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Mathias Willnat
University of Goettingen, mathias.willnat@uni-goettingen.de

Tim-Benjamin Lembcke
University of Goettingen, tim-benjamin.lembcke@uni-goettingen.de

Jannes Heinrich Diedrich Menck
University of Goettingen, jannes.menck@uni-goettingen.de

Felix Kegel
University of Goettingen, felix.kegel@uni-goettingen.de

Christoph Prinz
University of Goettingen, christoph.prinz@uni-goettingen.de

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Completed Research

Mathias Willnat
University of Goettingen
mathias.willnat@uni-goettingen.de

Tim-Benjamin Lembcke
University of Goettingen
lembcke1@uni-goettingen.de

Jannes Heinrich Diedrich Menck
University of Goettingen
jannes.menck@uni-goettingen.de

Felix Kegel
University of Goettingen
felix.kegel@uni-goettingen.de

Christoph Prinz
University of Goettingen
christoph.prinz@uni-goettingen.de

Abstract

Digitally enabled mobility services and their associated information systems (IS) have spread rapidly in recent times, for example in the form of smartphone and in-vehicle applications. Such services often enable users to achieve more environmentally friendly, equitable, and safe individual mobility. User interfaces typically feature digital maps to facilitate spatial orientation and choice. This study pioneers an investigation of digital maps for low-stake decision making as prevalent in mobility IS. To this end, we blend previous theoretical research on task and map complexity from other disciplines. By analyzing data from a discrete choice experiment, we confirm the hypothesized relationship between visual map intricacy, choice complexity, and informational performance, measured as behavioral consistency. We propose an IS research agenda to initiate a discussion about design of and human interaction with digital maps, their role for mobility IS, and for our field beyond.

Keywords

Digital Map Complexity, Mobility IS, Spatial Choice Consistency, Stated Choice Experiment.

Introduction

Motivation

Information systems (IS) facilitate a wide range of new or improved conveniences for organizing individual mobility, such as in-vehicle and smartphone applications. As these mobility IS become ubiquitous, so do the digital cartographic maps integrated therein. Digital maps in mobility applications are typically deployed to inform the users' spatial choices. Multiple IS studies on cognitive fit theory documented the superiority of cartographic visualizations compared to more abstract forms of information display (e.g., tables, charts) for spatial choice tasks. However, these contributions have focused primarily on strategic high-stake spatial problems, such as business site selection (Dennis and Carte 1998), school district assignment (Smelcer and Carmel 1997), and residential choice (Erskine et al. 2019). As such, their applicability to more mundane situations appears to be limited. Indeed, recent work suggests that these patterns may differ for low-stake tasks, such as mobility app usage (Willnat et al. 2021). The casual usability of digital maps depends on their respective task fit. Behavioral consistency may serve as a valid outcome measure to evaluate this fit since inconsistent choices can be understood associated with utility losses and, thus, users' detriment (DeShazo and Fermo 2002). Experimental studies in behavioral research identify task complexity as a major driver of inconsistency (Carlsson et al. 2012; Dellaert et al. 2012; DeShazo and Fermo 2002; Louviere et al. 2008; Rose et al. 2009). However, understanding complexity in the context of digitally supported spatial decision-making remains uncertain. While research in geography and geographic information systems (GIS) established a complexity notion of cartographic displays (MacEachren 1982), it has not yet been brought together with that of behavioral research and the peculiarities of mobile IS. Our study aims to initiate a discussion on digital map complexity (DMC) in mobility IS, as one of the most seminal application areas for digital maps. Conducting an experimental study exploring different levels of complexity, we seek to explore junctions with the notions of complexity and consistency in experimental behavioral science and geography, deriving a research agenda for our discipline.

Theoretical Background

The concept of behavioral consistency is deeply rooted in the utilitarian economics of rational choice theory (Peterson and Brown 1998; Sælensminde 2001). Thereby, in identical choice situations, a changing preference order violates the transitivity axiom and is therefore associated with utility losses and an inefficient outcome. Rigby et al. (2016) define choice consistency as “making the same choices when faced with the same choice sets,” matching the terminology used in numerous other studies (e.g., Brouwer et al. 2010, 2017; Schaafsma et al. 2014). Besides this binary notion, other authors employ the error terms of random utility discrete choice models as a continuous measure of decision consistency (Dellaert et al. 1999, DeShazo and Fermo 2002), arguing that inconsistent revealed preferences are a major cause of empirical dispersion from modeled estimators.

Several studies identify task complexity as an important driver for inconsistent choice behavior: For example, DeShazo and Fermo (2002) conducted a choice experiment to examine complexity by varying the number of alternatives, the number of attributes to be considered, and their distribution in five treatment groups. They find that increasing the variation of alternative attributes reduces the choice consistency. In a similar experiment, Dellaert et al. (2012) confirmed that increasing the number of alternatives, the amount of information, and the similarity of alternatives' utility increases the observed model error as a proxy for inconsistency. Louviere et al. (2008) and Carlsson et al. (2012) defined the complexity of a decision task in terms of the theoretical utility similarity between the different alternatives, applying utility functions to the respective attributes. They empirically confirmed that the more complex a decision task is (i.e., the more similar the utilities of the alternatives are, associated with statistical efficiency in survey design), the more inconsistent the decision behavior becomes. Mattmann et al. (2019) distinguished in their study between (self-reported) choice certainty, (observed) consistency, and monotonicity (defined as a strict preference for feature dominant alternatives). The authors gauge complexity as entropy, a quantitative measure of the indiscernibility of utility differences among the alternatives. The study provides confirmation for the hypothesis that complexity reduces choice certainty but finds no significant effect on consistency and monotonicity. Brouwer et al. (2017) rerun an intertemporal research design an identical choice task three times over two years and find that while the overall choice complexity reduces consistency, this effect diminishes over time due to restructuring and learning processes. A further intertemporal experimental study by Rigby et al. (2016) confirmed the moderating factor of complexity (measured as entropy) on consistency, while a selection bias is reported in temporally staggered surveys regarding participants' cognitive capabilities. Rose et al. (2009) highlighted how choice set complexity affects decision consistency in routing choices differently across cultural backgrounds.

Throughout these studies, we find that while the negative correlation between task complexity and decision consistency can be robustly reproduced in many contexts, various and differing notions of task complexity prevail. Louviere et al. (2008) identified two main concepts thereof. First, a situation can be regarded as complex if there is a large set of diverse information to be considered (e.g., many alternatives with multiple distinct and scattering properties). Henceforth, we refer to this as *intricate complexity*. Second, decision tasks are complex if the choice alternatives are perceived as offering a very similar level of appeal or in terms of rational choice theory if they provide a similar level of utility. This often corresponds to an efficient research design in choice experiments (Louviere et al. 2008); therefore, we denote it subsequently as *similarity complexity*. However, both interpretations imply a high level of cognitive burden to determine the best possible alternative. Various explanations are proposed as to why this results in inconsistent choice. Examples include individuals using simplified imperfect heuristics to reduce problem complexity (Kalkanci et al. 2011), deciders initially learning and later experiencing fatigue, yielding a U-curve in decision inefficiency (Swait and Adamowicz 2001), or deciders simply making mistakes due to insufficient cognitive capabilities (De Palma et al. 1994; Peterson and Brown 1998).

The concept of map complexity was shaped in its present understanding, notably by MacEachren (1982), who argued that excessive map complexity hampers its effectiveness in providing information. Thereby, he distinguishes between two complexity dimensions: First, *visual complexity* is defined as "the degree to which the combination of map elements results in a pattern that appears to be intricate or involved" (MacEachren 1982, p. 31). He proposed several quantitative measures for visual complexity, computed based on the number or density of graphical elements contained in a map. While he argues cartographers possess vast and immediate control over visual complexity, MacEachren claimed they were limited regarding the second dimension, *intellectual* or *cognitive complexity*. MacEachren (1982) characterized map-induced intellectual complexity as the confluence of information obtained from the map and those previously held, their interpretation, and consequent adjustment of the person's perceived reality. Therefore, a map is considered cognitively complex if, given an individual's personal contexts (e.g., experiences, attitudes, personality), it evokes a situation in which the person's evaluation of the perceived reality is highly demanding. In the case of spatial choice, this may mean that (regardless of possible visual confusion) it is difficult to reach a clear evaluation of decision alternatives based on one's cognitive processing of the situation illustrated by a map. A large body of subsequent work echoed this notion and refined this conceptual distinction by advancing characterization, measurement, and evaluation (e.g., Dumont et al. 2016; Fairbairn 2006; Schnur et al. 2018; Touya et al. 2016). However, to the best of our knowledge, no empirical investigation of the relationship between map complexity and spatial choice consistency has been reported yet.

Research Goal and Hypotheses Genesis

We identify several commonalities between the conceptual dichotomies of task complexity and map complexity. Both intricate and visual complexity are characterized by the volume of miscellaneous information, which may overstrain a decision-maker. Likewise, similarity and cognitive complexity are also associated contextually: Both notions are grounded in an understanding that the intellectual burden arises from assessing a situation, nourished by the objective circumstances but also by the individual's personal characteristics and the intricacy of the available information. In this sense, the entropy of the choice situation is directly driven by similarity task complexity and cognitive map complexity, but in a downstream form also by the degree of informational-visual clutter. The combined intricacy and entropy of a map-based task account for its overall complexity. Literature reports that the higher this complexity, the more likely erroneous factors compromise choice consistency, indicating ineffective behavior and therefore utility drain. Figure 1 shows these associations as grounded in the literature referenced above.

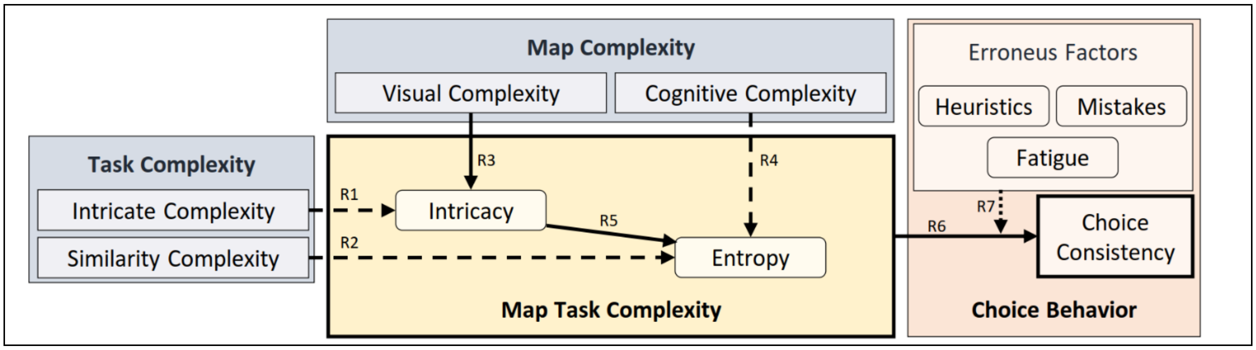

Figure 1. Reported and Conceptualized Relationships Between Map Complexity, Task Complexity, and (In-)Consistent Choice Behavior. Solid lines: investigated in this study; dashed lines: controlled for in this study (no variation); dotted line: assumed

This study aims to explore the empirically unanswered question of whether the complexity of a map supporting a choice task corresponds to the complexity of the respective map-supported choice task in the context of mobility IS. Therefore, we analyze two relations (denoted as R5 and R6 in Figure 1) to investigate whether the relationships conceptualized for task complexity are also robust for the case of map-induced complexity. In our experiment, intricate complexity and similarity complexity are kept stable; thus, their previously documented impact is controlled for (R1, R2). Similarly, the objective circumstances of the mapped situations are not varied (R4). Instead, in a 2-treatment experiment, one group is exposed to a higher level of visual complexity in a task-supportive digital map. Treatment manipulation checks are applied to verify the adequacy of the experimental design for increasing perceived complexity (R3). Our first hypothesis addresses the relationship defined as R5: [H1] *The ceteris paribus introduction of digital map features, raising the perceived visual map complexity, increases the overall choice complexity* ***(entropy)*** *of a spatial choice situation*. Hypothesis 2 explores whether the negative relationship between complexity and consistency (R6) can also be confirmed when the complexity is map-induced rather than task-induced: [H2]: *The ceteris paribus introduction of digital map features, raising the perceived visual map complexity, reduces the* ***individual consistency*** *of spatial choice behavior*. Both questions constitute pivotal avenues for an understanding of the human-technology interaction in spatial contexts. Yet, research to date does not provide any indication that substantiates the hypothesized relationships.

Methodology

Experimental Setup and Data Collection

We conducted an online discrete choice experiment for stated preference data collection. The experiment setup was as follows: After welcoming the participants and asking for their informed consent, we presented them the following scenario: "*You are in Montreal, Canada. After a few days of hiking in nature, you now want to explore the big city. You have started to appreciate the city's* ***free-floating bike sharing*** *system: You have to walk to the nearest available bike, pick it up and ride to your destination. Once you are there, you can simply park it anywhere along the sidewalk (no dedicated parking stations needed). You check the bikeshare app for the connection to the next sight you plan to visit. In the map view,* ***three available bicycles are suggested*** *to you and the locations as well as the corresponding walking and biking routes are displayed. Which of the three bikes do you choose? There is no price difference between these three alternatives. Further modes of transportation are not available in this scenario. [...] Please try to decide spontaneously as if it would be a real situation.*" The city of Montreal was selected because, on the one hand, we aimed to obtain a low level of local personal knowledge among the (predominantly German) study participants, but at the same time to choose a world region that in terms of general context such as climate, safety perception, etc. is not too far off from the respondents' lived experience.

Figure 2. Exemplary map visualizations of one choice situation. From left to right: North-aligned map (LC, HC) and map of the identical situation rotated by 72° (LC, HC).

After this introductory section, the survey proceeded with two scenario comprehension questions to verify participants' understanding. If answered correctly, the choice experiment followed. In a sequence of 40 cases, the participants were successively shown map visualizations in the style of a mobility app interface, upon which they were required to select one of the three featured bicycle positions. Participants were randomly assigned to one of two treatment groups. One group was shown maps that featured characteristics of high DMC as described in the literature: High color contrasts, diverse and partially overlapping landmark iconography, numerous text elements, high graphical resolution, and a high level of visible detail in the spatial information displayed. In contrast, the app interface of the other group presented the exact opposite characteristics of low DMC. We refer to these groups as HC (high complexity) and LC (low complexity). The different treatments are exemplified for two of the cases in Figure 2. We designed the scenarios to be nontrivial; for example, we avoided placing one available bicycle significantly closer to the starting point than the other two. However, the individual preference order is subject to hardly determinable variations since the catchment areas of the vehicles cannot be described empirically as radially uniform and are dependent on various personal and situational influences (Ortega et al. 2020; Willnat et al. 2021). Thus, we did not aim to model and explain specific choice behavior. The first eight choice situations varied, showing different map extracts with differently positioned bicycles. However, the subsequent 32 cases comprised just four further iterations of these same situations. In order to avoid participants noticing, the maps were rotated to ever new angles with all labels and landmark icons realigned accordingly. Figure 2 also shows an example of these map rotations. Once a participant completed the choice task in all 40 cases, some basic demographics were queried. Next, several items were surveyed on a 7-point integer ordinal scale (Likert scale). Specifically, we asked participants about their perceptions of the spatial choice situations iterated before. Thus, respondents were requested to assess their agreement with propositions referring to visual DMC as reported in the literature (Table 1).

	Item	**Reported by (among others)**
Visual Map Complexity	V1: The clarity between text elements and graphic elements of the map display was high.	Robinson et al. (1995)
	V2: The visual consistency of the symbolism in the map display was high.	Robinson et al. (1995)
	V3: The visual density of the map display was high.	Schwartz-Chassidim et al. (2014); Keil et al. (2020); Liao et al. (2018)
	V4: The color scheme of the map display induced visual confusion.	Touya et al. (2016); Wang et al. (2020)
	V5: Overall, I perceived the visual form of the map display to be too complex.	MacEachren (1982); Schnur et al. (2018)

Table 1. Surveyed Items on Visual DMC

Data collection took place in the summer of 2021 among business students at a German university as part of a voluntary methodological excursus on IS research. Students were awarded exam bonus points for their voluntary participation in this excursus. A total of 182 surveys were fully completed, excluding records with incorrectly answered comprehension controls. Unfortunately, we found that some maps did not load correctly under certain browser settings. In addition, the survey was conducted in English, which was not the native language for most participants. A subset of 63 participants reported that either technical difficulties or language barriers might have compromised the quality of their responses. The data of these participants were discarded and not further considered in our study. Thus, a total of 119 responses were included in our analysis, amounting to $40 \cdot 119 = 4{,}760$ individual decisions.

Data Analyses

The data analysis was conducted in several steps. First, we consolidated and cleaned the data set and characterized it descriptively. Subsequently, we performed a treatment manipulation check. Thereby, we verified whether participants perceived the distinct map visualizations such that typical properties of high and low DMC found in the literature are obtained. In the absence of an established measure for a latent construct *perceived map complexity*, the items listed in Table 1 are each assessed for mean differences using a one-tailed Welch's t-test. In line with the established notion, we expect lower agreement for items V1 and V2 among the HC group than LC and a reverse pattern for V3, V4, and V5.

As we tested the hypotheses, we used the entropy of the cases as a quantitative measure for overall task complexity and the behavioral consistency of the individuals as an outcome measure for informational performance of the maps. To test **hypothesis 1**, we compute the empirical entropies for each of the 40 cases (8 distinct choice situations, 5 rotations), grouped by map complexity treatment. Following Swait and Adamowicz (2001), entropy $H^{s,r,t}$ ($s \in S$: situation, $r \in R$: rotation variant, $t \in T$: treatment group) is defined as specified in equation 1:

$$H^{s,r,t} = -\sum_{j \,\forall\, J}\left[\pi_j^{s,r,t} \cdot \ln\left(\pi_j^{s,r,t}\right)\right] \geq 0$$

Here, j ∈ J: {A, B, C} represents the three decision alternatives (vehicle positions) per case, while π represents the probability by which these are chosen. Since the decision among the alternatives is determined by unknown (and for this study irrelevant) factors, π equals the empirical relative frequency of choosing j across all individuals:

$$\pi_j^{s,r,t} = \left|N_j^{s,r,t}\right| / \sum_{j\forall J} |N_j^{s,r,t}|$$

where |N| indicates the respective case cardinality across all individuals. For the three-choice experiments considered here, the entropy H can take values between 0 and ln(3) = 1.099. A high value translates as high choice complexity of the given task (Rigby et al. 2016). Hypothesis 1 can be considered supported if the measured entropy for the LC treatment proves to be significantly lower than for the HC treatment. Therefore, we apply a one-tailed Welch test because we must consider potentially unequal variances.

To test **hypothesis 2,** the decision consistency is compared between the two treatment groups. Common consistency measures in choice experiments include binary test-retest stability and the magnitude of error terms in estimation models. However, we argue that both approaches are inadequate in our study. While a binary measure (consistent/inconsistent) has high explanatory power when identical choice situations are repeated twice, it is highly restrictive in our case of five (rotated) iterations per situation. For example, we consider a choice pattern {A;A;A;A;B}, even though not perfectly consistent, still representing a higher level of consistency than {A;B;C;A;B}. This gradation is lost when applying a binary measure. The use of error terms of estimation models, on the other hand, is theoretically based on the assumption of monotonicity in the preference order over property bundles (axiomatic transitivity). However, this measurement also falls short in our case since we do not capture or evaluate the respective property bundles of the alternatives. Instead, we postulate the following definition of the individual consistency Q^i of participant i ∈ I for the purpose of this study:

$$Q^i = \sum_{s=1}^{S} \sum_{j\forall J} \sqrt{\left(\frac{5}{3} - \left|N^i_{s\forall r,j}\right|\right)^2}$$

The intuition behind this measure is as follows: If a naive individual without any consistency makes five choices among three alternatives in an identical situation (merely rotated five times), the expected number of times each alternative A, B, and C is chosen equals 5/3. The more a choice pattern deviates from this naive expectation, the higher the level of individual consistency Q^i. We take the root of squares to capture strictly positive deviations. For example, in line with our notion of consistency, this equation implies for one situation s: $Q_{\{A;A;A;A;A\}} = 20/3 > Q_{\{A;A;A;A;B\}} = 14/3 > Q_{\{A;A;A;B;B\}} = 10/3 > Q_{\{A;A;A;B;C\}} = 8/3 > Q_{\{A;A;B;B;C\}} = 4/3$. High values of this cumulative consistency score across all eight situations indicate highly consistent decision behavior throughout the experiment. In H2, we hypothesize that consistency is higher in the LC case than HC. Due to its calculation, Q must be considered ordinal rather than metric. Thus, we use the Wilcoxon rank-sum test for ordinal difference of independent samples for testing H2.

Results

Preliminary Analyses Results

Of our sample included for analysis, 62 participants identified as male (52%) and 56 as female (47%). Most respondents reported being in their twenties (average: 25 years). Of those willing to report a monthly disposable income, 53% classified themselves below 800 euros, with another 38% between 800 and 1300 euros. Almost all participants answered the Likert item "I have good local knowledge in the Montreal city center." with "strongly disagree" (79%) or "disagree" (15%), while only one responded with "agree." A narrow minority of 45% reported having used bikesharing systems at some point before.

To test whether our treatment was successful, we evaluated the data on agreement with the Likert items listed in Table 1, where the strongest level of support corresponds to a value of 7. Table 2 shows the results of the five one-tailed Welch's t-tests. We find that the mean perception differs in all instances in the expected direction. These differences show to be highly significant for the items V2, V4, and V5, while the tests of V1 and V3 yield low but not significantly small p-values. Given the limited sample size and abstract language of these items, we take these results to confirm an overall successful treatment manipulation.

Item	H_A	$\mu(HC)$	$\mu(LC)$	Test Statistics	p-Value	Significant H_A Confirmation
V1: high visual clarity	$\mu(HC) < \mu(LC)$	5.0	5.3	-1.08 (df: 111)	0.14	**No**
V2: high visual consistency	$\mu(HC) < \mu(LC)$	5.4	5.9	-2.01 (df: 116)	0.02	**Yes**
V3: high visual density	$\mu(HC) > \mu(LC)$	5.4	5.1	1.13 (df: 117)	0.13	**No**
V4: confusing color scheme	$\mu(HC) > \mu(LC)$	4.5	3.2	3.99 (df: 111)	<0.0001	**Yes**
V5: visually too complex	$\mu(HC) > \mu(LC)$	4.4	2.1	7.90 (df: 83)	<0.0001	**Yes**

Table 2. Treatment Manipulation Check Results Using Welch's One-Tailed t-Tests on Likert-Scaled Items (1: "strongly disagree"; 7: "strongly agree")

Hypotheses Testing Results

To test hypothesis 1, we computed the entropies of the 40 cases grouped by treatment. In line with our reasoning above, the mean entropy in the LC treatment (mean: 0.819, sd: 0.212) is indeed smaller than in the HC (m: 0.908, sd: 0.131). A Levene test showed that the null hypothesis of equality of variances is to be rejected (p = 0.006). Thus, Welch's test must be used instead of the standard t-test for equality of means. The calculation of the one-tailed Welch's test with a t-statistic of -2.266 and 64.929 degrees of freedom resulted in a p-value of 0.013. Since this value is below the standard critical alpha of 0.05, the null hypothesis (The entropies of the LC treatment are not lower than in the HC treatment) must be rejected. Consequently, our **hypothesis 1 is supported**.

We investigate hypothesis 2 using a Wilcoxon rank-sum test. This test provides evidence only if the value distributions of both samples have similar ranges and shapes. Visual inspection of the distributions confirmed these premises. In line with our hypothesis, across all $|I|=119$ participants, the median rank for Q in the LC treatment group was 69.5, well above that of the HC group (52.5). The Wilcoxon rank-sum test confirmed the significance of this difference with a p-value of 0.017. Thus, **hypothesis 2 is supported**.

Contributions Discussion and IS Research Agenda

This study confirms the hypothesis that the visual complexity of map representations in mobility information systems increases the complexity of a choice situation, analogous to the task complexity described thoroughly in the literature. This complexity can be measured quantitatively as increased entropy and decreased consistency in choice behavior. Our starting point was the hypothesized relationship between task complexity, map complexity, and choice consistency as performance indicators for a visualization format in the context of using digital maps for low-stake decision-making. However, in this paper, we consider only three of the seven relationships listed in Figure 1. We hope that this study will stimulate interest in IS research for human interaction with digital maps and that further conceptual extensions will be explored alongside the relations not considered in this paper and their respective interactions. We may note that further development of the methodological foundations seems worthwhile. To our knowledge, no suitable multi-item construct measures exist yet for the latent variables perceived visual and cognitive DMC. In addition to perceived DMC, there are several measures for *objectively* assessing visual complexity, e.g., counting and calculating the number of graphic elements contained in maps (Fairbairn 2006; MacEachren 1982; Schnur et al. 2018). When considering (perceived) complexity metrically (instead of binary as in our case), it seems important to consider whether their relationship is indeed linear or whether the user's perception bends physical reality, as for example, in the relationship of sound pressure (decibels) to loudness (sone). Beyond a mere understanding of map task complexity, the question arises as to the resulting design principles, i.e., how map-based interfaces should be configured to reduce complexity. Quantitative approaches to maintain the intricacy of choice designs within a cognitively reasonable range (Chung et al. 2011; Danthurebandara et al. 2015) do not easily translate to map-induced visual complexity. At times, we can even identify potentially conflicting findings that call for further resolution in forthcoming studies: For example, high color contrasts in maps are considered to increase visual complexity (Touya et al. 2016), whereas in table-like representations of choice alternatives they are considered to decrease cognitive stress (Himmler et al. 2021; Jonker et al. 2019).

Similar to our investigated case of vehicle choice in a bikesharing system, many mobility behaviors can be viewed as a sequence of discrete decisions, from modal and provider choice to vehicle and tariff selection, to a decision between alternative travel routes. In transportation theory, there is an ongoing debate whether differences in the attributes of choice alternatives are perceptible up to certain thresholds and should be considered in such contexts (Obermeyer et al. 2015). However, even aside from potentially realizable efficiency benefits, IS research to date suggests that user interfaces should be designed so that a user does not perceive their level of intricacy as overwhelmingly complex (Tuch et al. 2012; Verkijika 2021; Wang et al. 2021). Our study shows that special attention is required in designing cartographic elements in real-world mobility IS by service providers to control over-complexity. Currently, we observe that map design decisions are taken differently by the various mobility providers, both in terms of the choice between the third-party map services that induce different levels of complexity (Schnur et al. 2018) but also in terms of graphical modifications (contrast ratio, detail level, corporate colors, graphical overlays). Following Robinson et al. (1995), potential interventions to enhance map perception and design that deserve evaluation include selecting intelligible color schemes, simplifying typography and lettering, or adjusting the overall map compilation. Future research may shed light on the individual importance of these interventions in digital contexts. To this end, a study using a functional app could extend the findings of this work to determine the role of unique features associated with digital maps compared to analog maps. While our study was able to integrate some key capabilities of digital maps compared to analog maps (situational content, location-centricity, relevance of map excerpts, convenience of retrievability, problem-oriented specification), other distinguishing features were neglected in the evaluation due to the experimental design with static graphics, such as interaction responsiveness, continous zoom, visual customization, and dynamic direction alignment.

In-vehicle map-based information systems raise a particular challenge, as driver distraction can pose a risk to road safety. Given that task intricacy is known to imply longer decision times (Dellaert et al. 2012), based on the parallelism of task and map complexity shown in our study, one may hypothesize that this holds true also in the case of visual cartographic intricacy. We hope that further research will also extend these findings beyond digitally-enabled mobility to other applications of electronic maps in low-impact ubiquitous decision-making. For example, this could include digital orientation maps of visitor facilities, such as those commonly used in shopping malls, theme parks, or airports. Likewise, video games feature various forms of digital maps, either as interactive tabletops, mini-maps for animated proximity information, or in the style of analog maps for pure spatial orientation.

Naturally, this study is also subject to certain limitations that constrain the generalizability of our findings. Using a student sample, we focused on a population whose demographics largely correspond to the main user group of bikesharing services (Buck et al. 2013). However, this may limit transferability to other groups (Compeau et al. 2012) since digital natives who grew up relying on electronic maps may be more comfortable and confident with them than earlier generations more attached to analog maps. In addition, Louviere et al. (2008, p. 361) cautioned that "differences in individuals, temporal and spatial factors, and other sources" may also influence choice variability. For example, Olsen et al. (2017) emphasized that decision consistency can also be time-of-day dependent. Of course, it is impossible to control for all conceivable factors, and apart from strictly random assignment to treatment groups, domain experts are needed to assess the extent to which our results can be generalized to divergent contexts.

Conclusion

While electronic maps have become ubiquitous, human perception and interaction with them have received very little attention in IS research. Particularly, their performance for informing low-stake choice situations has mainly been neglected. Our study aims to address this gap and open a discussion about digital maps as an essential feature of location-based applications in our domain. To this end, we propose a conceptual blend of two well-established complexity dichotomies from other disciplines: First, map complexity drawn from geography and GIS research; second, task complexity drawn from experimental behavioral science. We were able to confirm key hypotheses raised from linking these research streams with data from a stated-choice experiment: Increased visual complexity increases the entropy of a choice situation analogous to task intricacy. Moreover, such increased complexity decreases the informational performance of a digital map as measured using individual choice consistency. We thus provide some initial indication that findings in behavioral science concerning decision task complexity, in general, may be transferable to map-based mobility IS usage. These findings may substantiate ensuing research threads. For example, robustness in related and distant contexts needs to be further analyzed. Furthermore, robust IS design principles for in-app map designs must be established. We hope that this work may inspire various further research in those directions in our field.

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