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DESIGNING POINT MAP SYMBOLS: THE EFFECT OF PREATTENTIVE ATTRIBUTES OF SHAPE

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ABSTRACT

The purpose of this study is to examine the influence of attributes of shape, for which there are remarkable indications that are preattentively processed, like terminations, topological property of having a hole, and the structure, on the way point symbols of different levels of abstraction are perceived by map readers. The paper discuses briefly a number of visual search theories, which can be related to map reading and more analytically, the indications for preattentive processing of features related to the visual variable of shape. Also it briefly reviews cartographic studies based on visual search theories. Following the reviews, an experimental study is presented, which required map readers to search for a designated target symbol with a unique feature among geometric and pictorial distractor symbols on realistic maps, on computer monitor. Adding features like a hole or terminations at the top of the target symbol resulted in more efficient searches.

INTRODUCTION

Shape is one of the most important visual variables for cartographic symbolization. It is considered appropriate to represent nominal differences, and it is the basic variable that defines the classification of qualitative point symbols on the continuum, that ranges from pictorial to geometric symbols. Although color is known to be more effective in searching map symbols (Lloyd 1997), shape supplies the cartographer with an immense variety of design choices. Nevertheless, selecting the most appropriate point symbol among numerous candidates to represent a certain phenomenon can be a rather confusing task for the map-maker, since the issue of the shape attributes remains obscure, and there is a difficulty to predict the way shape and map as a whole are processed by the reader throughout different map-reading tasks.

According to Bertin (1967/1983), shape is not a selective visual variable and results in symbols that must be studied carefully, one by one. That is, the reader neither can group and see at a glance the whole of symbols of the same shape, while ignoring the rest, nor can locate immediately a target symbol defined by its shape. Although shape does seem to be the least selective dimension, Bertin's opinion has been subject to criticism. Green (1998) has noted that Bertin came up with this conclusion by examining simple shapes of the same "spatial frequency" like rectangles and circles, while there is experimental evidence in psychological literature that this is not always the case.

The distinction between immediate and sign by sign perception suggested by Bertin (1967/1983) is analogous to the dichotomy of "preattentive" and "attentive" perception made by researchers in psychology and vision (Green 1998). An interesting result of their studies has been the discovery of visual properties that are "preattentively processed" and are detected immediately by the visual system prior to attention. Knowledge about properties, which are rapidly and accurately detected by the visual system, could be utilized in cartographic symbolization in order to facilitate the detection of symbols in search tasks. However, which are these "preattentive" or "basic features" is not a clear issue and researchers in psychology and vision underline the need for further experimentation (Wolfe and Horowitz 2004). Some features, important to cartographic symbolization, as color, orientation, motion and size are all well accepted basic features (Wolfe 1998, 2000, Wolfe and Horowitz 2004). From the other hand, shape is the most debatable basic feature. Several shape attributes have been suggested as basic features, with line termination being the predominant one (Julesz 1981, Wolfe 1998, 2000, Wolfe and DiMase 2003, Wolfe and Horowitz 2004). There are also evidences for closure, topological property of having a "hole" (Chen 1982, Pomerantz 2003) and curvature (Wolfe et al. 1992, Triesman and Gormican 1988). Also, some information about the structure of an object may be available preattentively (Wolfe and Bennett 1997). The findings of psychology and vision researches have a potential use in cartography but of course there is a need for expanding experimentation to realistic map use tasks, aiming to gain knowledge on the way map readers perceive shape in different map reading tasks, like symbol search or symbol grouping.

The purpose of this study is to examine the influence of attributes of shapes, for which there are remarkable indications that are preattentively processed, like terminations, topological property of having a hole, and the structure, on the way point symbols of different levels of abstraction are perceived by map readers. The paper discuses briefly a number of visual search theories which can be related to map reading and more analytically, the indications for preattentive processing of features related to the visual variable of shape. Also, it briefly reviews cartographic researches based on visual search theories. Following the reviews, an experimental study is presented which required map readers to search for a designated target symbol with a unique feature among distractor symbols on realistic display maps.

PREATTENTIVE PROCESSING

Visual search and texture segmentation are the most common experimental tasks performed for the identification of preattentive features. In standard visual search, subjects look for a target item with a unique feature among some distractor items. The subject has to detect the presence or absence of the target rapidly and accurately. For example, a viewer can immediately detect a red spot among green distractors regardless the number of distractors (the set size). In texture segmentation task, a target region of items differs from the background items. The subjects must preattentively locate the region of similar object (target region) and the boundaries that separate them. For example, a viewer can immediately locate a region of red spots in a field of green spots. In the examples cited above, the stimulus supports both efficient search and effortless segmentation.

There are several theories, which attempt to explain why some searches are preattentive and others require focal attention, but Triesman's Feature Integration Theory is the most influential (Treisman and Gelade 1980). According to this model, features are registered early, automatically, and in parallel across the visual field, while objects are identified separately at a later stage, which requires focused attention. Focused attention provides the glue, which integrates the initially separable features into unitary objects. Initially, Triesman argued that preattentive processing occurs in parallel and focused attention occurs in serial (Treisman and Gelade 1980). In later work, Triesman expanded her strict dichotomy of features being detected either in parallel or in serial, and argued that parallel and serial processing represent the ends of a continuum (Treisman and Sato 1990). Triesman has determined features that can be preattentively detected such as color, orientation, spatial frequency, brightness, direction of movement but she noted that some of these features are asymmetric (Triesman and Souther 1985). For example, in orientation, it is easier to find a tilted line among vertical lines than a vertical line among tilted lines. Julesz (1981), in Texton Theory, accepted the dichotomy of serial/parallel processing. He investigated preattentive visual processing with texture perception tasks and named the hypothetical basic elements of preattentive perception "textons". He supported that texture can be decomposed into elementary units: the texton classes of colors, elongated blobs of specific widths, orientation and aspect ratios, and the terminations of these elongated blobs. Duncan and Humphreys (1989), in Attention Engagement Theory, did not support the dichotomy of serial and parallel search modes and gave their own explanation of preattentive processing. For them, the difficulty of visual search varies continuously across tasks and display conditions. Search time depends on two similarity variables: (T)arget – (D)istractors and (D)istractors – (D)istractors. These variables affect search time as follows: first, as T-D similarity increases, search efficiency decreases; second, as D-D similarity decreases, search efficiency decreases; third, the most difficult searches occur when T-D similarity is high and D-D similarity is low (Duncan and Humphreys 1989). The Guided Search Theory proposed by Wolfe (1994), preserves the distinction between parallel and serial stages. But as Wolfe (1998, 2000) clarified, between parallel and serial searches there is a continuum, which can be explained by an early parallel mechanism working in tandem with a later serial mechanism. The results of preattentive visual processing can "guide" the deployment of visual attention with varying degrees of efficiency. For Wolfe and Horowitz (2004) efficient search is a necessary but not sufficient search property for showing the presence of a guiding feature. They added four other properties to be checked: effortless texture segmentation, search asymmetries, ability to participate in "illusory conjunctions" and ability to tolerate some distractor heterogeneity. Wolfe and Horowitz (2004) grouped attributes by the likelihood of being sources of guidance attention. Some of these attributes are of great concern for cartographic symbolization. For example they cited that color, orientation and size are undoubted attributes and shape, line termination, closure, topological status, and curvature are probable attributes, whereas intersection is probable non-attribute.

All these features mentioned above, using different terms, basic features, preattentive features, textons, attributes that might guide the deployment of attention, are of particular interest for cartographic symbolization. Focusing mainly on the visual variable of shape, and how it can be applied to enhance visual search tasks on maps, the following analysis is limited to features related to shape. Among the different aspects of shape, termination is the most supported basic features (Wolfe 1998, 2000). However, not all the data converge and there are issues that are still unclear, like the effect of the number of terminations or their location. In a visual search experiment, conducted by Wolfe and DiMase (2003), the presence of line termination was readily detected from distractors with no termination. Julesz (1981) conducted texture segmentation tests and supported that elongated blobs and their terminations are textons. Treisman and Gornican

(1988) found out that it was easier to find a "C" among "O" than vice versa. They suggested that line terminators of "C" were the critical features for visual search rather than the closure of "O", since it is easier to find the presence of a feature than to detect its absence. On the other hand, Enns (1986) found that if elongated elements are used in texture segmentation tasks, the presence or absence of terminators seems ineffective. Also, Pomeratz and Pristach (1989) supported that terminators are not formons; that is they are not effective basic features in form discrimination. Julesz (1981) clarified that the preattentive visual system cannot determine the location of terminations but can count their numbers (or density) or their first-order statistics. But from Wolfe's literature review, it comes out that the quantity of terminations is not so useful in guiding deployment of attention (Wolfe 1998, 2000).

Bergen and Julesz (1983) supported that intersections are "textons" based on experimental results: a plus (+) was easily found amidst Ls composed of the same vertical and horizontal lines, and a region of plusses was readily segmented from a background of Ls. But, Wolfe and DiMase (2003) noted that plusses are different form Ls not only in the presence of an intersection, but also in the number of line terminations (plus has four whereas L has two). Also, plusses are radically symmetric, while Ls are not, and plusses look smaller than Ls when the vertical and horizontal segments are of the same length. In experiment conducted by Wolfe and DiMase (2003) with stimuli that controlled these factors, search for the presence or absence of intersections was very inefficient. Even a stimulus with multiple intersections failed to be found efficiently among distractors with no intersections. Wolfe and DiMase (2003) suggested that intersection should not be included among salient features that support efficient search through visual displays.

Curvature is a probable basic feature. A curved target can be found efficiently among straight distractors in a visual search task (Wolfe et al. 1992, Triesman and Gormican 1988). If a curve is part of a bounding contour of object it can be considered as concavity or convexity. In a change detection task, observers were more accurate when a concavity than a convexity was introduced, or removed along the contour (Barenholtz et al. 2003).

For Julesz (1981) corner, closure and connectivity are not textons, and can be simply described by differences in termination number. But, three experiments on tachistoscopic perception of visual stimuli demonstrated that the visual system is sensitive to global topological properties, like having a hole, "connectedness" or "closedness" (inside vs. outside) (Chen 1982). From these experiments it came out that: the visual system was more sensitive to the topological distinction between a connected component with a hole (a ring) and one with no hole; a connected and a closed structure facilitated the detection of the target that was a part of it; the relationship inside versus outside a circle facilitated the discrimination of the target. Pomerantz (2003) reported the improvement in target detection from the addition of context elements that create configuration, even when those contexts alone provide no discriminative information. For example, by adding identical Ls to diagonals of positive and negative slopes new configurations (triangles and arrows) were created. The triangle is perceptually more different from the arrows than the positive diagonal is different from negative. Pomerantz (2003, p. 473) cited that "emergent topological properties that appear when the context is added (properties such as the presence or absence of a hole) may be the effective primitive."

The status of closure and topology raises the issue of the preattentive processing of the shape objects as a whole. Wolfe and Bennett (1997) conducted a series of experiments to examine if efficient search is possible for target objects that share form features (local attributes) with distractors, but have different shape (the form of an object as a whole). Search was inefficient when: targets and distractors had the same form features but different overall shape; target had in addition a unique form – "right angle"; target had in addition a new piece – an adjacent circle. Neither the "right angle", and more surprisingly, nor the change of topology resulted by the adjacent circle worked as basic feature.

Wolfe and Bennett (1997) also examined a conjunction search with simple shapes. Search for an item, which had a crown and points, among items that had either crowns or points but not both, was also inefficient even though the shape of the target was different from the shape of the distractors. But in cases that target had a unique characteristic -crowns or points- search was efficient, due to the properties that these individual pieces have, which permit efficient search. In another experiment target and distractors had the same preattentive attributes but the items looked very different from each other. The two items were composed of a closed curve and a squiggle, but one of them looked like a closed shape with a bump and the other one a closed shape with a tail (the tail can be considered as a termination). Searching for tails among bumps was easier than vice versa, but the search itself could not be characterized efficient. Wolfe and Bennett (1997) concluded that a target of one shape can be very difficult to be found among distractors of very different shape, if those shapes are preattentively represented by similar collections of basic features and attributes. Considering that objects get cut into parts at points of minimum curvature, Wolfe and Bennett (1997) examined the sensitivity of the preattentive stage of visual processing to this division. Search appears to be somewhat more efficient when the target and distractors differ in their part structure. Specifically, relatively efficient search may be possible for a target with two parts if the distractors have only part apiece. Although in their experiments there is no evidence for preattentive processing of overall shape, Wolfe and Bennett (1997) did not accept that there is no preattentive processing of overall shape. Instead, they considered more accurate to state that any preattentive processing of shape is quite limited. Donelly et al. (2000) supported that Wolfe and Bennett's (1997) experiments results are explicable in terms of non-target heterogeneity rather than an absence of early visual processes to the overall shape of objects. Based on their tests with homogenous distractors, Donelly et al. (2000) supported that shape similarity, rather than individual contour similarity, can determine search efficiency. But for Wolfe and Horowitz (2004), detection of a target that is defined by a candidate feature should be able to tolerate some distractor heterogeneity.

CARTOGRAPHY AND THE VISUAL SEARCH PROCESS

The models that psychologists have developed to explain visual search process offer to cartographers a basis for studying how map users search for specific information on maps. Nelson (1994) evaluated the usefulness of Attention Engagement Theory for modeling visual search for color targets on bivariate choropleth maps. Subjects had to search for target colors among distractor colors on a map. Nelson found that the most important factor affecting the searches was the similarity between the target and the distractors, but similarity between distractors did not play a large role in search efficiency, so the above-mentioned theory was not fully supported. Bunch and Lloyd (2000) conducted an experiment that required map readers to find a target boundary defined by two colors among other boundaries that were not targets. In this study, similarity of target colors and non-target colors, and similarity of non-target colors with non-target colors both affected the efficiency of the search as predicted by Attention Engagement Theory. Lloyd (1997) also examined the efficiency of searching for targets with unique features and targets that share features with other objects in a map environment, using symbols that varied in color, shape, and orientation. In his experiment an isolated target symbol was shown, followed by a map with symbols, and the subject had to determine the presence or the absence of the target symbol. His findings suggested that the most efficient spatial searches could be carried out by color differences between targets and distractor symbols, or by differences that combined color with other dimensions. The location of the target on the map had also a significant effect on reaction time. Nelson et al. (1997) examined Chermoff faces as multivariate symbols in visual search tasks. The effect of different combinations of symbols dimension and symbols parts in search efficiency was assessed. According to their results all searches employed serial search process, although feature searches (those in which the target symbol consists of a unique feature) were by far the easiest for subjects to complete. It is very interesting that both researches of Nelson et al. (1997) and Lloyd (1997) did not justify the link between parallel processing and searching for symbols with a unique feature. Nelson et al. (1997, p. 29) cited that "The complexity of Chernoff Faces, along with the placement of such symbols on a map, most likely increased noise levels considerably during the search process, effectively lengthening search times".

It is obvious that very limited research has been conducted about the influence of shape on visual search tasks on maps. Findings of psychology and vision research can further support cartographic research.

EXPERIMENTAL DESIGN

A visual test was designed to assess how different shape attributes affect the search process of geometric and pictorial point symbols on maps. The followings are examined:

- Whether there is a difference in reaction time between searching for a target with no unique feature and searching for a target with unique feature for geometric and pictorial symbols.
- Whether there is a difference in reaction time among targets having different unique features -target with termination, target with structure, target with topology -having a hole- for geometric and pictorial symbols.
- Whether there is a difference in reaction time related to target present and target absent trials.
- Whether the location of the target on the map affects the time needed to complete the search process.

Maps and symbols

The test consisted of two practice sessions and two blocks, one for geometric symbols and the other for pictorial. A base map and two blocks of symbols were specifically designed for the test. A map was designed to be the base for all maps that would be used in the test. It presented hypsometric zones in pale yellow, roads in green, a river and lakes in blue and boundaries in gray. No text was written on the map in order to avoid further noise. The size of the map was selected to be the largest possible that fitted onto the screen. It was much larger that the search area usually used in the experiments of psychology and vision. The map subtended 16^o of visual angle vertically and 21.24^o horizontally on the screen whereas, for example, in the visual search experiments of Triesman and Gelade (1980) an area subtending 14^oX8^o was used for search tasks. In the current study the specific size was selected, because it could be considered typical for map reading, and eye movements were necessary to perform the task.

Two blocks, one with geometric and the other with pictorial symbols, were designed to serve as targets and distractors in symbol search tasks (Figure 1). Specifically, ten abstract symbols were designed, six of them to serve as targets and four as distractors, and twelve pictorial symbols, eight of them to serve as targets and four as distractors. All the symbols had solid shape in black color. The abstract distractors had geometric shape, a circle, a triangle, a square and an hexagon. The pictorial distractors were mainly composed of rectangular and triangles: a bottle, a camping tent, a tree, and a castle. All distractor symbols subtended maximum 0.36^o of visual angle vertically and horizontally. The symbols of each block were adjusted so that they should appear to be perceptually equal. A rhomb and a house were used as a base to construct the abstract and pictorial targets correspondingly. The targets were produced by adding features that are probable basic features, to the base symbols. Specifically, the targets were produced by adding terminations at different positions of the base symbols, changing the topology with a hole, and changing the topology/structure by adding externally a circle or triangle. It was difficult to change one aspect of shape, without introducing concomitant changes in other aspect. For example, it was difficult to add a circle, aiming at the change of the structure, without altering some other properties of the symbol, like area, perimeter, height or width or the symmetry. However, it could be considered that the most prominent change was on the shape rather than the other properties of the symbols. The abstract targets were the followings (Figure 1): a rhomb (A1); a rhomb with two symmetrical terminations extruding from its two sides at the top (A2); a rhomb with two symmetrical terminations extruding from its two sides at the middle (A3); a rhomb with a triangle (with sides equal to the terminations) at the top (A4); a rhomb with a circle at the top (A5); a rhomb with a hole (A6). The pictorial targets were the followings (Figure 1): a house (P1); a house with two symmetrical terminations extruding from the two sides of the roof at the top (P2); a shorter house with the same terminations at the top, so as the height of the symbol to be the same with that of the distractors (P3); a house with two symmetrical terminations extruding from the two sides of the roof at the middle (P4); a house with a triangle (with sides equal to the terminations) at the top (P5); a house with a circle at the top (P6); a glass which has totally different structure from the distractors (P7); a house with a hole (P8).

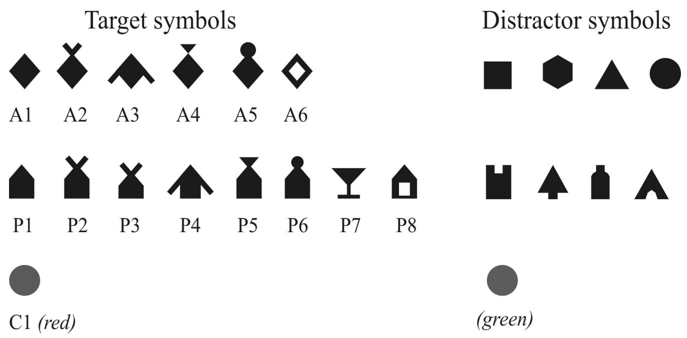
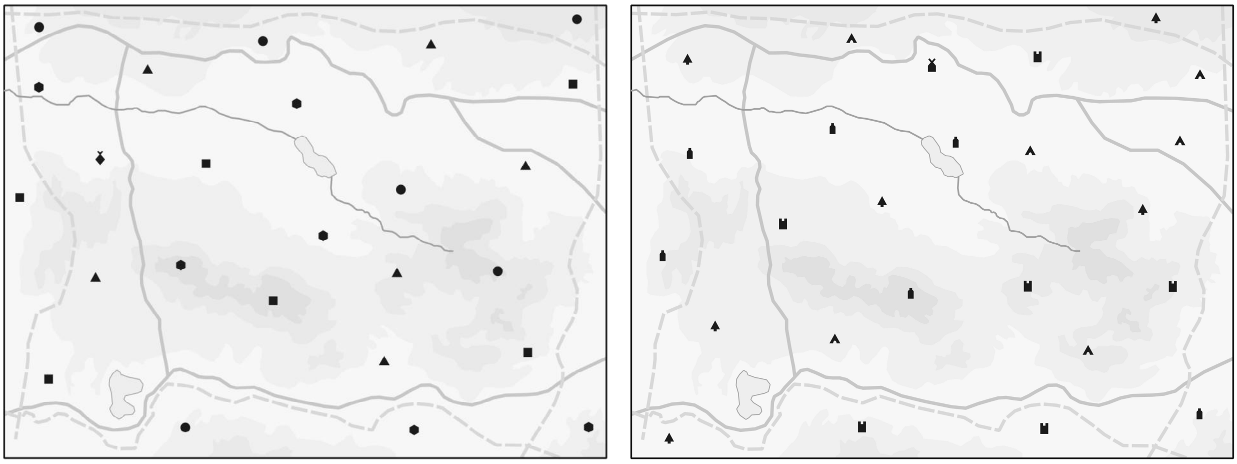


Figure 1. The geometric and pictorial symbols

The rhomb and the house without any other attributes were used as targets in order to have a control condition, determining how difficult the search could be. From the other hand, in order to have a control condition, determining how good performance could be, a red circle symbol (C1) was selected to be a target and green circles to be the distractors. It is well documented that color is a basic feature (Wolfe 1998, 2000), and that a red target is immediately detected among green distractors (Triesman and Gelade 1980).

For each target eight maps were composed: two maps with the target near the center, two maps with the target at the middle, two maps with target at the periphery; two maps with the target omitted. Totally 120 maps were composed (48 maps with abstract symbols and eight maps with the colorful symbols constituting the first block, 64 maps with pictorial symbols constituting the second block). On each map, each distractor was presented on six different locations, randomly selected, with the limitation the symbols to be spread all over the map in rather equal distances from one another. So, each map of the test had different layout of symbols. Within the two blocks the sequence of appearance of maps was randomized. Figure 2 shows a map with geometric symbols (A) and a map with pictorial symbols (B).

For the practice session, totally 28 images were composed (12 for abstract and 16 for pictorial symbols), two for each target. These images had a blank background of a pale yellow hue (the same hue was used on the base map), and all the other characteristics, dimensions, number and distribution of target and distractors were similar to the maps of the test. On some of these images the target was also omitted.



(A) (B)

Figure 2. A map with geometric symbols (A) and a map with pictorial symbols (B)

Subjects and Method

The test was conducted using a computer equipped with a 9X12 inches monitor and a software developed in Visual Basic. The 63 subjects of the test were volunteer students and staff of the School of the Rural and Surveying Engineering of the National Technical University of Athens, ages between 19 and 50. Subjects were tested individually at the presence of the researcher, sitting in front of a display at a distance of 80cm. The subjects were asked to participate at a visual search task. Each subject participated in the two blocks of trials. The block order was randomized for each subject. Within each block, subjects alternated between seeing the maps in a top-to-bottom order and vice versa.

At the beginning of the test, the researcher gave some oral instructions to the subject about the task. A practice session was executed before each block of trials in order to familiarize the subjects with the experimental procedure and the symbols, which they would be seeing. The practice sessions as well as the block sessions had the same structure. The only difference was that in practice session images with symbols on blank background were used as search displays instead of maps. An isolated target symbol was first shown on the middle of the screen on a blank background of a pale yellow hue for 1750msec. This period was adopted after trials with observers in order the procedure not to be too tired. Then a blank display appeared for 650msec, followed by the search display (the practice image at practice session or the map at block session). On 75% of the trials, the search display presented both the target and distractors, and on 25% of the trials, presented only the distractors. The subject determined whether or not the target was on the search display and responded a ‘target-present’ or ‘target-absent’ key correspondingly. Subjects had been instructed to produce a ‘target-present’ or ‘target-absent’ response as quickly and accurate as possible. After the subject’s response, another target was displayed. Reaction times and accuracy were recorded for each trial. Each subject responded to a total of 140 search trials. The test lasted approximately 15 minutes for each subject.

Results

Search times, of incorrect responses to target-present or target-absent trials were excluded for further analysis, as well as extreme search times that would result in a meaningless increase of the mean search time. Finally, 2853 (94%) successful search times were recorded for abstract symbols, 3630 (90%) for pictorial symbols and 501 (99%) for colorful symbols. Tables 1 and 2 show the mean search time (Mean) and standard deviation (SD) of successful searches, as well as the percentages of correct searches (CS) for geometric (including colorful) and pictorial symbols sequentially for target-present and target-absent trials. They also show the mean search time and standard deviation for successful searches, when the target was located near the center, at the middle, and the periphery of map. The standard deviations are quite high, in the two tables, indicating that there was a large spread of search times for each symbol. Application of the t-tests of dependent samples revealed significantly ($p<0.05$) longer search time for target absent trials than for target present for each symbol. Application of the t-tests of dependent samples revealed significantly ($p<0.05$) longer search time for each target when it was located at the periphery of map than on the middle or near the center, and when it was located at the middle than on the center, with the exception of four cases out of 45.

T-tests of dependent samples were computed to determine which of the mean search time scores were significantly different from each other, for each of the six geometric symbols, and the colorful one. The followings were found: First at target-present trials, all comparisons were significantly different from each other ($p<0.05$) with the exceptions of symbols A2 and A5, A4 and A5, A3 and A5, and A3 and A4. Second at the case of target-absent trials, all comparisons were significantly different from each other ($p<0.05$) with the exceptions of symbols A2 and A3, A2 and A4, A3 and A4.

	Target-present			Target-absent			Center		Middle		Periphery	
	Mean (msec)	SD (msec)	CS (%)	MS (msec)	SD (msec)	CS (%)	Mean (msec)	SD (msec)	Mean (msec)	SD (msec)	Mean (msec)	SD (msec)
A1	2118	752	75	4576	1571	98	1322	793	2356	1037	3203	1219
A2	1322	315	95	3012	1127	100	874	296	1362	524	1809	454
A3	1466	449	95	3048	1130	98	943	420	1548	741	2012	567
A4	1398	320	98	3085	1095	100	941	352	1204	364	2112	590
A5	1385	307	96	2761	1140	99	934	300	1370	472	1913	471
A6	989	198	98	2572	908	98	752	165	942	228	1274	334
C1	901	321	99	1207	641	100	808	315	941	364	957	442

Table 1. An overview of the results for geometric symbols

	Target-present			Target-absent			Center		Middle		Periphery	
	Mean (msec)	SD (msec)	CS (%)	MS (msec)	SD (msec)	CS (%)	Mean (msec)	SD (msec)	Mean (msec)	SD (msec)	Mean (msec)	SD (msec)
P1	2685	932	84	5729	1825	98	1607	1086	3140	1438	3650	1414
P2	2368	659	90	5051	1641	99	1284	626	2501	900	3573	1358
P3	2334	586	92	5101	1701	98	1115	626	2741	756	3298	988
P4	2692	866	80	5497	2063	90	1935	1261	2794	1141	3580	1380
P5	2718	783	82	5608	1669	97	2249	1211	2956	1130	3013	1151
P6	2776	1198	80	5776	1900	82	2254	1581	2962	1634	3254	1347
P7	1826	490	95	5074	1245	98	1196	569	2166	861	2072	669
P8	1355	324	99	3994	1242	98	922	355	1247	423	1897	589

Table 2. An overview of the results for pictorial symbols

T-tests of dependent samples were computed to determine which of the mean search time scores were significantly different from each other for each of the eight pictorial symbols and the colorful one. The followings were found: First at target-present trials, all comparisons were significantly different from each other ($p<0.05$) with the exceptions of symbols P2 and P3, P1 and P4, P1 and P5, P1 and P6, P4 and P5, P4 and P6, and P5 and P6. Second at the case of target-absent trials, all comparisons were significantly different from each other ($p<0.05$) with the exceptions of symbols P4 and P5, P4 and P1, P4 and P6, P5 and P1, P5 and P6, and P1 and P6.

Searching for a red symbol target among green symbol distractors took significantly shorter mean time for both cases, target-present and target-absent than any other search, as it was expected since visual search based on color are very effective (Wolfe 1998, 2000).

DISCUSSION AND CONCLUSIONS

This study examined the influence of attributes of shapes, for which there are remarkable indications from psychology and vision researches that are preattentively processed, like terminations, topological property of having a hole, the structure, on the way point symbols of different level of abstraction are perceived by map readers, through visual search tasks.

Adding a unique feature to geometric target resulted in more efficient search concerning both the duration of the search and the accuracy of responses, on target-present and target-absent trials. Specifically, searching for a simple rhomb among other geometrical symbols, a circle, a triangle, a square and an hexagon, lasted significantly more time than searching for a rhomb with terminations at the top, or extruding from the middle, or for a rhomb with different structure (having a circle or a triangle at the top), or for a rhomb with different topology (having a hole). Adding a unique feature at the rhomb, the similarity between target and distractor decreased, and as it could be anticipated from Attention Engagement Theory (Duncan and Humphreys 1989), search time decreased. Searching for the target with hole was significantly the most efficient search and searching for the simple rhomb target was significantly the least efficient search for each of the three cases: the targets located near the center, at the middle or at the periphery of the map.

Among the rest of the targets with unique feature, no significant difference in search time resulted when they were located near the center of the map. Probably, observers started searching at the center of the map, where they had seen the designated target in the previous display, and then moved to the periphery. So, it can be concluded that when no eye movement was needed, targets with terminations and structure were detected equally well among simple geometric symbols. Significant differences among targets with terminations and structures occurred, when targets located at the middle or at the periphery of the map and eye movement were needed, but no target outperformed systematically, yet the mean score of the rhomb with the terminations at the top was the best.

In contrast with geometric symbols, in the case of pictorial symbols, searching for a simple house among other solid figures, a castle, a tree, a bottle and a camping tent, did not always last significantly more time than searching for a house with an added feature. Specifically, adding a hole to the target or terminations at the top, regardless target height, the search became significantly more efficient at both target-present and target-absent trials. From the other hand, the targets resulted by changing the structure of the house, with a triangle or a circle at the top, and by adding terminations extruding from the roof at the middle of the house, did not produce a reduction in search time. Instead, there was a small delay. The resulted structures of targets were similar to the structure of some distractors and so, as distractor similarity increased search efficiency decreased. From the other hand, when the glass was used as target, which had a very different structure from the distractors, target - distractor similarity decreased and search efficiency was increased significantly. Both cases justified Attention Engagement Theory. However, it is difficult to explain why adding a unique characteristic to the target, as the terminations extruding from the middle of the house, did not improve search time. But as Nelson et al. (1997) claimed, while the majority of visual-search studies conducted are supportive of the link between parallel processing and searching for symbols with unique features, results that do not support the link are not uncommon. Concerning the location of the pictorial targets on the map the followings turned up: At the center of the map, probably when no eye movements were needed, there was no significant difference in search time among the house with the hole, the house with terminations, and the glass. From the other hand, there was significant difference between these symbols and the rest of the targets. When the targets were located at the middle and at the periphery of the map, the house with the hole and the glass were detected more efficiently than the rest of targets, whereas the house with terminations only at the middle of the map was superior to the rests.

Changing the topology of targets by adding a hole resulted in the most efficient searches for targets located near the center, at the middle and at the periphery of the map, for both geometric and pictorial symbols. According to Guided Search Theory (Wolfe 1994) the results of preattentive visual processing can “guide” the deployment of visual attention with varying degrees of efficiency. But if the initial stage of search was linked to the center of the map, a target on the periphery would not be detected, except if this initial stage provided information of the peripheral vision that could direct eye movements. In the case of a black house with a white hole target, the search could be based on color dimension rather than the “hole”, and it can be assumed that this information of peripheral vision directs eye movements. This explanation cannot be expanded to the glass symbol, which scored the second more efficient searches for pictorial symbols. As Lloyd (1997) noted for similar experimental results, further studies are needed to resolve such issues that will combine a search experiment with eye movement recordings.

The second more efficient search (mean score of time) for geometric symbols and the third more efficient for pictorial symbols resulted from the targets with terminations at the top, although they were not systematically for different target locations. For both geometric and pictorial symbols, visual search was significantly more efficient when targets had the terminations at the top rather than in the middle, implying that the location of the terminations had a critical contribution to their detection.

The time needed to search for a target was longer among pictorial symbols than among geometric symbols for both target-present and target-absent trials. The difference can be attributed to the more complex shape and the structure of pictorial symbols. Previous study of Forrest and Castner (1985) also revealed that abstract symbols are found faster than unframed pictographic symbols on maps. A significantly longer search time was needed for target-absent trials than for target-present for each target symbol of the test, a common result for psychological studies (Wolfe 1998, 2000), and cartographic studies (Bunch and Lloyd 2000, Lloyd 1997). At the case of target-absent trial, the subject has to search all the symbols of the image to determine if the target is present or not, whereas at the case of target present trial, the subject stops searching as soon as he finds the target. The spatial location of the target –center, middle, periphery- on the map influenced the time needed for its detection. Search time was shorter when the target was near the center of the map and longer at the periphery when eye movements were needed.

In the present study, the subjects had already seen the target in isolation before they searched for it on a map. Consequently, there was a “top-down” control of the search. The next step is to examine the efficiency of search when the observers have to look for a target symbol with a unique feature in the display without knowing its identity – to look for something like an odd-man-out in order to evaluate the “bottom-up” process.

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