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Abstract. Spatial environments have been largely studied over time, under different perspectives. Under a cognitivist perspective, they represent knowledge-intensive, meaningful spaces and entities that human agents relate to and adapt during their existence.

The comprehension/identification of space fundamentals by human agents can be of great interest in strategic planning, in that they may represent structures, pillars, invariant, resilient characters of the environment, on which to build/plan the layout and development of regions and towns.

Our work focuses on the potentials and problems of orientation and spatial knowledge in endogenous and exogenous agents in spaces with reduced - in particular extremely reduced - population, using a case-study experimental approach.

In particular, we are interested in the essential information for orientation in navigation and for the identification of the resources necessary to guarantee operative systems of relationship between agents and between agents and spaces. AQ1

Keywords: Knowledge management · Collective spatial cognition · Open space · Spatial variables · Environmental planning

1 Introduction

Under a cognitivist perspective, spatial environments represent knowledge-intensive, meaningful spaces and entities that human agents relate to and adapt during their existence [1]. They are intrinsically based on dynamic complexity, therefore trying to understand the typical spatial behaviours of a human agent is often hard task, inducing planning as well as managing problems in many domains [2]. Particularly experimental literature often shows that not always there is clear distinction between space 'fundamentals' and space ancillary, ornamental qualities in spatial analysis [3, 4].

The comprehension/identification of space fundamentals by human agents can be of great interest in strategic planning, in that they may represent structures, pillars,

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invariant, resilient characters of the environment, on which to build/plan the layout and development of regions and towns. The research on the spatial knowledge forms of living agents is today in progressive development, in environments of automatic computation of psychology or engineering [5]. Research on forms of spatial knowledge at the macro-scale is still limited [1, 6]. This work focuses on the potentials and problems of orientation and spatial knowledge in endogenous and exogenous agents in spaces with reduced - in particular extremely reduced - population.

The ways of progressive identification and enrichment of information during navigation in this type of space is analyzed here. In particular, we are interested in the essential information for orientation in navigation and for the identification of the resources necessary to guarantee operative systems of relationship between agents and between agents and spaces.

In this research framework, the paper is then organized as follows. A digression on the research background on spatial cognition issues follows the introduction and is carried out in chapter two. The third chapter briefly deals with the main characters of the research project where the present study is structured. Chapter four shows the experimental case study carried out here, with essential, describing methodology and discussing the results of the developed analysis. Brief concluding remarks are reported in the end, dealing with achievements, suggestions and possible follow-ups.

2 Spatial Cognition Research Background

Cybernetic and artificial intelligence studies include large reasoning about spatial cognition features, as they are important for operational planning. Rather interestingly, they put town a basic distinction between structured and unstructured spaces. Fundamentally, it parallels a similar distinction between spaces geometrically simple (elementary profiles, few unexpected events, few secondary items, few decisions required) and spaces geometrically complex (composite profiles, recurrent unexpected events, many secondary items and many decisions required) [7–9]. It is easy to understand that a robot develops movements and learns surrounding spaces more straightforwardly in simple geometries, so determining more identifiable cognitive situations. This seems rather clear, although robot agents can typify great part of reality and are able to move also in unstructured world-like human agents.

Human agents show a different situation. A reasonably recognizable space is for us geometrically simple, empty, maybe unidirectional space. This is represented, for example, by an interior corridor, long and empty, with a series of doors, windows, skylights. It consists of a point of origin and an end point, with no lateral intersections. This space could be assimilated to the arc of a graph, it is certainly simple and can be walked by the human agent with little attention.

Yet the human agent considers complex a very crowded space, with a multi-dimensional geometry that is difficult to recognize. This is, for example, an open space, like a rural area or a city fair, with an unclear form, origin, endpoint, thus demanding specific attention. A human walks casually through it, with the frequent risk of colliding with the imprecise trajectories of people, or getting lost, or losing her/his friend or child who still does not know how to move in a complex space. Such complex spaces may suggest human agents a preliminary action of memorization of characteristic landmarks with the aim of replace an incomprehensible "structure" or "geometry" [10–12].

Goodman [3] argued on a distinction between 'structure' and 'ornament', in human perceptions of complex spaces. The representation space is increasingly considered as a multiform issue, complex and intrinsically non-reducible. It also changes with time, but with features that are not always so obvious as traditionally expected [13, 14].

Such situation is even more complex, if possible, when dealing with the potentials and problems of orientation and spatial knowledge in endogenous and exogenous agents in spaces with reduced - in particular extremely reduced - population.

It is a question of identifying and experimentally analyzing variables and systems of latent variables in spaces with reduced (or non-existent) information content on the anthropic levels of spatial structuring.

It is a matter of laying the foundations - also through experimentation on human agents - of the modelling of functional (operational) cognitive systems that are suitable for these spaces.

As a general consideration, these are cognitively poorly structured spaces. However, we assume the research hypothesis that a good cognitive structuring of such large spaces of nature, hostile to itself to the intensive population, is possible when the essential (ontological) latent variables are identified. These variables are therefore investigated, which are considered quite similar to those of high-population spaces with a high degree of randomness of interactions and transformations.

From reasoning on the available literature, the work aims to analyze some experiential narratives focusing on the themes of the cognitive characterization of rural paths. In particular, the results of experiments conducted with students of the engineering school of the Polytechnic of Bari are analyzed in a modelling perspective.

A general research objective of the experimentation is to investigate the fundamental characteristics of the open space through spatial cognition by agents who navigate within open spaces themselves. Relevant data are analyzed in order to draw correlations between elements present in protocols collected by ad-hoc experimentation.

A more specific objective of the present paper is to analyze the possible dependence of spatial sensations and perceptions from the other physical and relational elements that characterize the rural open space.

3 The Case Study

Las year, an experimentation campaign was carried out with 180 students of the 2nd year of the master's degree in Building Systems, Urban Planning course. Each agent had to choose and travel a route in an open rural space, photographing elements that s/he considered to be of interest and recording sensations, perceptions and/or emotions along the way. The track, the places of interest and the notes were recorded and georeferenced through smartphone apps and personal and residential details were reported on an online repository.

The present analysis was carried out on a reduced sample of 16 observations. This is a small part of the entire population involved, since the work of control, formatting and normalization of the great amount of data is only at the beginning. Apart from personal details, data are mostly stored on kml/kmz (Google Earth) files, from which numerical elements are then drawn out in the form of string, text and graph (Figs. 1 and 2).

Fig. 1. Example of track with the location of photo takings

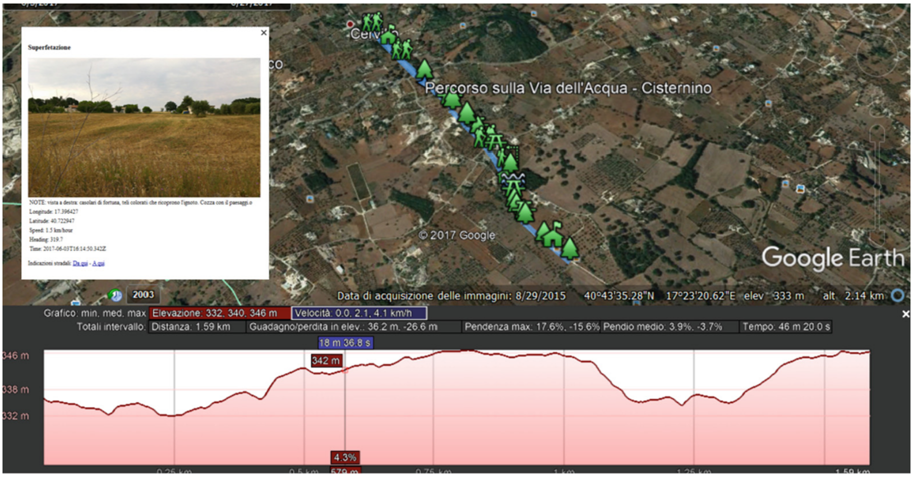


Fig. 2. Example of track with photo and note taking locations

In particular, textual notes taken by each agent along the route have been analysed by using simple data mining software Concordance, to draw out word and concept frequencies. The aggregation of textual concepts into categories has then been developed by manual ex-post analysis. In the end, the complete database is reported in Fig. 3, whereas specifications of acronyms, including the clusters of concepts grouped by synthetic categories, are reported in Fig. 4.

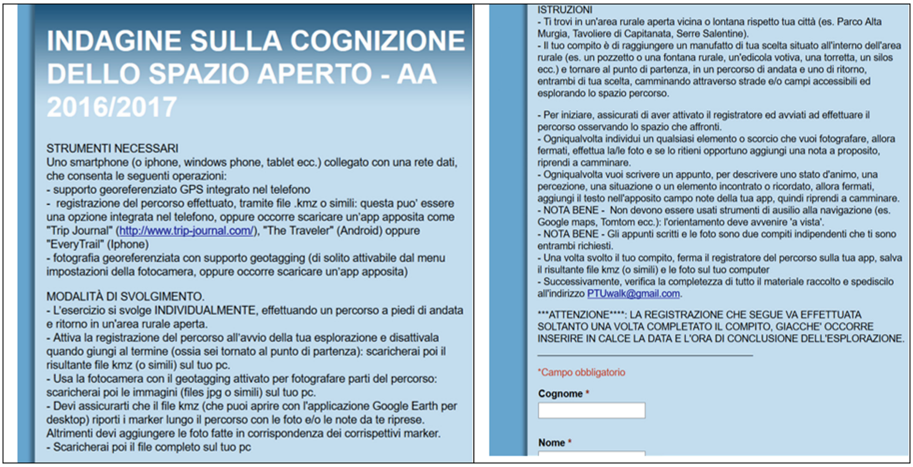
#	Matricola	Città di residenza	Luogo		percorso				features							
			toponimo	linea d'aria residenza - luogo (km)	altezza min (m)	dislivello (m)	lunghezza (km)	tempo impiegato	costruzioni	fauna	flora	paesaggio naturale	dissipazione e inquinamento	sensazioni, percezioni, emozioni	industrie, trasformazioni, impianti	strade
1	552201	Fasano	Cisternino	12	368,2	44,9	1,6	00:46:20	14	2	4	10	2	6		4
2	553745	Bitritto Puglia	Bitonto	15	81	26,7	2	00:42:00	14			3		4	2	5
3	555252	TRIGGIANO	Carbonara	3,3	41	15,4	0,835		10			13	3	5		1
4	555512	Laterza	Laterza	6,6	350	48,4	4,3	00:40:00	5			12	5		3	7
5	566879	Lucera	Lucera	5	192	19,8	2,82		2	1		7				4
6	566927	Rocchetta S.A. (FG)	Rocchetta	1,6	596	76	1,02	00:12:04	13		3	7				5
7	567428	Altamura	Altamura	6	388	23,4	0,8	00:29:00		1		6		1		11
8	567559	Foggia	Siponto	32	1	3	2,31		8	1		15	5	12		9
9	567604	Foggia	Segezia	14	134	208	12	00:45:12	9		1	11				10
10	567637	Martina Franca	Chiancaro	1,5	397	423	2,9	00:51:39	15	1		7	3		2	3
11	567658	Manfredonia	Amendola	18	34	39	0,617			2	1	30		2		15
12	567719	Troia	Troia	0,6	1	1	2,29					6			2	12

Fig. 3. Excerpt of the collected database (features are described through the citation frequencies of relevant words in the notes)

	LUO	linea d'aria residenza - luogo (km)
	ALT	altezza min (m)
	DIS	dislivello (m)
	LUN	lunghezza (km)
	TEM	tempo
Costruzioni, edificazioni	COS	EDILIZIA, BORGO, MASSERIA, CASALE, COSTRUZIONE, URBANI, CONVENTO, FONTANA, PIETRA, PONTE, CHIESA, EDIFICIO, MURETTI, SILOS, TORRE, VILLA, ABBEVERATOIO, ABITATO, CASA, DEPOSITO, FRANTOIO, PAESE, PORTA, POZZO, TORRI, TRULLO, ARCO, ARCO, CAPANNI, CASTELLO, FINESTRE, MANUFATTO, MARMOREE, MONASTERO, SCALA
Fauna	FAU	CAVALLI, INSETTI, ANIMALI, CANI, COLEOTTERO, DOG, FAUNA, VIPERA
Flora	FLO	VEGETAZIONE, ALBERI, PIANTA, FLORA, CIPOLLE, ERBA, FICO, FIORE, FRONDE, MORE, POMODORI, VERDURE
Paesaggio naturale	PAE	CAMPO, GRANO, RURALE, COLTIVAZIONI, TERRA, ULIVI, VIGNA, CAMPAGNA, TORRENTE, VALLE, AMBIENTALE, AMBIENTE, FLUVIALE, INCOLTO, NATURA, PAESAGGIO, AGRICOLO, AGRUMETO, BUCOLICO, FIUMETTO, PARCO, RACCOLTO, ACQUA, AMBIENTE, ARATURA, CANNETO, FILARI, MONTI, PARK, STEPPA, STERPAGLIA
Dissipazione e inquinamento	INQ	RIFIUTI, DEGRADO, ABUSIVISMO, AMIANTO, ECOMOSTRO
Sensazioni, percezioni, emozioni	SEN	ABBANDONO, LONTANANZA, VISTA, SENSAZIONE, IMMAGINE, PERICOLO, APERTO, BRUCIATA, DETURPA, INCOMPIUTO, ODORE, SECCO, SPAZI, ANTICO, BENE, BREVE, FENOMENO, GRANDI, PANORAMA, RISTORO, TEMPO, BELLO, COLORI, DISSESTATO, ESPLORARE, FORTUNA, LIBERTÀ, ORIZZONTE, PERICOLANTE, PIACEVOLE, PROSPETTIVA, RUMORE, SCORCIO, SCORGERE, SENSO, SGRADEVOLE, SUGGESTIVO, TRANQUILLITÀ, VENTICELLO, ABBAIARE, ACCIDENTATO, ACRE, AGEVOLE, APPARIVA, ARIA, ARSO, ASSENZA, BENESSERE, CALDO, CALMA, COGNITIVA, COMODO, CONFONDE, CONTRASTO, DIMENSIONI, DISMISURA, DISTESA, EFFETTO, ESALAZIONI, FATICA, GRADEVOLE, IGNOTO, ILLUMINAZIONE, LUCE, ORIENTARMI, PACE, SICUREZZA, SPENSIERATEZZA, SPERANZA, STANCHEZZA, TORRIDO
Industrie, trasformazioni, impianti	TRA	INDUSTRIALE, PALE, EOLICO, ARTIGIANALE, RECINTO, CANCELLO, ACQUEDOTTO, AZIENDA, DIGA, TRATTORE, ANTENNA, PALI, PANNELLI, PISCINA, TRALICCI
Strade	VIE	STRADA, PERCORSO, SENTIERO, ATTRAVERSARE, TRAGITTO, ASFALTO, CAMMINO, STERRATO, RAGGIUNGERE, SEGUIRE, PASSEGGIATA, SALITA, BIVIO, FERROVIA, INCROCIO, SVOLTA, CURVA, RETTILINEO, TRACCIATO, TRAFFICATA, VIAGGIO

Fig. 4. Legend of the aggregated variables

The internet portal of the experimental session, with personal details as well as relevant directions and information for respondents, is reported in Fig. 5.



INDAGINE SULLA COGNIZIONE DELLO SPAZIO APERTO - AA 2016/2017

STRUMENTI NECESSARI
Uno smartphone (o iphone, windows phone, tablet ecc.) collegato con una rete dati, che consenta le seguenti operazioni:
- supporto georeferenziato GPS integrato nel telefono
- registrazione del percorso effettuato, tramite file .kmz o simili: questa puo' essere una opzione integrata nel telefono, oppure occorre scaricare un'app apposita come "Trip Journal" (http://www.trip-journal.com/), "The Traveler" (Android) oppure "EveryTrail" (Iphone)
- fotografia georeferenziata con supporto geotagging (di solito attivabile dal menu impostazioni della fotocamera, oppure occorre scaricare un'app apposita)

MODALITÀ DI SVOLGIMENTO.
- L'esercizio si svolge INDIVIDUALMENTE, effettuando un percorso a piedi di andata e ritorno in un'area rurale aperta.
- Attiva la registrazione del percorso all'avvio della tua esplorazione e disattivala quando giungi al termine (ossia sei tornato al punto di partenza): scaricherai poi il risultante file kmz (o simili) sul tuo pc.
- Usa la fotocamera con il geotagging attivato per fotografare parti del percorso: scaricherai poi le immagini (files jpg o simili) sul tuo pc.
- Devi assicurarti che il file kmz (che puoi aprire con l'applicazione Google Earth per desktop) riporti i marker lungo il percorso con le foto e/o le note da te riprese. Altrimenti devi aggiungere le foto fatte in corrispondenza dei corrispettivi marker.
- Scaricherai poi il file completo sul tuo pc

ISTRUZIONI
- Ti trovi in un'area rurale aperta vicina o lontana rispetto tua città (es. Parco Alta Murgia, Tavoliere di Capitanata, Serre Salentine).
- Il tuo compito è di raggiungere un manufatto di tua scelta situato all'interno dell'area rurale (es. un pozzetto o una fontana rurale, un'edicola votiva, una torretta, un silos ecc.) e tornare al punto di partenza, in un percorso di andata e uno di ritorno, entrambi di tua scelta, camminando attraverso strade e/o campi accessibili ed esplorando lo spazio percorso.

- Per iniziare, assicurati di aver attivato il registratore ed avviati ad effettuare il percorso osservando lo spazio che affronti.
- Ogniqualvolta individui un qualsiasi elemento o scorcio che vuoi fotografare, allora fermati, effettua la/le foto e se lo ritieni opportuno aggiungi una nota a proposito, riprendi a camminare.
- Ogniqualvolta vuoi scrivere un appunto, per descrivere uno stato d'animo, una percezione, una situazione o un elemento incontrato o ricordato, allora fermati, aggiungi il testo nell'apposito campo note della tua app, quindi riprendi a camminare.
- NOTA BENE - Non devono essere usati strumenti di ausilio alla navigazione (es. Google maps, Tomtom ecc.): l'orientamento deve avvenire 'a vista'.
- NOTA BENE - Gli appunti scritti e le foto sono due compiti indipendenti che ti sono entrambi richiesti.
- Una volta svolto il tuo compito, ferma il registratore del percorso sulla tua app, salva il risultante file kmz (o simili) e le foto sul tuo computer
- Successivamente, verifica la completezza di tutto il materiale raccolto e spediscilo all'indirizzo PTUwalk@gmail.com.

ATTENZIONE*: LA REGISTRAZIONE CHE SEGUE VA EFFETTUATA SOLTANTO UNA VOLTA COMPLETATO IL COMPITO, GIACCHE' OCCORRE INSERIRE IN CALCE LA DATA E L'ORA DI CONCLUSIONE DELL'ESPLORAZIONE.

*Campo obbligatorio

Cognome *

Nome *

Fig. 5. The experimentation portal (powered by Google Forms features)

As previously mentioned, the specific objective of this work is to analyze the possible dependence of spatial sensations and perceptions from the other physical and relational elements that characterize the rural open space. In this framework the statistical analysis method of multiple regression analysis was used as a pilot methodological experiment. As Fig. 3 shows, some items in the database were missing. However, the regression was carried out using the Data analysis plug-in of Microsoft Excel (Italian version), which allows the interpolation of existing data to make up for missing information. Statistical results are summarized in Fig. 6.

Statistica della regressione	
R multiplo	0,982640754
R al quadrato	0,965582851
R al quadrato corretto	0,896748553
Errore standard	0,751293047
Osservazioni	16

ANALISI VARIANZA

	gdl	*SQ*	*MQ*	*F*	*Significatività F*
Regressione	10	79,17779379	7,917779379	14,02764147	0,004668639
Residuo	5	2,822206212	0,564441242		
Totale	15	82			

	Coefficienti	*Errore standard*	*Stat t*	*Valore di significatività*
Intercetta	-3,570862097	2,296282993	-1,555061858	0,180651519
LUO	0,078783236	0,033579746	2,346153427	0,065874277
ALT	-0,016870336	0,0022455	-7,512953976	0,000660929
DIS	0,026831546	0,003343132	8,025870826	0,0004855
TEM	-0,107639794	0,025144141	-4,280909603	0,007856704
COS	-0,301188845	0,088042521	-3,420947527	0,018818889
FLO	4,465275009	0,565118875	7,90147915	0,00052237
PAE	-0,053589763	0,040582835	-1,320503191	0,243879332
INQ	2,184816712	0,377690286	5,784678067	0,002172805
TRA	0,489347216	0,370403873	1,321117981	0,243689162
VIE	-0,085035897	0,05014506	-1,695798089	0,150690871

Fig. 6. The multiple regression analysis output

The above analysis leads to a synthetic regression equation:

$$Y_{SEN} = -3.57 + 0.08X_{LUO} - 0.01X_{ALT} + 0.27X_{DIS} - 0.1X_{TEM} - 0.3X_{COS} + 4.47X_{FLO} - 0.05X_{PAE} + 2.18X_{INQ} + 0.48X_{TRA} - 0.08X_{VIE}$$

Starting from the statistical analysis of the database, as resulting in the above regression equation, some suggestions of a certain interest emerge.

First of all, we can note that the expression of sensations and perceptions during navigation increases in relation to the quantitative variation of some features.

Particularly, the expression of sensations increases if presences of pollution and dissipation of resources appear in the route (INQ: coeff. = +2.18; p = 0.002).

It also increases in relation to the presence of floral and vegetational elements (FLO: coeff. = 4.46; p = 0.001).

It seems to increase even in relation to the distance of the route from the place of residence of the agent (LUO), as well as to the presence of industrial plants and elements of environmental transformation (TRA), but the relevant p-values are unacceptable, probably due to the small sample.

On the other hand, the expression of sensations and perceptions during navigation increases with the decrease of the presence of rural and urban buildings (COS: coeff. = 0.30, $p = 0.019$).

It also increases with the decrease of the time necessary to complete the route (TEM: coeff. = 0.11; $p = 0.007$).

Moreover, the expression of sensations and perceptions seems to decrease with increasing altitude (ALT: coeff. = −0.02; $p = 0.001$), but tends to increase with the increasing difference of altitude levels along the route (DIS: coeff. = +0.03; $p = 0.001$).

4 Conclusions

The above study seems to show outcomes of a certain suggestion, even if not completely robust and/or satisfying in statistical terms.

As a matter of facts, there are many coefficients with low numerical value, so that the investigated variables have little influence on the dependent variable - i.e., the agent's spatial sensations and perceptions along the route (SEN). Furthermore, some variables exhibit little causal dependence and in some cases observation data are missing and need to be interpolated. Concerning the aggregation of textual concepts by categories, it has been developed with a raw and hybrid approach that has possibly determined errors. In fact, while the word frequency has been collected through data-mining tools, it has been subsequently contextualized and categorized manually by the analyst through ex post analysis.

Yet after carrying out the whole analysis, it was still possible to derive interesting qualitative considerations.

In fact, they seem to suggest that the perception of an open space, largely devoid of the strongly structuring elements present in confined urban spaces, still depends on some recurrent physical and landscape elements that end up giving it a cognition based latent structure.

Such suggestions can be particularly useful and interesting to support decisions regarding the management of open spaces, their valorisation during the identification processes of physical and/or identity resources for hypothesis of environmentally sustainable development of settlements, as well as for land use planning purposes.

In the current stage research, some follow-up activities seem to be important to be carried out in the next future. They will particularly aim at giving greater robustness and reliability to the analysis and develop more aware and useful considerations. First, an enlargement of the analysis to the entire sample of 180 observations will be an indispensable and significant step, also trying to include missing data with their proper values where available. Secondly, attempts will be made to integrate the statistical analysis with probabilistic inference techniques, in order to compensate statistical errors induced by the multiple regression tool.

Concerning follow-up activities, the survey carried out here will be subsequently complemented by ontological aggregative approaches, as increasing emerging in spatial cognition literature [15]. This effort is oriented to investigate the possible realization of formal models more suitable to replicate and/or to interpret the complexity of the relevant environmental system.

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