Original article

Utilizing geospatial intelligence and user modeling to allow for a customized health awareness campaign during the pandemic: The case of COVID-19 in Saudi Arabia

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ABSTRACT

Background: As of 2022, people are getting better at learning how to coexist with the Covid-19 global pandemic. In Saudi Arabia, many attempts have been made to raise public health awareness. However, most health awareness campaigns are generic and might not influence the desired behavior among individuals.
Objectives: This study aims to apply geospatial intelligence and user modeling to profile the districts of the city of Jeddah. This customized map can provide a baseline for a customized health awareness campaign that targets the locals of each district individually based on the virus spread level.
Methodology: It is ongoing research, which has resulted in the creation of a health messages library in the first phase [1]. This paper focuses on a second phase of the research study, which aims to provide a customized baseline for this campaign by applying the geospatial artificial intelligence technique known as space-time cube (STC). STC was applied to create a local map of the Saudi city of Jeddah, representing three different profiles for the city's districts. The model is built using valid COVID-19 clinical data obtained from one of Jeddah's general hospitals.
Results and implications: When applied, STC displays three profiles for the districts of Jeddah city: high infection, moderate infection, and low infection. To assess the geo-intelligent map, a new instrument was created and validated. The usability and practicality of this map were quantitatively evaluated in a cross-sectional survey using the goal-question-metric measurement framework, and a total of 43 participants filled out the questionnaire. The results indicate that the geo-intelligent map is suitable for everyday use, as evidenced by the participants' responses. We argue that the developed instrument can also be used to assess any geo-intelligence map. This research provides a legitimate approach to customizing health awareness messages during pandemics.

1. Introduction

The ongoing global Covid-19 pandemic hit the world in 2020, bringing chaos to all life sectors and resulting in curfews, lockdowns, and social distancing rules being applied. Before the Covid-19 vaccines became available in early 2021, the major line of defense that governments, health authorities, and societies provided were health awareness programs regarding the virus, how it spread, and how to

protect individuals from getting infected. This type of awareness has been vital in lowering the infection rates and slowing the virus spread to allow medical staff to cope with the increasing numbers of Covid-19 patients, especially those with critical conditions requiring ICU care. Moreover, the idea was to ensure a large enough supply of essential medical equipment, such as ventilators. Today, after almost 65% of the world population has received at least one dose of a COVID-19 vaccine [2], health awareness campaigns are still critical in the fight against the virus. Many vulnerable individuals have been unable to receive the vaccine due to medical conditions, their age (e.g., young children), or where they live; for example, only 15.2% of people in low-income countries have received at least one dose [2].

Saudi Arabia has taken stringent measures to control the fierce, rapid spread of the COVID-19 virus. The Saudi Arabian Ministry of

Health (MOH) conducted an intensive awareness campaign, communicating via official traditional media channels and various social media channels to equip individuals with facts and precautionary measures. Moreover, MOH provided a geographic information system (GIS) dashboard [3] that features an interactive map showing COVID-19-related data on a national level (overall and by city). This particular dashboard is useful, as it focuses on each region and city; however, it does not go into further detail about specific areas within each city. The city's overall COVID-19 infection data might be sufficient for smaller towns and cities, where the population is around 100,000 or less, but it might prove to be insufficient in larger cities, such as Jeddah, which spreads over an area of 1600 km² and has a population of four million people [4].

This study aims to apply geospatial intelligence and user modeling to profile the districts of the city of Jeddah. This customized geo-intelligent map can provide a baseline for a customized health awareness campaign that targets the locals of each district individually based on the virus spread level. Jeddah has more than 83 districts spread across an area of 1600 km² [5]. Hence, creating a visualized local map of the city in which positive COVID-19 cases are represented, according to their districts and using data obtained from MOH providers, would assist in providing a two-fold solution: allowing people to know (1) if they have been around areas where active and positive cases have been recorded, and hence that they must take necessary steps to prevent being infected with COVID-19, and (2) that they must avoid visiting those areas if possible, based on the customized messages sent to residents of those districts.

The first phase of this study aimed to customize the messaging campaign based on the motivation and ability of individuals [1]. This research paper represents the second phase, which aims to add another layer of customization, which involves situational location-aware segments to separately target the local citizens of each district. This phase is driven by the data on confirmed COVID-19 cases and the sources of the infection on a district level that are analyzed using ArcMap [6]. In particular, this research seeks to address the following research questions:

- How can geospatial intelligence and user modeling techniques be combined to create a customized map that can provide a baseline for a customized health awareness campaign to target the locals of each district individually based on the virus spread level?
- What is the average level of user satisfaction and the practical implications of a geo-intelligence map?

2. Materials and methods

This section highlights the stages that this research study followed, as depicted in Fig. 1. More details are provided in the following four subsections.

2.1. Stage 1: The creation of the geo-intelligence map

The localized geospatial intelligence map is created following four steps. The four steps elaborate on the technical work of how geospatial artificial intelligence has been applied and combined with user modeling.
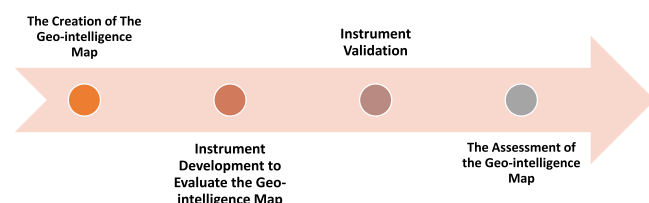

Fig. 1. Research Stages.

2.1.1. Step 1: Data collection

Data were collected from governmental (public) health providers in Jeddah. Official approval for the data collection was granted by the Saudi MOH authorities in Jeddah. MOHS gave the research team three specific general hospitals in the city to be accessed for the purpose of this research. All the team members had to obtain a certificate for good clinical practice prior to being granted access to the data. Despite communications and site visits to all three hospitals, only one hospital, King Fahad General Hospital (KFGH), fully collaborated and provided the requested clinical data for each patient. This data included age, gender, address, infection status, and the source of virus transmission. In total, 2750 records of individuals who had tested positive for COVID-19 between March 25 and June 25, 2020, were obtained from KFGH and collected. Although the data were provided, further preprocessing and manipulation were required before they could be inserted into the GIS application, as explained in the next section, Step 2.

2.1.2. Step 2: Data preparation

The data provided by health authorities required preprocessing and manipulation before being inserted into the GIS application (ArcGIS). For example, some clinical data were split between two different files; one contained the patients' personal information, while the other held their district addresses. Hence, some records had to be manually matched using the patients' record IDs. After the matching process was performed and any records with missing or incomplete data were eliminated, a total of 477 medical records were available for this research.

2.1.3. Step 3: Creating a local GIS map of COVID-19 for Jeddah by district

The dataset was processed and analyzed using an ArcGIS application [7]. The data were inserted into ArcGIS to create a local map of Jeddah districts showing the confirmed cases of COVID-19. Most of the raw source data files were missing the patients' spatial and address information. Hence, the raw data had to be manually geocoded using the city and district name, using the ArcGIS world geocoding process. The total number of geocoded cases used in the analysis was 69.

Using the space-time cube (STC) technique enables the visualization of spatial-temporal data in 2D or 3D, analyses the distribution of the data, and examines temporal patterns in the context of space and time. Each bin on the map represents a collection of events at a specific time for a specific location. The lowest bin is the oldest, and the highest bin is the latest event that represents a time series. The horizontal slicing of the cube represents the time slicing of the condition of all the events in that period. In the context of Covid-19 cases, the lowest bins represent the earliest positive cases found, while the highest bins represent the most up-to-date positive cases confirmed. This analysis can be used as a real-time analysis.

The statistical significance of the events were learned from the STC using an analysis technique known as emerging hot spot (EHS) analysis. EHS uses vectors to identify locations of statistically significant hot spots and cold spots in the data by aggregating points of occurrence or converging points that are in proximity to one another based on a calculated distance. The analysis groups indicate when similar high (hot) or low (cold) values are found in a cluster. EHS analysis has been widely used in spatial epidemiology to target audience-specific segments [7]. In this research, EHS analysis was utilized to target specific geolocation areas with high infection rates. With data about COVID-19-positive patients alongside the districts in which they reside, the map of Jeddah (Fig. 2) shows which district had the highest number of recorded infected cases, and residents could hence be alerted about how "close" they were to an infected area. For example, the *Al-Jameaah* district had the highest case number with a total of 10 cases, followed by the *Madaan Al-Fahad* district with 7 cases from June 18 until June 30.
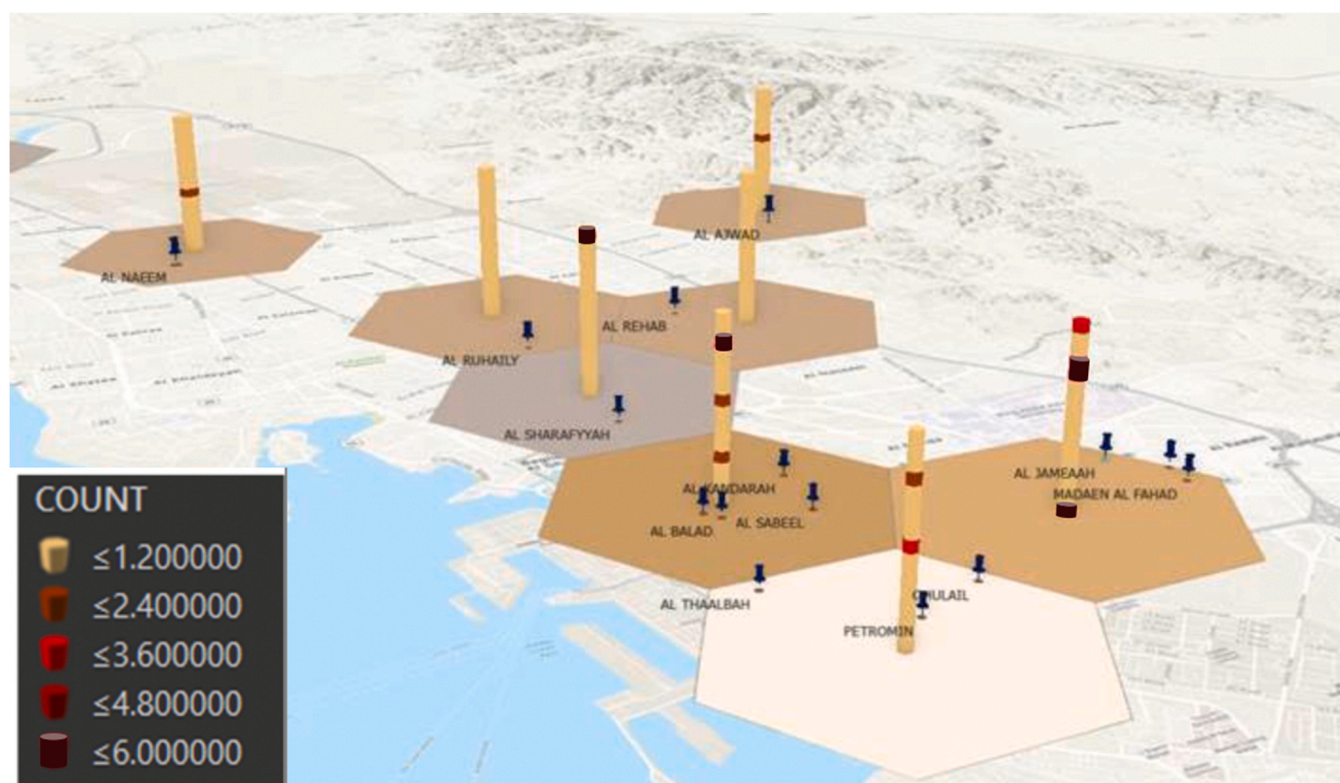
Fig. 2. Space-Time Cube of COVID-19 Patients – City of Jeddah, SA.

In Jeddah city's neighborhoods, the numbers of cases were compared to those in the neighboring districts. The darker cube represents more activity on a particular day. In this study, STC was created by aggregating COVID-19 cases within a 5-KM radius. Each pin in Fig. 2 is an aggregated case for a single day. The pins are rendered from the oldest to the newest time series data. The COVID-19 case trend can be visualized from the bin color ranges, as shown in the legend for Fig. 1. The patients' demographic information, including age, gender, district, and the spatial distribution for each pin for a day or range of days, will be used for the awareness campaign that will be explained in Step 4.

2.1.4. Step 4: User (district) modeling

To create the customized awareness campaign, a user modeling process was needed. In this research, user modeling was performed to give individuals a meaningful and customized message about the status of the corona virus pandemic in their districts. In this process, each district, or group of districts that share similar characteristics, needs to be modeled and given a unique user profile. The districts were divided into three main levels (profiles) in terms of how they were affected by the pandemic: high (red), medium (orange), and low (green). The levels that resulted from the performed analysis using STC can be seen in Fig. 3. The red color indicates a high case number (>=5), the orange color indicates a moderate case number (3−4), and the green color indicates a very low case number (<=2).

2.2. Stage 2: Instrument development to evaluate the geo-intelligence map

While searching the literature and based on our knowledge, no validated instrument was available that could be used to assess the developed geo-intelligent map in terms of users' satisfaction and practical implications. Thus, the geo-intelligence map elaborated in the previous subsection was evaluated using the goal question

metric (GQM) approach [8]. GQM is a measurement framework that assists in identifying the objectives of the measurement process. It answers "how" and "where" improvements must occur [9].

To use GQM for the evaluation, two main goals were identified: satisfaction and practical implications. Subsequently, two main questions were defined under each goal to characterize a measurement object, with a focus on quality issues. This was done to determine the map's quality from a selected viewpoint, that is, from the vantage of public health authorities and decision makers. Finally, some metrics were specified for each question.

Han and his colleagues defined user satisfaction as "the users' subjective feeling toward a product" [22] (p.16). Since the intervention in this research was a simple map, the focus was on the map's layout and its overall presentation. Next, metrics based on the map's items/contents were identified. For example, legends were important components of the map. Therefore, the first metric is to ask, "To what extent map are the legends readable?" In addition, the map quality was an important metric; thus, the second question was related to it. Establishing the practical implications was another important goal in evaluating the map. The practical implications would be defined as the end results that occur in specific situations [23]; in this research, this involved visualizing the district profiling of the COVID-19 status on a map based on the cases and geolocation. Thus, measuring the practical implications from the perspective of public health authorities and decision makers was essential. Two questions were defined; the first question focused on map usability and the second involved regular map usage. These two questions were important since it was assumed that public health authorities and decision makers would regularly use the map to make decisions, such as whether to lock down a certain district or when to start quarantine depending on the red profiling status in most districts. Eventually, two goals were identified and four main questions were generated, which led us to create a total of 10 items (questions). These items represent the initial instrument. In total, 10 metrics
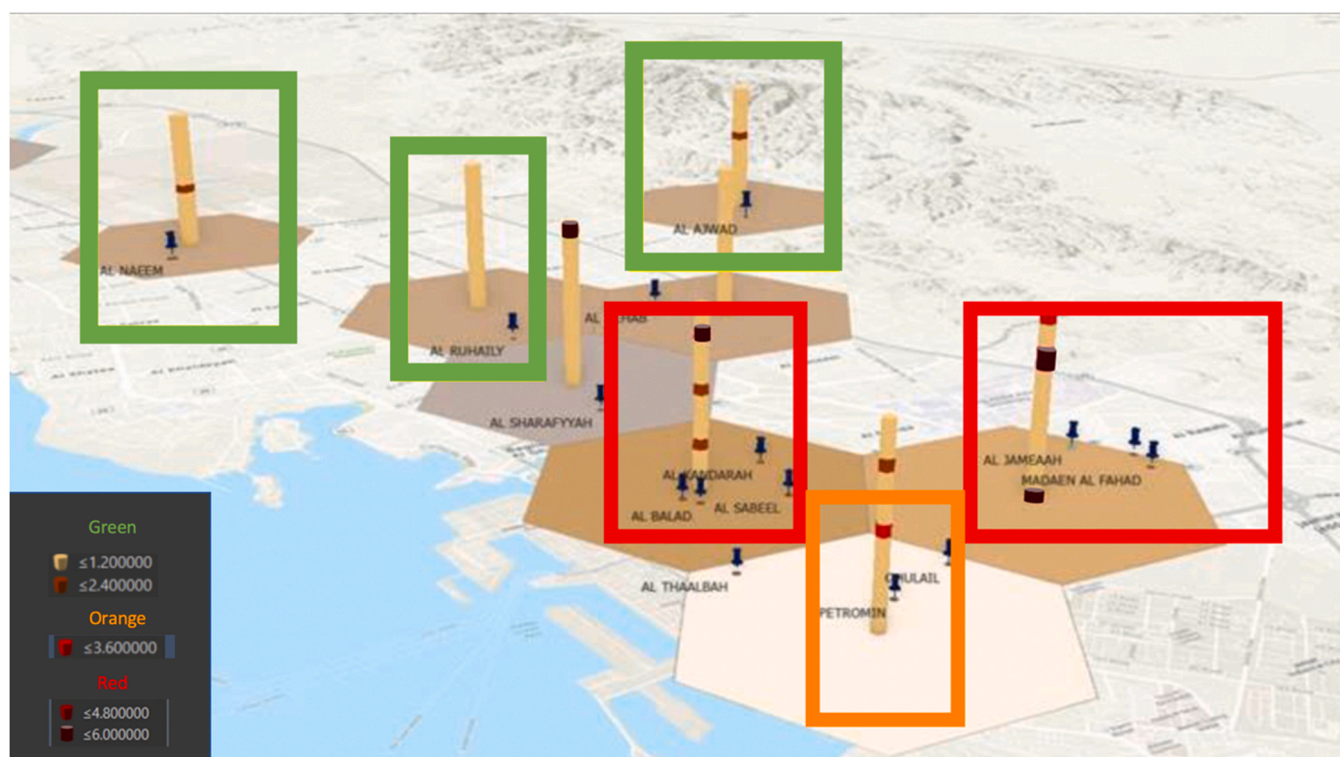
Fig. 3. User Modeling Based on the District.

were identified from the two defined goals. To collect the quantitative data, the following 5-point Likert scale was used: extremely (5), very (4), moderately (3), slightly (2), and not at all (1). The higher the degree, the better the visual map quality was. This developed instrument is validated first, and more details are provided in the next section(s).

2.3. Stage 3: Instrument validation

At this point, the validation of the new instrument was essential. Thus, content and face validity tests were conducted, followed by exploratory factor analysis (EFA), to evaluate the instrument elaborated in stage 2.

Content validity refers to each item that evaluates the exact domain of the content [10]. Three experts from the field of public health and information systems were involved. The original draft of a document explaining the measure was created using Google Forms and sent to an expert via email. **Then, face validity** was primarily measured by six experts from the public health field to ensure that it assessed the "concept it purports to measure" (p. 542) [11]. Usually, during this phase, the validation must be conducted by the targeted audiences, who complete a questionnaire during the assessment [11]. In this case, a document explaining this measure was also sent to the targeted experts by email and was built using Google Forms. Finally, **EFA** was used to identify the construct validity of the developed measure. A survey was sent to 80 participants following convenience sampling via email and a social media channel (What's Up). A gentle reminder was sent every three days.

Statistical analysis was performed using R version 3.6.3. Counts and percentages were used to summarize the distribution of categorical variables. Mean ± standard deviation was used to summarize the distribution of continuous normal variables, and the median/interquartile range [IQR] was used for continuous non-normal variables. Cronbach's alpha was used to assess the reliability of the

questionnaire scale(s). Values greater than 0.7 indicated good reliability and inter-item correlation [12].

EFA with Promax rotation was performed using a sample of 40 responses to assess the underlying factor structure of the 10 items related to the satisfaction and practical implications of the geo-intelligent map. According to Kline (2011), the required sample size for EFA is from two to five participants per item. The number of items in this study was 10, so an estimated sample size of 40 was adequate. Maximum likelihood was used to estimate the parameters [13]. The Kaiser–Meyer–Olkin (KMO) test was used to assess the suitability of the data for EFA with 0.5 as the minimum acceptable value [14]. The KMO test measures the sampling adequacy for each variable in the model and the full model. The KMO statistic measures the percentage of variance among the variables that can be attributed to the common variance [14]. EFA assumes some correlation between the included items. Factor loadings > 0.3 indicate that a satisfaction proportion of the variance in the item is explained by the underlying factor [14]. However, lower values were accepted as long as the item did not load on more than one factor due to the small sample size [15]. The proportion of the variance explained by the two factors was also assessed. Values greater than 50% were deemed acceptable.

2.4. Stage 4: The assessment of the geo-intelligence map

2.4.1. Procedure

A survey that measures participants' satisfaction and the map's practical implications (Appendix A) was sent to another 60 participants following convenience sampling and using two recruitment channels (email and What's Up). Although much larger sample size may be needed for validity studies, a survey of previously published quantitative studies shows that 59% of the sample sizes were less than 100 [16].

The survey was created using Google Forms, with attachments of two geospatial maps and a brief statement explaining the purpose of the survey. In addition to the 10 validated questions, more open-

Table 1
Responses to Likert Scale Items Related to Geospatial Map.

	Extremely	Moderately	Slightly	Not at all
To what extent are the map legends readable?	10 (25.00%)	16 (40.00%)	10 (25.00%)	4 (10.00%)
To what extent are the district names Readable?	9 (22.50%)	20 (50.00%)	8 (20.00%)	3 (7.50%)
To what extent do you think the traffic light color codes used in the map are understandable?	25 (62.50%)	10 (25.00%)	4 (10.00%)	1 (2.50%)
To which degree did you like the map presentation?	12 (30.00%)	16 (40.00%)	10 (25.00%)	2 (5.00%)
To which degree do you like the quality of the map overall?	12 (30.00%)	20 (50.00%)	5 (12.50%)	3 (7.50%)
To which degree would you recommend others to use this map?	15 (37.50%)	15 (37.50%)	7 (17.50%)	3 (7.50%)
If you were to use this map daily to check the COVID-19 statues in certain districts in Jeddah city, to which degree would you find it acceptable?	18 (45.00%)	13 (32.50%)	5 (12.50%)	4 (10.00%)
To which degree would you continue to reuse the map considering that the map data on the status of Covid-19 cases is updated on a daily basis?	19 (47.50%)	11 (27.50%)	6 (15.00%)	4 (10.00%)
To what extent does the map help in tracking the disease spread?	23 (57.50%)	8 (20.00%)	6 (15.00%)	3 (7.50%)
To what extent does the map help health authorities/decision makers in making informed decisions (e.g., lockdown quarantines) within the city?	21 (52.50%)	14 (35.00%)	3 (7.50%)	2 (5.00%)

ended questions focused on participants' opinions regarding the map in general were included. A reminder was sent every other day.

2.5. Analysis

Statistical analysis was performed using R v 3.6.3. Counts and percentages were used to summarize the distribution of the categorical variables. Mean ± standard deviation was used to summarize the distribution of the continuous normal variables, and the median/ interquartile range [IQR] was used for the continuous non-normal variables.

3. Results

3.1. Instrument validation results

Some improvements were made based on the experts' feedback during the content and face validity phases. In the EFA phase, the questionnaire was completed by 40 respondents. Males and females represented 15% and 74.7% of the included respondents, respectively. The respondents aged 25–39 years represented approximately one-third of the study sample (35%), and respondents aged 40–59 represented almost half of the sample (42.5%). Researchers represented one-third of the respondents (32.5%), and physicians represented 12.5%. Public health practitioners and dentists represented 12.5% each.

The answers indicated a positive attitude toward the geo-intelligent map. The percentage of users who responded "extremely" ranged from 47% to 67.5%. The district names and map legends were extremely readable by 22.5% and 25% of the participants. A detailed summary of the responses is shown in Table 1. Regarding map presentation, 30% of the participants said they liked the map presentation "extremely" and 40% said they like it "moderately."

Fig. 4 shows that 65–90% of the respondents chose either "extremely" or "moderately."

The results from EFA indicated that the two factors explained 62% of the variance in the 10 items, which was considered adequate (see Table 2).

The KMO statistic was 0.894, greater than the prespecified lower bound that indicated good data adequacy for factor analysis **(see Table 3)**.

Two factors were identified using factor analysis with Promax rotation **(see Table 4)**. Factor 1 included five items related to the map's practical implications: understandability of traffic light color codes, acceptability of the map for everyday use, continuous reuse of the map to get daily updates regarding Covid-19 status, the usability of the map in tracking the disease, and the extent of help provided by the map to make informed decisions. Factor 2 included five items related to map users' satisfaction: readability of map legends, district names, map presentation, quality of the map, and the likelihood of recommending the map to others. As assessed by Cronbach's alpha, the reliability of the two scales was > 0.7, which was considered acceptable. All the loadings were greater than 0.5, and none of the items loaded on more than one factor. Thus, none of the items was removed, and all 10 Likert scale items were included in the final factor structure. More than half the respondents (53%, n = 44) mentioned that the format was good, and almost 90% (n = 77) mentioned that the aim of the questionnaire was clear. One respondent suggested that the project title needed to be translated to Arabic to give the respondents a clearer understanding of the research. Nearly all the respondents mentioned that the questionnaire was clear (> 90%).

Numbers represent factor loadings. Items that belong to each factor are colored in gray.A light gray font shows low loadings.

The results suggest that the geo-intelligent map is suitable for everyday use, as evidenced by the responses to items. The percentage of respondents who responded with "extremely" ranged from 33% to 59%, while the percentage of those who responded with "extremely" or moderately" was ~90% for all the questions. The readability of the district names and the legends had the lowest scores across all 10 items related to the geo-intelligent map. EFA also showed that the used items loaded onto two factors with no need for item omission. Moreover, most of the respondents (95%) did not have issues with time completing the questionnaire. Thus, the proposed factor structure can be used to assess the proposed geo-intelligent maps.

3.2. The geo-intelligent maps assessment results

The sample included 43 participants (17 of them dropped out of the study due to lack of time). Of these, 65.1% (n = 28) were males and 34.9% (n = 15) were females. Respondents aged 24 years represented 6.98% of the study sample, and respondents aged 25–39 years represented 39.5%. Over half the respondents were aged 40–59 years (51.2%), and only one respondent was aged 60 + years. Researchers represented approximately one-third of the respondents (44.2%), and physicians represented 14%. Public health practitioners and dentists represented 9.3% each.
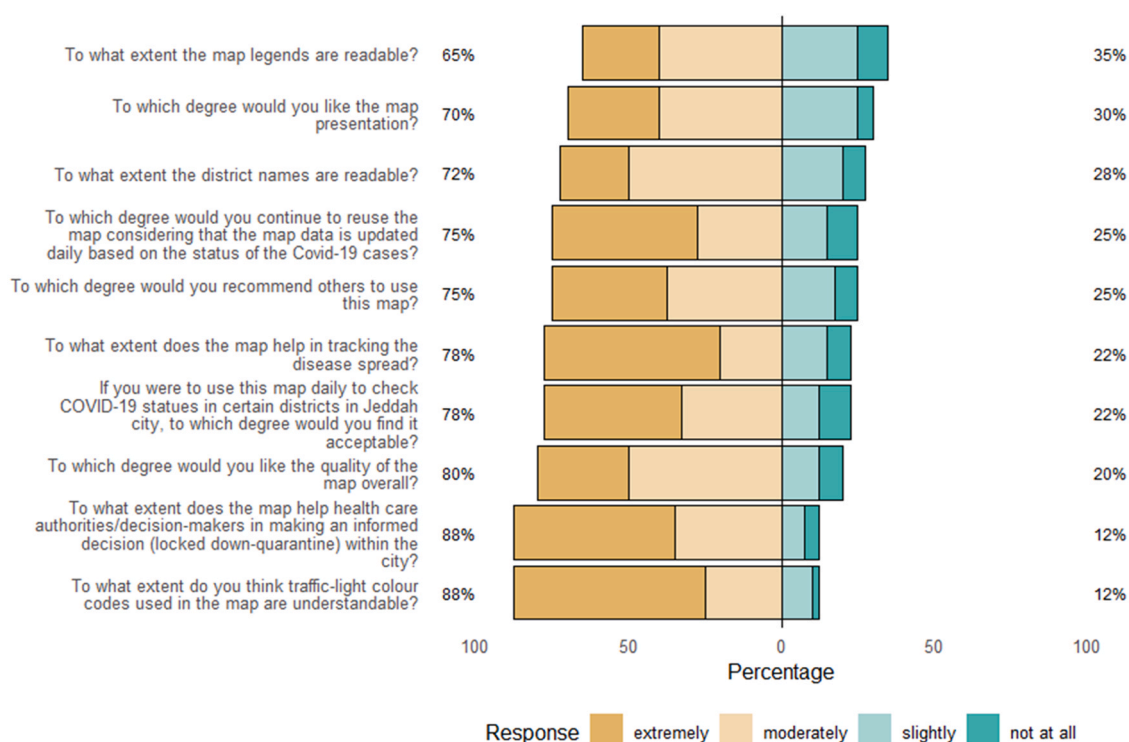
Fig. 4. Participants' Responses to Items, Note: The number on the left represents the percentage of participants who responded with "extremely" and "moderately," and the number on the right represents the percentage of participants who responded with "slightly" and "not at all.".

Fig. 5 shows that approximately all the participants (~100%) responded with "extremely" and "moderately." All the patients found the map legends "extremely" and "moderately" readable, and all of them "extremely" and "moderately" liked the map presentation. Nearly all the patients (93%) found the district names extremely and moderately readable, and 98% thought they were moderately and extremely likely to continue using the map if it were updated on a daily basis.

The answers indicated a positive attitude toward the geo-intelligent map. The percentage of users who responded with "extremely" ranged from 41.8% to 72%. A detailed summary of responses is shown in Table 5. Regarding map presentation, two-quarters of the respondents (62.8%) said they "extremely" liked the map presentation. Regarding district names and map legends, 41.9% found the district names extremely readable, and 44.2% found the map legends extremely legible.

More than 90% of the respondents thought that the length of the questionnaire was about right. The majority of the respondents

Table 3
KMO and Bartlett's Test for sampling adequacy.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.833
Bartlett's Test of Sphericity	Approx. Chi-Square	315.531
	df	45
	Sig.	< 0.001

(> 90%) thought the questionnaire's aim was clear. Moreover, the majority believed that the questionnaire format was good and that the questionnaire was clear and well structured. Nearly all the respondents mentioned that the questionnaire was clear (> 90%).

4. Discussion

The Saudi MOH has utilized information technology systems, tools, and applications to a good extent during the COVID-19

Table 2
Total Variance Explained by the Resulting Factors.

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.905	59.053	59.053	5.552	55.516	55.516
2	1.129	11.286	70.339	0.699	6.992	62.508
3	0.775	7.747	78.086			
4	0.543	5.430	83.516			
5	0.411	4.107	87.623			
6	0.402	4.017	91.640			
7	0.284	2.845	94.485			
8	0.216	2.156	96.641			
9	0.192	1.923	98.564			
10	0.144	1.436	100.000			

Extraction Method: Maximum Likelihood.
a. When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

Table 4
Factor Analysis of the Geospatial Map Questionnaire.

	Practical implication	Satisfaction
To what extent are the map legends readable?	0	0.58
To what extent are the district names readable?	0.02	0.59
To what extent do you think the traffic light color codes used in the map are understandable?	0.54	0.04
To which degree did you like the map presentation?	0.18	0.7
To which degree did you like the quality of the map overall?	0	0.9
To which degree would you recommend others to use this map?	0.41	0.56
If you were to use this map daily to check the COVID-19 status in certain districts in Jeddah city, to which degree would you find it acceptable?	0.78	0.14
To which degree would you continue to reuse the map considering that the map data on the status of Covid-19 cases is updated on a daily basis?	0.9	–0.23
To what extent does the map help in tracking the disease spread?	0.78	0.11
To what extent does the map help health care authorities/decision makers make an informed decision (e.g., lockdown quarantines) within the city?	0.67	0.19
Cronbach's α	*0.91*	*0.89*

Numbers represent factor loadings. Items that belong to each factor are colored in gray.A light gray font shows low loadings.

pandemic, including the use of GIS maps and location-based services (LBS) via mobile applications and mobile text messages, among other applications. Effective awareness campaigns, including the provision of relevant information from reliable sources, can improve people's knowledge and must be effective in developing positive attitudes among the public toward adopting preventive measures. Reliable information is vital for designing and implementing preventive measures and promoting health awareness in the fight against COVID-19 [17]. Mheidly and Fares urged the informatics researchers community to develop novel health communication strategies [18]. This research is one attempt at achieving such a goal, where we have leveraged geo-spatial intelligence and user modeling to profile the districts of a city. This customized map can provide a baseline for a customized campaign fight against Covid-19.

This research addresses two main research questions. The first involved how to combine geospatial intelligence and user modeling techniques to create a customized map that can provide a baseline for a customized health awareness campaign that targets the locals of each district individually based on the virous spread level? After obtaining clinical data about confirmed COVID-19 cases in Jeddah from one of its general hospitals, the data were aggregated using STC analysis in a local city map. Individuals are most likely to apply the health tips given in an awareness message when the message is equipped with more contextual information about where the individual lives. This research utilized a geospatial artificial intelligence technique, the space-time cube (STC), to create a local map that goes one level beyond the national GIS dashboard map provided by MOH. The map created here shows overall national data and data regarding COVID-19-positive cases in each city. It uses health data from the highly populated city of Jeddah to increase residents' awareness by creating a customized message focusing on the district in which people reside. This research approach toward building a customized health campaign should provide individuals in this city with a better understanding and awareness of their approximate exposure to the virus without jeopardizing their privacy. This approach is less invasive than mobile tracking applications, which some individuals might hesitate to install and use due to privacy concerns [19]. Moreover, from a governmental perspective (both national and global), this highly localized map should allow more targeted/tailored messages to be sent to the public as part of an effective awareness campaign.

The second research question in this study involved the average level of user satisfaction and the geo-intelligent map's practical implications. The results obtained from the survey suggest that the geo-intelligent map is suitable for daily use. Most of the responses (~90%) from the geo-intelligent map assessment stage were
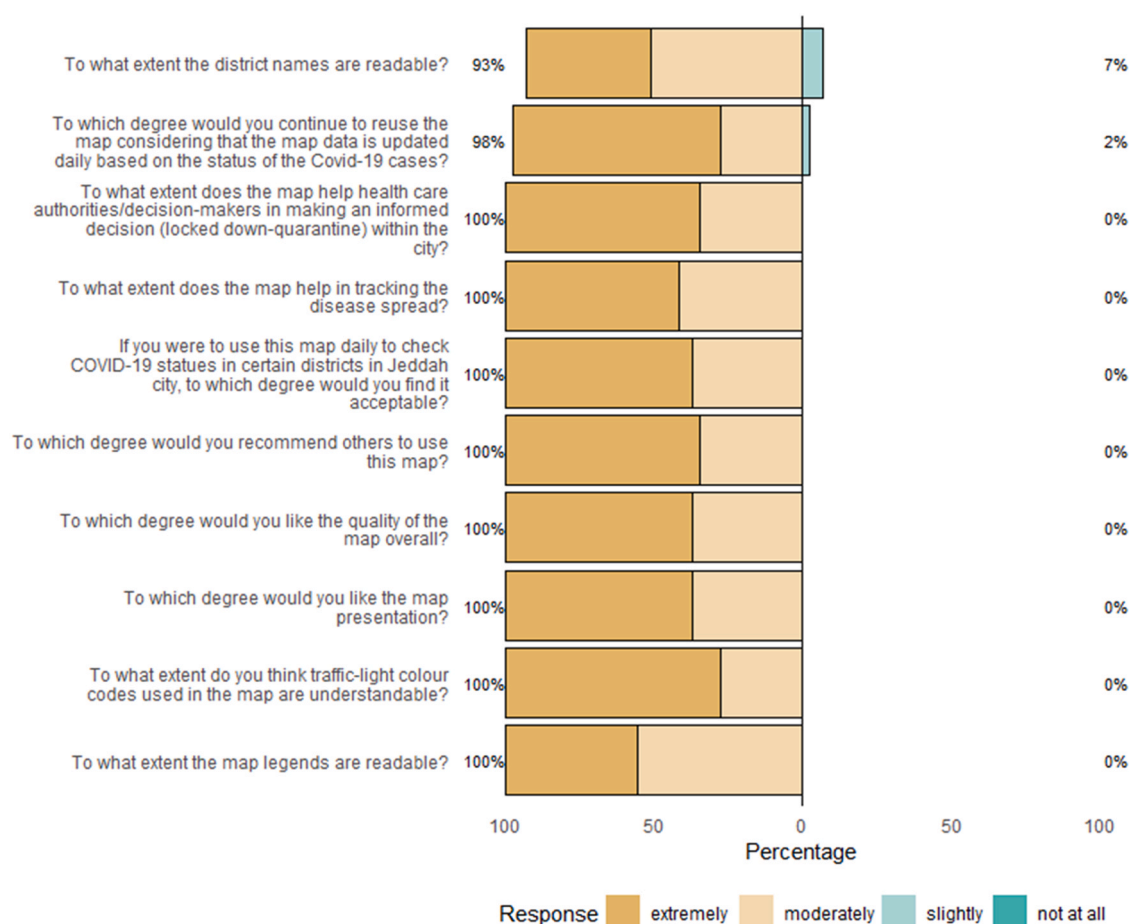
Fig. 5. Participants' Responses to Items, Note: The number on the left represents the percentage of participants who responded with "extremely" and "moderately," and the number on the right represents the percentage of participants who responded with "slightly" and "not at all.".

Table 5
Participants' Responses to the Developed Map.

	Extremely	Moderately	Slightly	Not at all
To what extent are the map legends readable?	19 (44.19%)	24 (55.81%)	0 (0.00%)	0 (0.00%)
To what extent are the district names readable?	18 (41.86%)	22 (51.16%)	3 (6.98%)	0 (0.00%)
To what extent do you think the traffic light color codes used in the map are understandable?	31 (72.09%)	12 (27.91%)	0 (0.00%)	0 (0.00%)
To which degree did you like the map presentation?	27 (62.79%)	16 (37.21%)	0 (0.00%)	0 (0.00%)
To which degree did you like the quality of the map overall?	27 (62.79%)	16 (37.21%)	0 (0.00%)	0 (0.00%)
To which degree would you recommend others to use this map?	28 (65.12%)	15 (34.88%)	0 (0.00%)	0 (0.00%)
If you were to use this map daily to check the COVID-19 status in certain districts in Jeddah city, to which degree would you find it acceptable?	27 (62.79%)	16 (37.21%)	0 (0.00%)	0 (0.00%)
To which degree would you continue to reuse the map considering that the map data on the status of Covid-19 cases is updated on a daily basis?	30 (69.77%)	12 (27.91%)	1 (2.33%)	0 (0.00%)
To what extent does the map help in tracking the disease spread?	25 (58.14%)	18 (41.86%)	0 (0.00%)	0 (0.00%)
To what extent does the map help health authorities/decision makers in making informed decisions (e.g., lockdown quarantines) within the city?	28 (65.12%)	15 (34.88%)	0 (0.00%)	0 (0.00%)

"extremely" or "moderately" positive for all the items. This indicated that the users of the geo-intelligent map are satisfied and have seen the practical implications of the map.

Mainly, this study contributes to the research in this field in two ways. The first contribution is to society, where the developed geo-

intelligent map can be combined to use in any customized health awareness campaign to combat any future/similar pandemic. Having a clear approach to developing a customized messaging health awareness campaign that can be followed by others is essential. This research provides a proof of concept in terms of how to create a
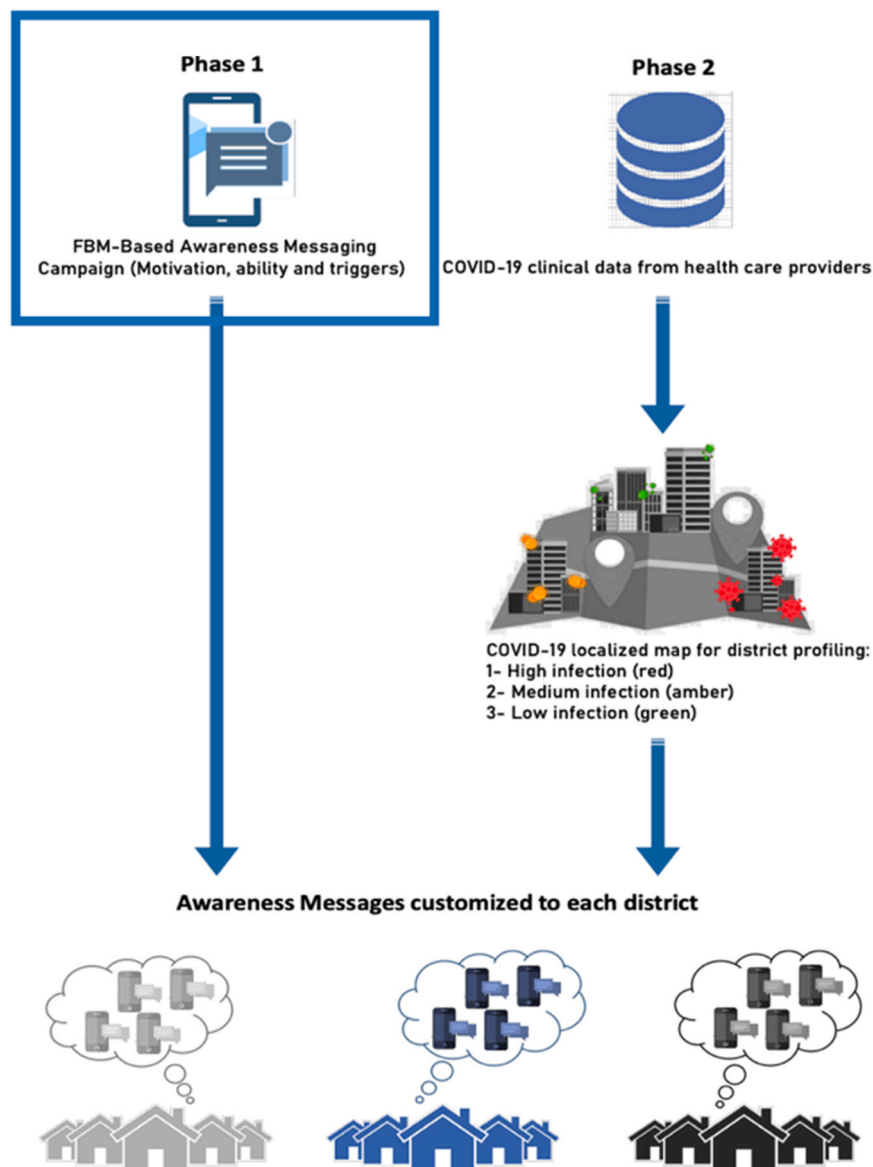
Fig. 6. The Two Main Phases of the Customized Awareness Messaging Campaign.

customized awareness health campaign during a pandemic, in this case involving Covid-19 (2020–2022), by creating a map based on the geospatial intelligence technique. The next phase will involve combining the messages created in phase 1 of this project [1] with the visualized map from the second phase (as described in this paper) to send actual messages to users in infected districts and measure the impact of these customized messages. The combination of the two phases can be visualized in Fig. 6. The second contribution is to the body of current knowledge, as a new instrument was developed and validated using content, face, and EFA validity to measure the satisfaction and the practical implications of a customized geo-intelligent map.

5. Conclusions

The research presented in this paper aims to develop and evaluate a customized health awareness campaign to promote precautionary behavior during COVID-19 in Saudi Arabia. Its goal is to support government policymaking and effective evaluations of pandemic prevention and control during the outbreak of COVID-19.

It indicates that the combination of geospatial intelligence and user modeling techniques to create a customized visualized accessible map could play an important role in preventing and controlling health pandemics.

One of the main limitations of this research was getting access to data sets from the hospitals in Jeddah. Despite obtaining permission from the Saudi MOH, the procedure to access data from multiple hospitals was complicated and varied from one system to another. Moreover, patients' privacy issues and COVID-19 restrictions and social distancing measures added additional layers of complexity. In addition, the records obtained from the only cooperating hospital were missing some crucial locational data. Another limitation is the small sample size in the geo-intelligent maps assessment stage. Increasing the sample size would be beneficial to be considered in the future, to increase the validity and generalizability.

The research presented in this paper provides a proof of concept in terms of how to create a customized awareness health campaign during a pandemic through creating a visualized customized map based on the geospatial intelligence technique.

Funding

Conflicts of Interest

No conflict of interest.

Appendix A

Goal 1: Satisfaction.

Question. (Q1): Do users like the map layout?

a. Q1. M1: To what extent map are legends readable?
b. Q1. M2: To what extent are district names readable?
c. Q1. M3: To what extent do you like the traffic light color codes used in the map (red-amber-green)? Are they understandable, given that red indicates highly infected areas while green is the least infected area.
d. Q1. M4: To which degree did you like the map presentation?

Question. (Q2): Are users generally satisfied with the map?

a. Q2. M2: To which degree did you like the quality of the map overall?
b. Q2. M3: To which degree would you recommend others to use this map?

2. Goal 2: Practical implications.

Question. (Q1): Is the map practically usable?

a. Q1.M1: If you were to use this map daily to check the COVID-19 status in certain districts in Jeddah city, to which degree would you find it acceptable?
b. Q1.M2: To which degree would you continue to reuse the map considering that the map data is updated daily based on the status of Covid-19 cases?

II. Question (Q2): Is the map practical to use on a regular basis?

a. Q2.M1: Does the map help in tracking the disease spread?
b. Q2.M2: Does the map help health care authorities/decision makers in making informed decisions (e.g., lockdown quarantines) within the city?

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