Safeway of using map reduction without poignant performance of routing in data base.

D. Sandeep, Asst. Professor,Santhiram Engineering College,Nandyal.

K.V.SaiPhani, Asst. Professor,Santhiram Engineering College,Nandyal.

Abstract: Map-based navigation is a diverse undertaking that stands in contradiction to the purpose of completeness of web mapping services. As every navigation project is exclusive, it also requires and might dispense with extraordinary map records to assistpowerful and efficient wayfinding. Task-orientedreduction of the elements displayed in a map might alsoconsequentlyhelp navigation. In order to investigateresults of map reduction on courserecognition and visual attention towardunique map factors, we created maps in which areas offside an inserted coursehad been displayed as transparent. In a directionmemory experiment, wherein participants had to memorize routes and healthy them to routes displayed in following stimuli, these maps have beencompared to unmodified maps. Eye motion analyses discovered that inside thedecreased maps, areas offside the pathhave been fixated much less often. Route reputationperformance was no longertormented by the map reduction. Our resultsindicate that task-oriented map reductionmay additionally direct visible attention closer torelevant map elementswithout charge for pathpopularity.

Keywords:cognitivecartography;empiricalcartography;spatialcognition;volunteeredgeographic information; landmarks; map pictograms; route memory; recognition.

1. Introduction

Intoday'sworld,humanlifeisaccompaniedbyhigh mobility.Travelingtounfamiliarregionshas becomesimpleandcheap,increasingtheneedfornavigationinunfamiliarenvironments.Geographic information in the form of maps or navigation systems is thus of increasing importance. Modern web mapping services such as OpenStreetMap, an example of Volunteered Geographic Information (VGI) [1], and Google Maps provide fairly accurate geographic information at no cost [2,3]. In the era of smartphones and mobile internet, these map distributers can be used virtually everywhere. Additionally, navigation apps can support way finding in unfamiliarenvironments.

Besides navigation, maps are often used for telling stories. Television, films, social media, travelogues, newspapers, and audio books are ubiquitous examples of media used for conveying stories, demonstrating their high social relevance. As stories often have a spatial component—things exist and happen in space—maps can be used for this purpose. Today, maps can easily be extended with other valuable media, such as texts, audio, and video [4–6]. This helps to widen the number of map genres and to adapt the needs of a spatial story [7].

In both cases—navigation and storytelling—it can be advantageous to focus on the essential information.Manymapsespeciallytopographicmaps, aretask-independent.Suchmapsarecreatedandcanbeseenasarobustalternativeformulti factorial ANOVAmodels.Recognitionperformance(hitsandcorrectrejections)maineffectswerecalculatedfor thebetween-subjectfactor(reduced/standardmap)andthetwowithin-subjectfactors(landmarks/no landmarks in the study maps and the recognition stimuli). Additionally, interaction effects between the three factors wereassessed.

Given that d' values put correct and incorrect responses into proportion, calculating d' requires aggregation of hits, misses, correct rejections, and false alarms across participants and specific conditions.ThisunderminesthebenefitoftheGEEmodeltohandlecorrelationsofmultipleresponses fromthesamesubjectsatthelevelofsingleitems.Thesameistrueforthevisualattentionmeasures, whichgeneratedonlyonefixationcountandaveragefixationdurationvalueperparticipantandstudy map.Inaddition,thefixationdatadidnotfollowaGaussiandistribution.Therefore,thenonparametric Mann–WhitneyUtestwasusedtocompared'andeyefixationsdatabetweenthetwomapconditions (reduced/standard map). For the examination of the to represent the real environment in a most complete way. Thus, they display all information that complies with the categories provided in the legend or an ontology. As an example, one expects a city map to contain all streets in the depicted area. Such information might, however, be irrelevant to the user when performing a certain task. Leaving out unneeded information can have several consequences. One might assume that reduced maps which do not display all information provide fewer distractions when navigating. Also, the user of a reduced map might get an impression that the map is, in fact, incomplete. As a consequence, the user develops an open-world assumption. Assuminggapsorerrorsinthemapopensthepossibilityofmoreflexibleuseandmightaidthemap userwhentellingastoryorbeingconfrontedwithinaccuratemapinformation.Despiteoftheassumed usefulnessofreducedmaps,potentialpositiveornegativeconsequenceshaveonlybeenexaminedin part so far[7,8].

Inthisarticle,weexamineinwhichwaytheabsence ofinformationinamapusedforanavigation task influences our cognition. A reduced map provides less information that distracts the user, but alsolessinformationthatprovidescontexttotherelevantpartsofthemap.Wefocusonthefollowing two researchquestions.

RQ1. Does the reduction of map elements towards only the informative parts of the map affect route memory?

RQ2. Does the reduction of the represented content of a map shift visual attention towards a displayedroute?

For answering these questions, participants were asked to memorize a route in a reducedmap. Thereafter, it was tested how well the participants performed at recognizing the shape of theroute.Theseresultsweresetintocontextbyacomparisontorecognitionperformancewhenusing a conventional nonreducedmap.

2. Background

Bothdigitalmapsandnavigationsystemsencloseatradeoffbasedontheirdesign.Asmentioned before, maps are usually task-independent and strive for completeness. Additionally, they allow users to obtain survey knowledge of their surroundings [9]. However, they also contain a lot of information that is irrelevant for specific navigation tasks. Studies have shown that the degree of visual complexity in a map affects performance in map-based memory tasks [10–12]. While Kuchinke et al. [10] showed that topographic detail improved recognition performance of object locations in maps, Edler et al. [11–13] found that improvements of memory performance based on thepresentationofadditionalmapelementsbecomeless noticeableatexceedinglyhighlevelsofmap complexity.Giventhatvisualcomplexityofstimulicanincreasethecognitiveloadoftheperceiver[14], existenceofatippingpointcanbepresumedwheretheamountofdisplayedinformationisnolonger helpfulformap-basedmemorytasksanddistractsfromrelevantvisualelements.Navigationappson theotherhandarehighlytask-orientedand,asusualforlocation-basedservices(LBS),thedisplayed content depends on the context (current position). They support efficient wayfinding in unfamiliar environments,buttheyusuallyvisualizeonlyanarrowareaaroundthepositionoftheuser.Thiscan impairorientationandroutememory,asdistantgloballandmarksarenotdisplayed[15].Additionally, the lack of active interaction with the environment prevents the acquisition of spatial knowledge about the environment [16]. An ideal navigation aid would therefore combine the strengths of digital maps and navigation systems—fast and efficient wayfinding, limited cognitive load, focus on relevant map elements, and a survey view of the environment that supports the formation of survey knowledge[9,17].

Inourexperiment,weexaminetheuseofreducedmapsadaptedtospecificusecasesinorder to overcome the tradeoffs of maps and navigation systems in way finding tasks. When people want to communicate a route without external aids, they often use sketch maps, hand-drawn maps that showthewholerouteatonce,butleaveoutmostperipheralelementsshownina“classical”

They are usually incomplete, i.e., they only contain roads and road sections alongside the route, and landmarks at decision points. Such sketch maps are a graphical representation of the task-oriented cognitive map of their creators . These sketch maps seem to be perfectly reduced to tell the story of how to follow the route to aid route learning and navigation. Therefore, reducing maps based on sketch map pattern may improve route memoryperformance.

Based on this assumption, we investigate the possibility to limit the complexity of maps and the consequential effects on cognitive load. The common cartographic approach for reducing map complexity is generalization. Generalization describes the process of simplifying boundaries of map elements and removing seemingly less relevant elements. However, map users may not recognizetask-orientedmapgeneralizationinstantly,certainlynotwhat elementshavebeenremoved. Consequentially, an open-world assumption will not be generated before the map user is confronted with a confusing mismatch of the current position and its map representation, e.g., if a small road is not displayed in the map. Therefore, we apply a different approach by displaying areas offside of the route transparent. Given that visual attention is affected by the transparency of stimuli, transparent areas offside the route could shift the visual attention of the user towards relevant map elements,namelytheareaaroundtheroute,whileanon generalizedsurveyviewoftheenvironment is still available. Eye fixations are reported to indicate visual attention and are therefore commonly usedtoassessvisualattentiontowardsspecificstimulusa reas.Consequently,investigatingeye fixationsonmapsusinganeyetrackercouldunveilwheth erdisplayingspecificmapareastransparent shifts visual attention towards other non-transparent mapareas.

Ifallelementsinamapoffsideadisplayedroutearei nvariablydisplayedtransparent,itneedsto be considered that this may also deteriorate positive aspects of a survey map. Especially landmarks are highly relevant for orientation, navigation and the formation of cognitive maps and are expected to be important elements of navigation stories. Therefore, the display format of landmark pictograms can affect navigation and route recognition performance. Landmark pictograms in OpenStreetMapandGoogleMapsaredisplayedbasedo ntheselectedscaleofthemap. Whenasmall scaleisselected,onlyfewofthedepositedlandmarkpicto gramsaredisplayed.Atthelargestscale,all depositedlandmarksaredisplayed.Removingoraddin gsuchmapelementsbasedonmapproperties as scale would force the user to rely on other map elements for route recognition, which may in turn impair recognition performance. In order to assess whether the task-specific reduction of maps and the display of landmark pictograms affect route perception and recognition, we test the following hypotheses in ourexperiment.

Hypotheses1(**H1**). Displaying areas offside of the route transparent does not impair route recognitionperformance.

Hypotheses 2 (**H2**). Displaying areas offside of the route transparent shifts visual attention towards the route.

Hypotheses 3 (**H3**). Adding or removing landmark pictograms after the route has been memorized impairs route recognition performance.

Methods

The study was conducted in accordance with the Declaration of Helsinki. The experimental designhasbeencontrolledbytheethicscommitteeofthe FacultyofGeosciencesattheRuhr-University Bochum and was classified as ethically acceptable (13 July2018).

Participants

Thestudysamplecomprised69geographystudent s(30females,39males)oftheRuhr-University Bochum with normal or corrected vision and no neurological diseases. Their age range was between 18 and 37 years (M = 23.07; SD = 3.45). Participation was rewarded with a payment of 5EUR.

Materials

Participantsweresortedintotwoexperimentalbetween-subjectconditions(standardvs.reduced maps) with the same distribution of sexes in each. For both conditions, six maps (study maps) containing a route marked with a red line, a green starting point indicator, and a red destination indicatorwerebuilt(Figure1).ThebasemapswereextractedfromOpenStreetMap(OSM)inascaleof 1:10,000 and represented the same six regions in both conditions. All maps showed European urban regionsselectedtopreventhighfamiliarityoftheparticipantswiththedisplayedregions.Inthefirst condition (reduced maps), all map areas with a distance of more than 10 pixels to the route were displayedtransparent(alphavalue=12).Inthesecondcondition(standardmaps),nomapareaswere displayedtransparent.

Two variants of each map in both conditions were generated. One variant contained OSM landmarkpictogramsclosetoeachroutediversionaswellasatadditionalrandompositionsinthemap. TheusedlandmarkpictogramswereselectedfromtheOSMlandmarkpictogramrepositorybasedon theirsalienceandmeaningfulness[31].Twentylandmarkswithmoderatesalienceandmeaningfulness werechoseninordertopreventextensiveattentiontowardssinglelandmarkpictogramswithhigher salience [32] or higher meaningfulness [33]. For each landmark position in the study maps, one of these 20 landmark pictograms was selected at random. The second study map variant contained no landmark pictograms. After the route was inserted and all street names were removed, maps were exported in a size of 30 × 20 cm (1063 × 709 pixels). See examples for both experimental conditions and variants in Figure1.

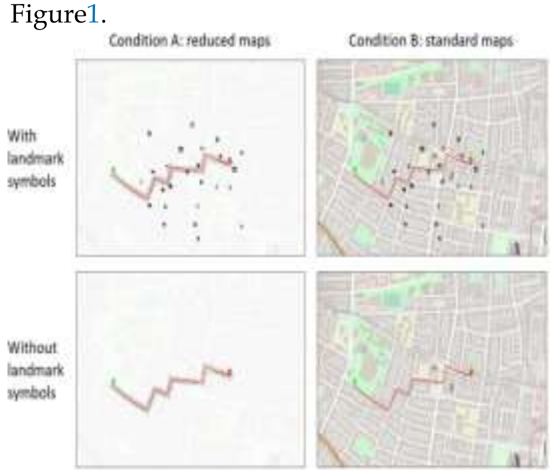

Figure1. Studymapconditionsandvariants.Accordingtotheirexperimentalcondition,participants saweithersixreducedorsixstandardstudymaps.Participantsfrombothconditionssawthreemaps with landmark pictograms and three maps without landmarkpictograms.

Additionally, four types of recognition stimuli (examples in Figure 2) were generated for each of the six study maps to test whether participants could recognize the correct route shape among incorrect route shapes. These stimuli had the same size as the study maps. They also contained a route marked with a red line, a green starting point indicator, and a red destination indicator. Therecognitionstimulishowednomap,butablankwhitebackground.Perstudymap,atleast

one of the four corresponding recognition stimuli contained the same route shape as the study map (correct route). The other recognition stimuli contained altered versions of the original route shape (incorrectroute).Therandomamountofcorrectroutesshapeswasintendedtopreventthatparticipants recognizeaconstantproportionofcorrectandincorrectroutes,asitwouldenablethemtoanticipate whether the following stimulus shows a correct route if all correct or incorrect route shapes have already been shown. Similar to the study maps, two variants of each recognition stimulus were generated. One variant contained the same landmark pictograms as the version with landmarks of their corresponding study map. The second variant contained no landmark pictograms. All correct and incorrect routes contained six route diversions. Route diversions of incorrect routes were also placed close to landmark pictograms positions (if the stimulus contained landmark pictograms), but differentpictogrampositionsthantheonesusedforthecorrectroute.Inthecaseofincorrectroutesin stimuliwithoutlandmarks,routediversionswereplacedclosetothepositionsoflandmarkpictograms intheircorrespondentstudymapstimulusthatincluded landmarks. Inbothexperimentalconditions (reduced and standard maps), the same recognition stimuli wereused.

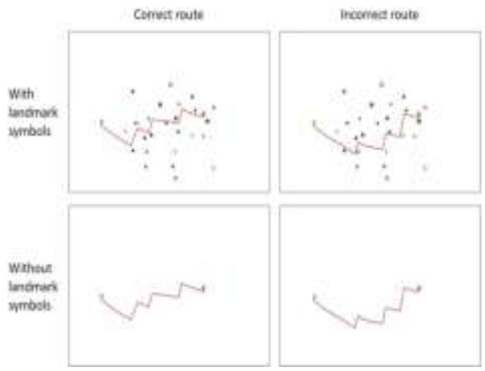

Figure 2. Recognition stimulus variants. After each study map, four recognition stimuli were shown to the participants. At least one of these stimuli contained the same route as the study map. The rest contained slightly changed route shapes. Whether landmark pictograms were displayed in a recognition stimulus was determined atrandom.

Procedure

In order to prevent response biases, no information about the study purpose was given to the participants before or during study participation . They were told that information concerningthestudypurposewouldbeprovidedafterth eexperiment.Beforetheexperimentstarted, the procedure was explained and the participants gave informed consent. Hereafter, they took a seat infrontofaTobiiTX-300(300Hz,23inches)eye-trackermonitorthatwasusedtovisualizethestimuli. The distance between the eyes and the monitor was 65cm.

Theexperimentconsistedofapracticetrialandsixex perimentaltrials.Atthebeginningofeach trial, a study map was shown for 30 s. During this time, participants had to memorize the route displayedinthemap.Participantswerepresentedonlyma psthatbelongedtotheexperiment condition a participant was assigned to (reduced maps or standard maps). Three of these six study maps shown in the experimental trials were randomly selected to display landmarks while the other 3 maps did not contain landmarks (i.e., within-subject factor 'study map landmark' yes or no). The presentation order of the six selected study maps was randomized. After every 30 s study phase, thefourrecognitionstimulibelongingtothepreviouslysh ownstudymapwerepresentedsuccessively, each for eight seconds. The presentation order and the variant selection of each recognition stimulus (with or without landmarks) were randomized. The matching of study maps and recognition stimuli with and without landmarks allowed to compare recognition performance between conditions in whichlandmarkswereshownonlyinthestudyphase,only intherecognitionphase,inbothphasesor innoneofthem.Aftereveryrecognitionstimuluspresenta tion,participantshadtoanswerwhetherthe routedisplayedinthepreviousrecognitionstimulushade xactlythesameshapeastheroutedisplayed in the last study map. The answers were given by pressing one of two keyboard keys labeled with "yes" and"no".

RecognitionPerformance

Performance in the recognition task was assessed according to the signal detection theory in the form of hits, misses, correct rejections, and false alarms. If the route shape in a recognition stimulus matched the route shape in the study map (old stimuli), participants could either correctly state a match (hit) or wrongly state a mismatch (miss). If the two route shapes did not match (new stimuli)participantscouldeithercorrectlystateamismat ch(correctrejection)orwronglystateamatch (false alarm). Because of the redundancy in these measures, only the hits and correct rejections were investigated in the statistical analyses. The misses and false alarms were merely used to calculate d', an additional recognition performance measure based on all four response types. The benefit of d' is that it puts correct signal detection (hits and correct rejections) and noise responses (misses and false alarms) in proportion. The d' value increases if the ratio of hits and correct rejection increase. It decreases if the ratio of misses and false alarms increase. This allows to make statements about the sensitivity of how well participants discriminate old from new stimuli. For information about d' calculation see Macmillan &Creelman.

Conclusion:

Thepresentstudywastargetedatassessingtheeffec tsofmapreductionandlandmarkdisplayon routerecognitionandvisualattention.Wewereabletode monstratethatreducingamapbydisplaying mapareasoffsidearoutetransparentdoesnotaffectroute recognitionperformance.However,reducing the map shifted proportionally more fixations towards a displayed route. Presenting incongruent information by removing or adding landmark pictograms after a route had been memorized only affected recognition performance of new stimuli (correct rejections and false alarms), but not of old stimuli (hits and misses), which we argued to be affected by our experiment design. Overall, our findings indicate that task-oriented reduction of map complexity is a feasible approach to reduce the cognitive load of the user without compromising route recognition. Besides navigation apps, other map-based LBS as point of interest locators may benefit from our results. However, further research concerning map reduction levels, completeness, landmark display, and their effects on orientation and navigation performance is required for gaining a deeper understanding of how to design task-orientedmaps.

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