor of whether the relative superiority of detecting one feature to the other is a task dependent or independent phenomenon, has been well answered. This experiment was intended to investigate which pre-designated feature, an endpoint or its complementary state of closure(s), was more quickly detected in a detection task by taking the demand characteristics of the task into consideration. In the task participants were requested to judge whether a pre-designated target feature was present or absent in a singly presented stimulus figure.

Few attempts have been made to investigate the roles of features in early perception by a detection task. One reason why detection tasks have been rarely employed stems from the unavailability of stimuli having a large number of variants which are insured to possess the features concerned. However, the task has its merit of directly measuring the relative detectability of the features without serious low-level interferences which are sometimes apparent in segregation and search studies. That is, the effects of preattentive feature detection are confounded by the effects of multiple presentations of element figures. For example, the distances between element figures affected the easiness of segregations (Sagi & Julesz, 1987), and performance was improved by grouping of non-target figures (Bacon & Egeth, 1991; Kanbe, 2008) and was degraded by heterogeneity in non-target figures (Treisman & Souther, 1985) in feature search tasks. In addition, most of the stimuli used in these experiments were simple figures (viz., made up of a small number of component parts), and hence could possibly cause higher-level interference to what was detected. For example, most of the results inferable as a quick detection of closures or of an endpoint might at the same time be interpretable as a quick identification of a familiar shape (e.g., a triangle, an arrow, a slash, a quadrilateral) by means of its codability (or its name).

A limitation of the detection task, on the other hand, is also clear. As will be argued in Discussion, there is no established criterion over the distinction between attentive and preattentive detections applicable to the present task.

Specific types of random figures, called (6, 5) figures, were employed in the present experiment. A (6, 5) figure has five line segments which are spanned between five pairs of the vertices of a regular hexagon. As for these figures, not only the numbers of endpoints and closures embedded in them but also various other properties are known. At the same time, the total number of (6, 5) figures is also known to be 3003. Among them, the number of figures without any endpoint (or completely closed) is 162 and the number of figures having one endpoint is 720. Completely closed figures include those having smaller closures inside of their perimeters. In this respect, the terms the presence of an endpoint and the presence of closures are henceforth to be used. With the use of a large number of stimulus figures, the effects caused by singular, prototypical figures (e.g., stimulus codability) could be avoided and the familiarization with the stimuli would be kept low. Since each stimulus was presented as a single figure, the effects inherent in the multiple stimulus presentations in a display will not arise.

**Method**

**Participants**

Fifteen male and three female university students aged 18–22 volunteered to take part in the experiment. All participants had normal or corrected-to-normal vision. They had no prior experience with psychological experiments.
Stimuli

A (6, 5) figure singly presented on a CRT constituted a stimulus figure. Each stimulus was drawn by spanning line segments between five pairs of the points. The points were located at the vertices of a regular hexagon with 3.8 cm sides. The center of the regular hexagon coincided with the center of the CRT. A filled circle with a diameter 0.4 cm stylized each of the six points. The center of a filled circle was 0.2 cm outwardly displaced from the corresponding vertex. The lengths of line segments subtended $3.3^\circ$ (for the shortest lines) to $6.6^\circ$ (for the longest lines) of visual angles.

Problem selection

The following two types of (6, 5) figures were sought in the population and respectively pooled. End figures were those that had one endpoint and Cls figures were those having no endpoint, or inversely, completely closed. A point which is not connected with any other points by line segments is called an isolated point. All 720 End figures respectively possess one isolated point, whereas, out of a total of 162 Cls figures, 72 figures have one isolated point and 90 figures have two isolated points. A total set of 320 figures were independently generated for each participant. In the set 160 End figures and 160 Cls figures were randomly selected from the respective pools. Each figure selected by the above rule was called a problem. The total set was divided into four subsets in which 40 End problems and 40 Cls problems were combined and shuffled. Each subset included both practice and test problems. See examples of problems in Figure 1.

Procedure

The experiment was conducted on an EPSON 360V microcomputer connected to a MITSUBISHI XC-1498C color monitor. Timing was measured by a TIR-6(98) timer/counter module. Participants sat in front of the CRT at a distance of 65 cm from the center of the display and their heads were placed on a chin-rest. At the start of each trial, a “ready” message was presented. When a participant pushed the return key, the message was cleared and a blank screen continued for 2.5 s. Then, with a beep, a fixation circle with a diameter of 0.7 cm appeared at the center of the screen for 0.5 s. Subsequently, the fixation circle was replaced with a screen containing a figure that constituted a problem. Participants were requested to judge whether a prescribed feature (i.e., an endpoint or complete closure) was present or absent in a given figure. The experiment consisted of two sessions prescribed by the key responses. That is, participants were instructed to press F5 key if they found a target feature and press F6 key if they could not find the target in one session, and to press F6 key if they found a target and F5 if they could not in the other session. Each session was further divided into two blocks being specified by a target feature. A target feature (either endpoint or closure) was designated prior to the start of each block. The four blocks, corresponding to the four subsets of problems, were specified by the functions of the keys and by the target features ordered in ABBA fashion with the assignments of the key and the feature in the first block randomized.

Each block started with practice trials consisting

Figure 1. Stimulus examples. Panel A shows an example of End problems and panel B gives an example of Cls problems.
of 15 problems and test trials consisting of 65 problems followed, and thus each participant was given in total 60 practice trials and 260 test trials. In the practice trials feedback answers were given to participants but no feedback answers were given during the test trials. The principal measure for each response was the response latency that was defined as the time elapsed from the onset of a stimulus figures on the CRT to the participant’s response by pushing F5 or F6 key. In a written instruction the definitions and illustrated examples of (6, 5) figures having an endpoint and closures, respectively, were given before the start of the experiment. Both speed and accuracy in responses were emphasized.

Results and Discussion

The analyses only included correct responses in test trials. Mean latencies and percent errors of the respective problem types are illustrated in Figure 2.

There was no significant difference in error rates: between Clos (+) and Clos (−), $z=0.87$; Clos (+) and Endp (+), $z=1.49$; Clos (+) and Endp (−), $z=0.18$; Clos (−) and Endp (+), $z=0.63$; Clos (−) and Endp (−), $z=1.31$; all $ps>.05$, two-tailed. Hence, the following argument will be made only about latencies. Here, the parenthesized “+” indicates the presence of the feature when the target was an endpoint (Endp) or closures (Clos), and “−” indicates the absence of the feature when the target was an endpoint (Endp) or closures (Clos), respectively. A repeated two-way analysis of variance (ANOVA) on latencies showed that the main effects of problem types, $F(3, 4508)=22.6$, participants, $F(17, 4508)=50.3$, and their interaction, $F(51, 4508)=3.85$, were all significant, all $ps<.001$; $MSE=0.063$. The multiple comparisons by the Scheffe’s method revealed that there were significant differences between Clos (+) and Clos (−), Clos (+) and Endp (−), Clos (−) and Endp (−), as well as Endp (+) and Endp (−), all $ps<.01$; but no significant differences were found between Clos (+) and Endp (+), and between Clos (−) and Endp (+), $ps>.05$. Or, the results could be ordered from shorter to longer latencies as Clos (−) ≤ Endp (+) ≈ Clos (+) < Endp (−), and as Clos (−) < Clos (+). The symbols “≈” and “<” indicate the difference insignificant, and the right term longer than the left term, respectively.

The effects of the problem types are considered to include the effect of task demands and of stimulus figures. Provided that the effect of stimulus figures exists but that of task demands does not, the latencies are predicted to be shorter in Clos (+) than in Endp (+), as well as shorter in Endp (−) than in Clos (−) when closures are detected quicker than endpoints. On the other hand, when endpoints are more quickly detected, the latencies would become shorter in Endp (+) than in Clos (+), as well as in Clos (−) than in Endp (−). The results seem more favorable to the priority of the endpoint detection, but looking more closely at latency differences, the difference was not significant between Endp (+) and Clos (+).

It must be noted that the figures of Clos (−) and Endp (+) as well as those of Clos (+) and Endp (−) had identical states of endpoints: the presence of an endpoint for the former pair and its absence for the latter. If only the effect of the stimuli and not of the task demands works, there should be no difference in performance between these identical states. However, a significant difference between the Clos (+) and Endp (−) was found, which could be called an asymmetry in detectability. The existence of the asymmetry suggests the implausibility of the absence of the task effect account. It would rather indicate the involvement of such cognitive functions as mental set for a target feature. Collapsing the presence and absence conditions, the means of the detections of closures was 0.697s and of an endpoint 0.733s, and the difference was significant, $F(1, 4544)=21.8$, $p<.001$ (by a repeated ANOVA with problem types and participants as factors). In this respect, the set for closure detections was more efficient than the set for endpoint detections. One interesting result was that the latencies in Clos (−) were shorter than in Clos (+), and in fact the shortest latencies were obtained in Clos (−).

Concerning the results of many search studies, Table 2 of Treisman & Gormican (1988) summarizes that positive search (i.e., search for a present target) is
almost always faster than negative search (i.e., search for an absent target) regardless of whether the search speed is fast (i.e., in a parallel mode) or slow (i.e., in a serial mode). Hence, the obtained shorter latencies in Clos (−) than in Clos (+) would be difficult to compromise the notion that the detection of a feature was executed by searching process.

An alternative account would thus be that the presence of closures is set up as a default decision state when a closure is assigned as a target, and if a break of the default state takes place (i.e., an endpoint is found at a certain place in the display area), it would quickly trigger the absence decision compared with the case where no perturbation occurs. Likewise, if the absence of an endpoint is the default decision state when the target is an endpoint, which in fact is the same default state when the target is closures, a break of the state is quickly detectable and leads to the presence decision. This explanation presumes that mental sets are attentively tuned to default decision states, whereas the detection of a break of the state is executed fairly automatic. Hence, it could successfully predict that Clos (−) has shorter latencies than Clos (+) when the target is closures, and that Endp (+) had shorter latencies than Endp (−) when the target is an endpoint. In addition, if the relative superiority of the closure set to the endpoint set, which supplementary afford efficiency to the closure conditions, is premised, the obtained order of latencies could be explained.

Although the lack of evidence makes the evaluation of the plausibility of this account difficult, its internal consistencies could be secured: the rejection of the feature search assumption, the existence of the asymmetry in detectability, and the relative superiority of the mental set for closure detections to the set for endpoint detections. All these pieces of information were consistent with the premises of the account. Even if the present task could not fully separate early feature detection process from higher cognitive functions as had been envisaged, it could at the same time provide an insight into how the early detection processing and the later cognitive functioning are interrelated.

References


