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Finding Geometrical Associations Between Meaningful Objects in the Web: A Geostatistical Approach

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ABSTRACT

The study reported in this paper was aimed at investigating the existence of schemata specifically involved in the cognitive organization of a web page. Particularly, the hypothesis was that the location of some web objects (namely, links to specific contents) might be expected by the users at specific spatial locations. Using a method providing geometrical information concerning the organization of web contents, we found that user's expectations could be linked to the activity of low- and high-level schemata allowing performance optimization. Potential benefits of the Cognitive GeoConcept procedure for supporting information architects' decisions are discussed.

Keywords: *schemata, spatial representations, spatial point patterns, page layout, usability*

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1. Introduction

How people manage to operate in a complex world is a long lasting problem in Psychology. Human skilled performance has been described in several different ways, and cognitive models have been derived. Among the others, research in Cognitive Ergonomics strongly contributed to this theoretical mission, investigating human performance in real-world tasks from text selection (Card, English, and Burr, 1978) to driving (Hale, Quist, and Stoop, 1988; Summala, 1988), just to name a few.

The general perspective we will endorse throughout this paper is that interaction with technological artifacts happens by means of representations or schemata (see Norman and Shallice, 1986 for an account on this construct) allowing the optimization of our behaviors. This is a very accredited perspective, albeit definitions of schema and optimization may differ among scholars. For example, Tversky and Kahneman (1974) proposed the idea of heuristics that are shortcuts supporting human decision-making

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(see Kahneman, 2003 for a recent account on heuristics), whereas others have emphasized the role of physical, environmental, and social contexts (see Suchman, 1987 for a general perspective on situatedness). All these contributions have in common the idea that the human cognitive system selects the most effective strategies for interacting with other people, objects, and -more generally- events.

The present research paper, however, moves from considerations mainly derived from the work of John R. Anderson (Anderson, 1991; but see also Anderson, 2002 for a recent review), who proposed the existence of an optimization criterion within his rational analysis. Recently, our laboratory applied this very rationale to the field of traffic psychology (Couyoumdjian, Di Nocera, and Ferlazzo, 2002), showing the existence of an optimization criterion for speed selection aimed at minimizing mental workload. This mechanism was related to the activity of expertise-based schemata favoring expert drivers, suggesting that (automatic) workload control is a learned strategy.

Since the abstraction of the approach described above, interaction with web sites may be conceptualized as governed by schemata as well. Those schemata would be aimed at the optimization of user's behaviors during navigation tasks. Some of them may be involved in the way people evaluate web sites (see Di Nocera, Ferlazzo, and Renzi, 1999; in press, for a model consistent with these ideas), whereas others may underlie the types of actions that are executable within a web site (namely, searching, browsing, pointing, writing, and the like). Furthermore, one additional class of schemata may be specifically involved in the way people look for information either within the entire site or the web page. Such hypothetical schemata might refer to a prototypical organization of the information, and would contain rules and specifications for the location of 1) objects within the page layout, and 2) contents within the site structure.

It is commonly accepted that schemata would be hierarchically organized: from general, expertise-dependent schemata to lower-level schemata that are strictly intertwined with structural and functional constraints in the cognitive system. For instance, page scanning often occurs consistently with reading direction, which is culturally-dependent, but not expertise-dependent. Tversky, Kugelmass, and Winter (1991) reported that culture also affects graph reading on the x-axis. People show better comprehension of graphs organized according to the reading direction of their printed language. On the contrary, culture seems to have no effect on y-axis graph reading: everybody shows a preference for graph organizing high values at the top and low values at the bottom of the axis. Of course, the reading direction schema is not located at the very bottom of the hierarchy. Yet, to our aim, this is still a good level of specification.

2. Spatial representations for web sites?

A leitmotiv of any Human-Computer Interaction handbook is that effective design cannot leave out knowledge about the mental models of the user. Any cognitive-based perspective agrees with the idea that if system appearance (the visible structure of the system which acts as a filter between the user and the designer) is not consistent with design (the outcome of the designer's conceptual model), the user will likely experience disappointment, frustration, and stress. Understanding how individuals find objects in a web page may favor a design reflecting the type of organization the user expects. This would make the sites more accessible, easy to browse, and satisfactory. Yet, the idea that the way people relate to objects deployed in space has a critical role in interface design is not new. Several authors (Rosenfeld and Morville, 1998; Wurman and Bradford, 1996) showed that interaction with hypertexts is strongly affected by users' spatial knowledge. Card sorting, for example, is a practice that has been proven to be very useful for organizing informative units into a hierarchical structure, particularly when the amount of information to be delivered is abundant (Maiden and Hare, 1998). However, the elements arranged into a single web page should be also deployed in a way suited for optimizing navigation. Unfortunately, research on this issue is scarce. The only empirical study on expected location for web objects is that of Michael Bernard (Bernard, 2001). Regrettably, this research was affected by serious methodological problems. For example, users did not interact with a computer, but with a depiction of a browser window, on which they had to arrange pictures of links and banners, according to positions defined *a priori* by 8 x 7 grid squares. Most importantly, subjects performed the task only once per web object (twice for advertisement banners). However, we would like to clarify that our considerations about the shortcomings of Bernard's study are only limited to the experimental rigor and by no means to its applied potential. Bernard (2001) used a sort of "paper prototyping" technique (Rettig, 1994), which is indeed quite useful and popular among interaction designers.

The present study is based on a less explicit method, eliciting users' responses to verbal labels indicating the to-be-positioned web objects on a large number of trials. We called this method "Cognitive GeoConcept", for it is aimed at finding geometrical associations between meaningful objects (links to other pages or functions).

According to what discussed above, two different results can be expected from this study:

1. "low-level" schemata (spatially and semantically based) would be involved in the process - both experienced and inexperienced users should show the same pattern of arrangement;
2. "high-level" schemata (mainly based on navigation experience) would be involved in the process - only experienced users should show an interpretable pattern of arrangement.

Of course, motivational and emotional factors may also play a role, as reported in the recent literature on "affective computing" (Picard, 1997). However, they will not be taken into account in the present research paper, as it is primarily aimed at studying spatial schemata.

3. Method

Participants. Twenty-three students (14 females) volunteered in this experiment. Their mean age was 25.2 years. Thirteen subjects reported to use Internet every day, and were classified as experts. Subjects classified as novices reported to navigate few times per week (5 users) or month (5 users). All users reported being right-handed, with normal or corrected to normal vision, and were naïve as to the purpose of the experiment.

Stimuli. Fourteen words indicating links to resources often found in web sites (about us, buy, catalog, check your e-mail, contact us, help, home, jobs, news, play & win, register, resources, restricted area, search) were used as stimuli.

Procedure. Participants sat in front of a 17" computer monitor and received detailed information about the procedure and the meaning of the labels used. They had to respond as quickly as possible to the stimuli by clicking on the area of the (blank) screen where they would expect to find the corresponding link in an imaginary web page. Stimuli were presented centrally, white on black, for 200 ms. On any trial the mouse pointer returned to the center of the screen. Particularly, the procedure can be outlined as follows (see figure 1):

1. a string indicating a link (i.e. “buy”) was centrally administered on the screen;
2. subjects clicked on the portion of the screen where they would expect to find that link;
3. the pointer returned to the center of the screen;
4. another stimulus (i.e. “home”) was presented and a new click was required.

Fifty repetitions of each stimulus were randomly administered to the subjects, making the number of trials very large (700 in the present experiment).

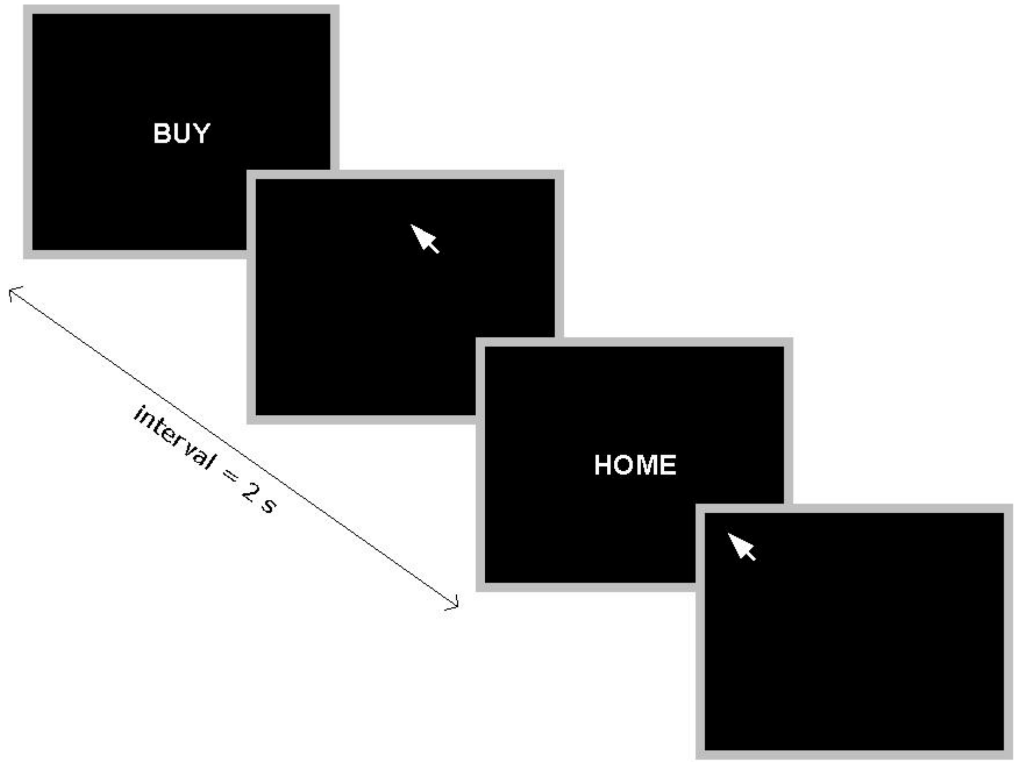

Fig. 1: A graphical representation of the Cognitive GeoConcept procedure.

5. Analyses

Artifacts rejection. Prior to analyze the data, we visually inspected the patterns generated by each label, and found that within the first ten trials the clicks were highly dispersed. However, that was not surprising, because point patterns are known to vary along time. That happens for several reasons, and in our case one of the most important is memory. Indeed, albeit subjects were usually consistent with their initial response pattern, and spontaneously clicked around the same location where they initially “placed” a link, changes in their choice could happen. Another factor determining pattern variability is practice. Our experimental setup provided very fast stimuli administration and required very fast responding. Subjects needed some time to familiarize with the procedure and to become more confident with the task. In both cases, changes could have affected the overall result, because we averaged clicks coordinates. For this reason we run several analyses using time as factor. Particularly, for each stimulus, we divided trials in five blocks of ten trials each. Repeated measures ANOVA designs by Block (1^{st} vs. 2^{nd} vs. 3^{rd} vs. 4^{th} vs. 5^{th}) were run for each stimulus using reaction times as measure. Analysis for “catalog”, “help”, “home”, “buy”, “about us”, “resources” showed no significant differences between reaction times in the different blocks ($p>.05$). Significant effects were found for “register” ($F_{4,84}=2.51$, $p<.05$), “check your e-mail” ($F_{4,88}=2,69$, $p<.05$); “news” ($F_{4,88}=7.83$, $p<.001$), “jobs” ($F_{4,84}=4,27$, $p<.01$), “play & win” ($F_{4,80}=3,57$, $p=.01$), and “contact us” ($F_{4,84}=3.11$, $p<.05$). In all cases significant differences were found between the first block and the others. Accordingly, only data from blocks 2 to 4 for all the stimuli were used in the successive analyses.

Conventional analyses. Coordinates were analyzed using Cluster Analysis (Ward’s method). Input distance matrices (for Experts and Novices) were computed using average point-to-point Euclidean distances. Positioning responses were further examined using quadrat counts. A 4 x 4 grid was used to divide the area in 16 quadrats (figure 2). Angular transformations of the proportion of clicks within the quadrats were then analyzed using a mixed ANOVA design Expertise (Experts *vs*. Novices) x Link (contrasting the 14 different links) x Row (1^{st} *vs*. 2^{nd} *vs*. 3^{rd} *vs*. 4^{th}) x Column (1^{st} *vs*. 2^{nd} *vs*. 3^{rd} *vs*. 4^{th}).

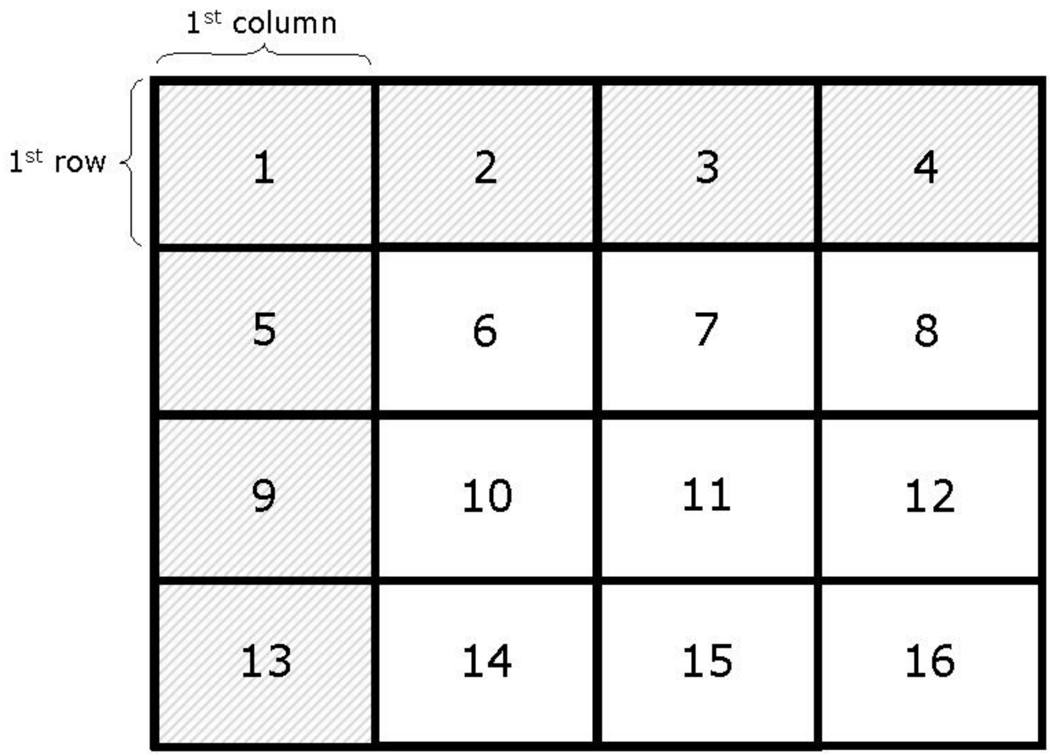

Fig. 2: The imaginary 4 x 4 grid used to partition the screen in 16 quadrats.

Spatial analyses. The spatial equivalent of uniformly and independently distributed random variables is the Complete Spatial Randomness (CSR). Any point pattern distribution analysis needs some sort of comparison with this distribution. In the present study we used this rationale to investigate the distribution of the users' clicks on the screen.

The spatial index we used was the Nearest Neighbor Index (Clark and Evans, 1954), which is one of the most widely used distance statistics. Computing it is very easy, and many other distance statistics are founded on it. As a first step, the nearest neighbor distance or d(NN) should be computed as follows:

$$\mathbf{d(NN)} = \sum_{i=1}^{N} \left[\min \frac{(d_{ij})}{N} \right]$$

where $\min(d_{ij})$ is the distance between each point and the point nearest to it, and N is the number of points in the distribution.

This index is nothing more than the average of the minimum distances. The second step is to compute the mean random distance or d(ran), that is the d(NN) one would expect if the distribution were random.

$$\mathbf{d(ran)} = \mathbf{0.5}\sqrt{\frac{\mathbf{A}}{\mathbf{N}}}$$

where A is the area of the region (the measurement unit of the index is related to the one used here), and N is the number of points.

The final step is the actual computation of the Nearest Neighbor Index as follows:

$$\mathbf{NNI} = \frac{\mathbf{d(NN)}}{\mathbf{d(ran)}}$$

This ratio is equal to 1 when the distribution is random. Values lower than 1 suggest grouping, whereas values higher than 1 suggest regularity (i.e. the point pattern is dispersed in a non-random way).

It is also possible to compute the statistical significance for this index (as we have done in this study). Indeed, Complete Spatial Randomness (CSR) hypothesis was tested separately for Experts' and Novices' clicks distributions using the Nearest Neighbor Index (NNI). However, here we will not enter into the details of statistical inference for spatial data: the interested reader may refer to Haining (2003) for an exhaustive account.

6. Results

CSR test showed that the two point distributions were not random. Experts' NNI was 4.02 ($Z=77.99$, $p<0.01$), whereas Novices NNI was 3.28 ($Z=51.67$, $p<0.01$). Both results indicated regularity. Cluster Analysis showed different patterns for the two groups. Experts showed five clusters (figure 3) named *user input* (register, check your e-mail), *user commitment* (play & win, buy, contact us), *company info* (news, search, about us, home), *corporate identity* (product catalog, jobs), and *access to resources* (resources, restricted area). One link (help) only combined with the others at larger distance. Novices showed six clusters (figure 4): *user input* (buy, search, play & win), *access to resources* (resources, register), *corporate identity* (catalog, jobs), *general* *functions* (home, help), and two uninterpretable clusters. One link (check your e-mail) was separated from the other groups.

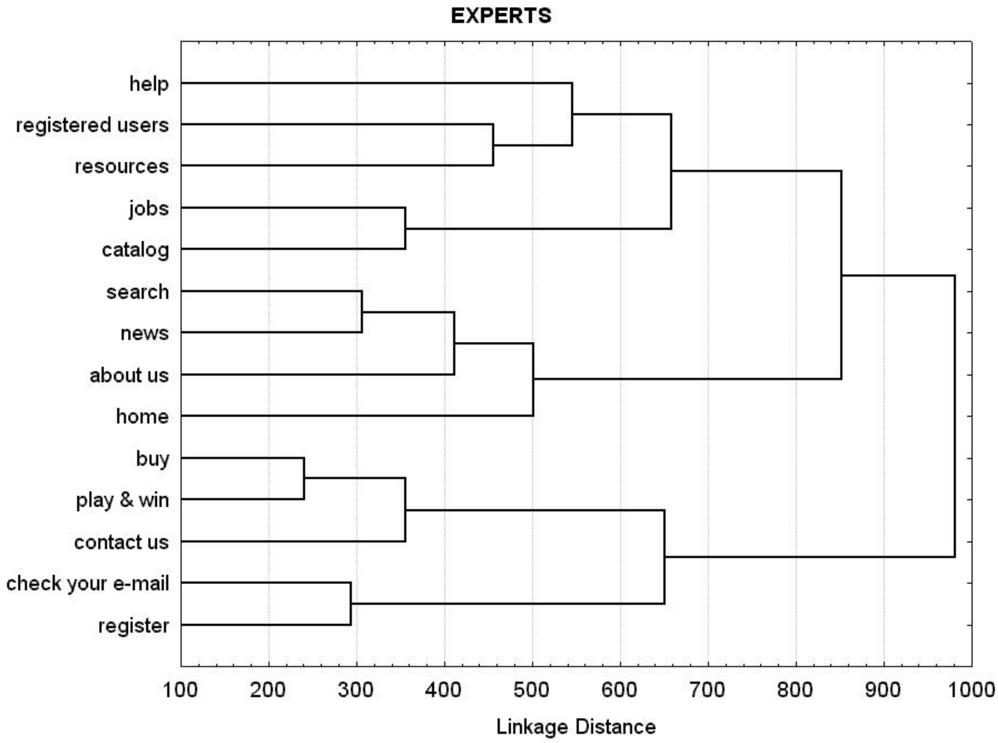

Fig. 3: Horizontal tree diagram summarizing the clustering of links for the experts. Note how easy can be the naming of the clusters in this case.

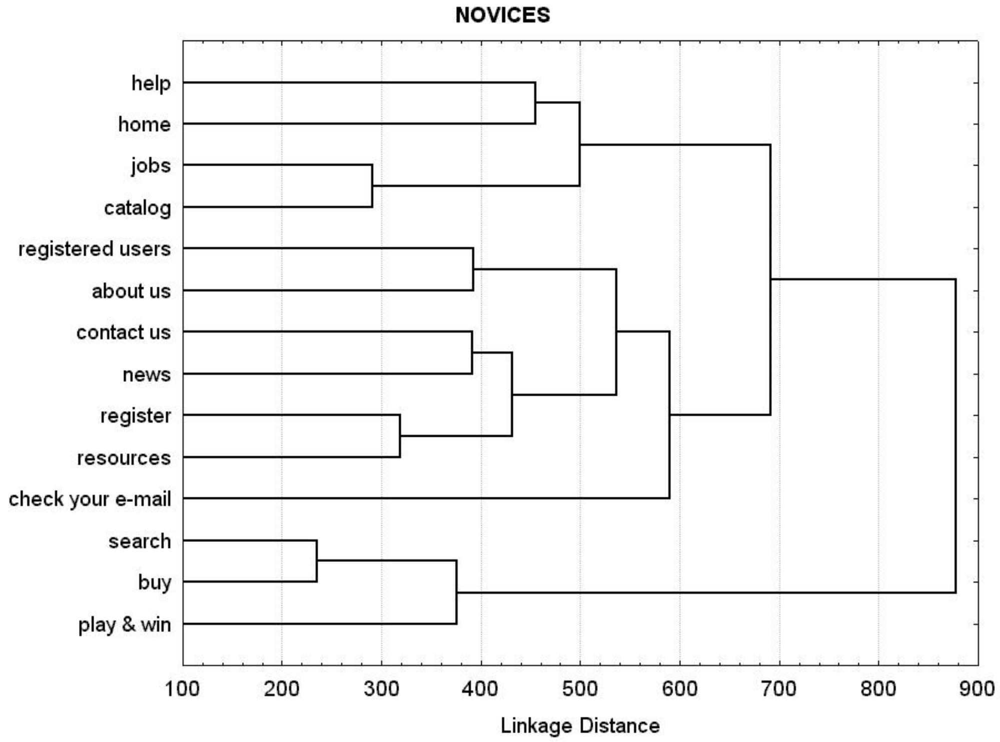

Fig. 4: Horizontal tree diagram summarizing the clustering of links for the novices. Note how difficult can be the naming of the clusters in this case.

The Analysis of Variance showed a significant Expertise x Link x Rows x Columns third order interaction ($F_{117,2457}$=1.63, p<0.01). Thus separate factorial analyses of variance were run for each link. A "Row" main effect was found for the stimuli "check your email", "registered users", and "jobs" ($F_{3,63}$=2.80, p<0.05; $F_{3,63}$=2.70, p<0.05; $F_{3,63}$=3.67, p<0.05, respectively). Duncan testing showed that the individuals' preference for locating those stimuli significantly increased downward. Furthermore both "registered users" and "jobs" showed a main effect of "Column" ($F_{3,63}$=4.31, p<0.01; $F_{3,63}$=3.04, p<0.05, respectively). Duncan testing showed that subjects located both stimuli within the farthest (left and right) columns significantly more often than within the two central columns. Rows by Columns interactions were showed on the proportion of clicks to the stimuli "search" ($F_{9,189}$=2.17; p<0.05), "news" ($F_{9,189}$=2.63; p<0.01), "about us" ($F_{9,189}$=2.50; p=0.01), and "home" ($F_{9,189}$=9.91; p<0.01). High variability of clicks to "search" did not allow any further interpretation of this result. On the contrary, Duncan testing showed that "news" was located in the quadrat defined by the first row and the second column significantly more often than in all the other positions, whereas "about us" was located more often within the first column (with a proportion of clicks increasing from the lower to the upper part of the screen). Finally, “home” was more often assigned to the uppermost-leftmost corner. An Expertise by Row interaction was found for the stimulus “home” ($F_{3,63}$=4.84, p<.01). Duncan testing showed that it was due to the novices locating this link also in the lowest part of the screen. Three links (buy, help, and resources) showed an Expertise by Row by Column interaction ($F_{9,189}$=2.49; p<0.01, $F_{9,189}$=7.32; p<0.01 and $F_{9,189}$=2.32; p<0.05, respectively). Particularly, “buy” was mostly assigned to the lowermost-rightmost corner by experienced users, whereas novices preferred the uppermost-rightmost area, “help” was assigned to the uppermost-rightmost corner only by experts, and “resources” was assigned to the upper part of the screen by expert and novices with opposite patterns (leftward for experts *vs*. rightward for novices).

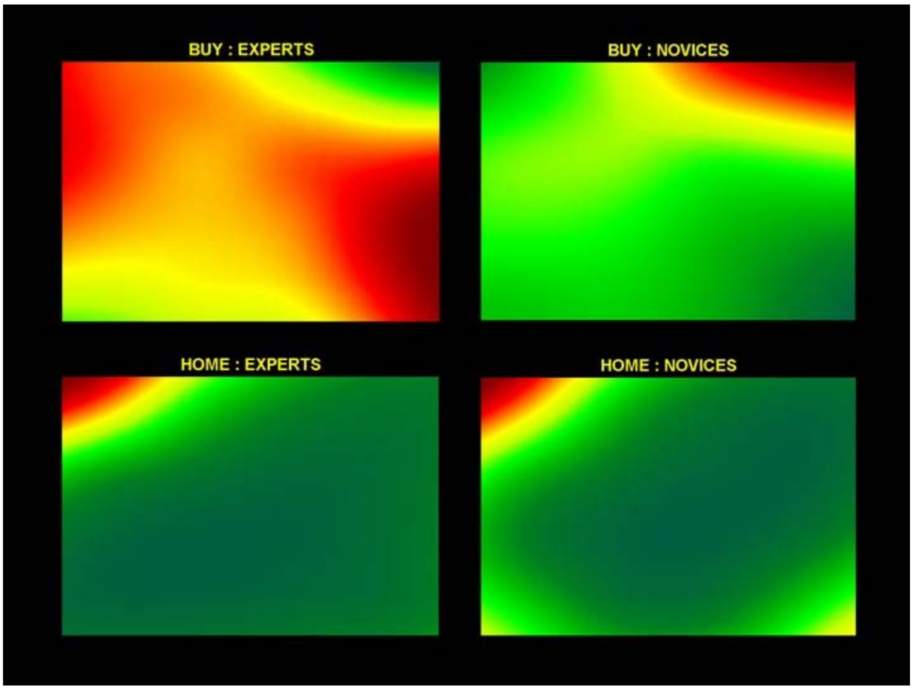

Fig. 5: Spline interpolations for dispersed (buy) vs. concentrated (home) patterns, separately for experts and novices. Dark red indicates high clicking areas, whereas dark green indicates low clicking areas.

7. Discussion

According to Tversky (2003), the invented space of graphics consists of elements (icons, for example) and the spatial relations among them (for example, distance and direction), both conveying meaning. They represent natural correspondences that “reduce load on working memory and cognitive operations” (p. 77). The present study was aimed at investigating the existence of spatial schemata specifically involved in the cognitive organization of web pages, which are invented spaces as well. Our hypothesis was that the location of some links could be expected at specific spatial locations. Expectations would be due to the activity of schemata whose aim is to optimize user's performance. Two possible patterns of results could have been expected, according to the type of schemata involved in the process: either spatially- and semantically-based schemata or schemata based on navigation experience.

Cluster analysis results partially supported the first prediction, as some important clusters were matched for the two groups. However, experts' were the only really interpretable clusters, whereas novices' showed at least two uninterpretable clusters. We are aware that one of the most important issues affecting users' performance was the nature of the stimuli we used. Indeed, our study was general in its scope, and stimuli represented links to functions and resources available in different typologies of websites. Using links from one type of website may provide much clearer clusters.

Analyses performed on single links provided information extending that obtained from cluster analysis. Expected positions matched the most common among websites (i.e. home, help, etc.), supporting the idea that strategies also affect users' performance. Our results are thus in contrast with those reported by Bernard (2001) who found no effect of expertise on spatial organization. Likely, such a discrepancy might be due to the methodological differences between the two studies.

Overall, the theoretical scope of this study was partially fulfilled: "natural" deployment of web objects seems to occur, albeit this is not always the case. Again, some objects showed a common location for experts and novices, suggesting a semantically-based organization. However, we do not exclude that this may be due to subject's previous knowledge about web sites. In fact, one limit of the studies comparing experts' and novices' performance is that novices are never completely fasting from the conventions used in interface design. It is actually hard, nowadays, to find people who never navigated a web site. Thus, we carefully consider the differences only in the degree of knowledge the two groups have.

Natural positioning is somewhat related to the "affordance issue" in interface design. Norman (1999) argued that objects deployed in an interface represent cultural constraints (conventions shared by a cultural group), and they do not provide real affordances (Gibson, 1977; 1979). Albeit we do not completely agree with this account, this single study cannot rule out this possibility, nor can it completely support the idea of "natural" locations for web objects.

Still, the usefulness of the procedure as a technique for supporting information architects' decisions has been attested. In the future, guidelines may be derived from the Cognitive GeoConcept procedure, and may be used to gather clear indications for design.

8. Conclusions

The results of the present study are very encouraging, although more research is needed, as well as replication studies using wider samples and different stimuli. Also, other indexes should be used to assess the validity of the procedure. Indeed, clicks may be affected by processes such as memory and decision-making. Hence, there is a need for more stringent measures, possibly related to early processing. Psychophysiological measures may do, but they are difficult to implement and have some shortcomings. For example, Ward and Marsden (2003) have attempted the use of psychophysiological measures for monitoring physiological activity during the navigation of ill- and well-designed sites. However, different mental events can produce near identical physical responses, representing one of the most important shortcomings. Eye-movements, instead, may represent a more convenient measure. Indeed, collecting unintentional gazes towards particular screen areas during the Cognitive GeoConcept task is technically feasible, and preliminary data we collected at our lab showed consistent patterns between fixations and clicks (consistently with findings reported by Chen, Anderson, and Sohn, 2003). However, this coherence was showed only by novices, suggesting the existence of motor schemata, partially independent from visual processing, in expert users.

Of course, the present study leaves unanswered many questions about the nature of the schemata discussed above. However, it may be useful in the future to make use of the knowledge gained in this domain to test the efficacy of specific page layouts. For instance, one might evaluate the performance of users interacting with websites organizing space according to the groupings found. Also, extending this testing procedure to specific groups of users (i.e. juniors *vs*. seniors) would be useful. This may eventually lead to improve our comprehension of the processes involved in human-technology interaction, and to design "objects" that wait for users' inputs … there where the users expect them to be waiting for.

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