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Visualization of Big Environmental Data using the Card Sorting method

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Valsamou Vasiliki*

Abstract

Card Sorting method is mainly applied to investigate the mental models of users, having no chance to visualize them. In this pilot study, the method is used to evaluate the usability of a big data environmental MIT website. In order to evaluate the visualization of the information, the method was modified. The cards presented the interfaces while the categories described the situ of interfaces on monitor's screen. Qualitative and quantitative evaluation methods were combined as follows: (a) Hypertext recording to investigate the workflow, (b) Think-Aloud method with users to define the evaluation scenarios, (c) two Tree Test to identify the problematic nodes, (d) SUS and finally (e) Cart Sorting. The sorting was on-line, remote, moderated & hybrid. The following questionnaire of the tool was adopted to evaluate the graphical approach and the designer's color pallet. The procedure pointed out two crucial differences from the existing design. One was proposed to improve usability. This modified Card Sorting method appeared to facilitate the visualization of mental models on the tool's screen, while designers' groups may use the modification to evaluate their work.

Keywords: Cart Sorting, Tree Test, visualization of mental models, usability, interface's situ evaluation, human computer interaction.

Introduction

Card Sorting is a user-centered method of analysis workflow in web designing. According to Allison et al, only 7% of recent evaluation studies of websites include or refer to the Card Sorting method, mainly used as an architectural structure tester (Allison et al., 2019). Main purpose of the method is to investigate the several approaches a user-visitor anticipates to find information under a hierarchical structure. Methodology, acquires the participates to pill up cards scattered on a physical or digital table without reference to their visual position, as being stated by several usability investigators (Lamantia, 2003; Nielsen, 2024; Paul, 2008; Rugg & McGeorge, 2005; Spencer, 2009; Tankala & Sherwin, 2024) in addition to usability expert groups i.e.: NNgroup, Syntagm, Usability gov., Userlytics, Usertest etc.

On the other hand, Indices describe ideas that need a spherical analysis approach. Weightings are both statistically and participatory developed. According to Drago the latest statistical tense

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to indices developing is “Symbolic” and “Interval” composition (Drago, 2022; Drago, 2017). Moreira stated that beside the statistical approach of indice construction, human centered methods such as interviews, queries, public opinion (PO), budget allocation (BA), ad-hoc / subjective process based on expert opinion, have been used in success with weighting (Moreira, 2012; Saltelli, 2006).

During the present postgraduate study, Card Sorting method was challenged to evaluate the visualization of “The Green Future Index 2021, MIT Review Technology, Insight” website (https://www.technologyreview.com/2021/01/25 /1016648 /green-future-index). On the first sight, it looked like a unique site for the use of Card Sorting method. The procedure led the Card Sorting to a differentiated application of the method adapted to the ability of the participants.

The query: What will the cards represent?

Most postgraduate studies make use of open-source Card Sorting tools while few of them have free use (UXTweak, XSort, Kardsort, Figma, Miro 51%, Optimal workshop 43.52%) (Lee, 2021). These tools either have limitations of cards or participants per sorting (Optimal Workshop, UXtweak, UXMetrics) or unlimited cards, categories and participants with limitations of data time accessibility or lack of linked analysis (Figma, Miro) (Lee, 2021). On-line sorting complies with Rugg & Mc George description procedures severally verified by most Usability Groups through the years. In addition, tools with linked visualizations are most popular (Optimal workshop 43.52%, Maze, UXMetrics) (Lee, 2021). Tools mainly adopt directed manipulation tools i.e.: drag and drop of cards, gaining versatility of movement among the cards in separate piles forth and back the primarily and ending piles on the visual table. Most categories are named according to each participant’s hierarchical mental model (Tankala & Sherwin, 2024). Participants place the cards without reference to their design position (situ) on the media screen, i.e.: monitor’s, notepad or cell phone’s screen.

The Green Future Index 2021 data, as well been described in the linked report, derived from international government and organization data banks/lakes as: Word Bank, Bloomberg, FAO, IRENA etc. After homogenization, each Country’s score represented by a climax 1-10. Weighting proved most important to fulfill the scope of the index (fig.1). Several interviews of well-known sustainability experts, as stated in the report, led to an uneven percentage contribution of the 18 separate indexes to the five-pillar construction with a unique 40% percentage to Climate Policy pillar. Visualization of the 1824 data, of all the indexes including pilar and 76 country indexes fulfilled by a 6 pages dark mode website, connected by a category top menu. Each page was represented with a different color referred to information levels either on an interactive spatial visualization or an interactive country list with economic, spatial, score, rank criteria.

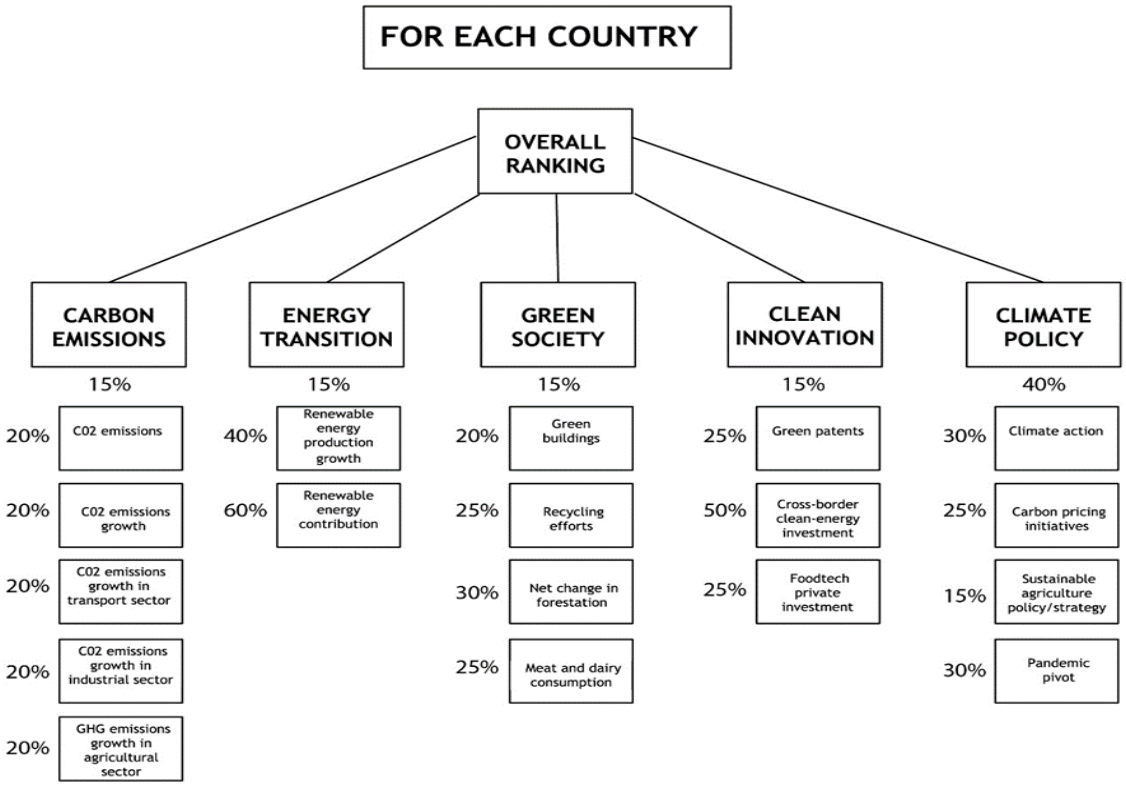


Figure1: Structure and weighting of the Green Future Index.

Evaluation of the website visualization refers either to graphical approach or architectural structure, i.e.: itineraries of hierarchy (Spencer, 2009:21; Styliaras et al, 2019:227-238). In order to make use of a free 20 card open-source tool, the 18 indexes looked like fitting in (Optimalsort, UXTweak). On the contrary, it has no sense to evaluate such a well-constructed Weighting of MIT specialist team, clearly described in the report. In addition, the participants should be aware of the procedure of indices construction, especially being experts in sustainability (Meadows, 1998). That wouldn't be handled by relevant seminars about the Green Future Index 2021 indexes and pillars construction, being inspired by the linked report. The participants should be already aware, ideally with an ecological background updated to Paris Agreement, which was difficult to gather within postgraduate study time limitations (United Nations, 2024). On the other hand, there was the obvious choice of 76 countries' representation on Card Sorting cards, but it was meaningless. Figma, Miro or Google slides tools were a fine choice to accomplish the procedure (Lee, 2021). Envisioning the procedure, participants had to group the 76 countries under their mental model's classification. Probable criteria would be that of spatial, score or economic criteria, which have already been applied. Extra criteria would lead to addition of extra columns or modification of existing column's visualization in the interactive country list. The visualization of the interactive global map wouldn't be affected, since the spatial criterion is mainly applied. Besides, the moderator wouldn't affect statistical analysis but only explanatory (Righi et al., 2013). So far as visualization interferes with the Design of a website, in addition to the present overwhelming amount of information, there was a challenge to test whether the Design of the website worked.

Methodology

Previous research referring to Card sorting evaluation of spatial visualization websites, verified that Moderated Card Sorting had a significant importance in the correct organization and obtaining important comments during the classification (Nielsen & Chan 2024; Paul, 2008; Spencer, 2009:101; Tankala & Sherwin, 2024; Rugg & McGeorge, 2005). Lloyd et al. proceeded to participant's sketching their mental model which appeared very effective and meaningful (Lloyd et al., 2008). Roth et al. tested the classification of map symbols into groups and their correct description. Participants were asked to register their verbal comments in relevant comments field (Roth et al, 2010). It is highly recommended to apply a tree test before a Card Sorting evaluation in order to identify problematic nodes (NNgroup, 2019; Sauro, 2012; Userlytics, 2024). According to usability experts, a concept such as visualization or sustainability need firm research before scenarios definition (Spencer, 2009; Tankala & Sherwin, 2024; Usability gov, 2022; Rugg & McGeorge, 2005). Hypertext registration was used in order to check existing terminology of hierarchy (Urh et al, 2014).

Making use of the above, the evaluation was carried out in two parts: Tree test and Card sorting, starting with an investigation of architectural structure and user's notions about the website. Card Sorting was combined with qualitative and quantitative methods, so the evaluation workflow was described as follows:

Hypertext registration - to investigate the workflow. Website accomplishes two tasks: one of each country's score (performance) and another of two countries' score comparison through all indexes, pillars and indice (comparison). The workflow is diagrammatically depicted on fig.2. It's obvious that the workflow does not have the shape of a tree but that of two connected pyramids, i.e.: a cone, while the visitor has the opportunity to find information via several direct manipulation tools plus complicated routes.

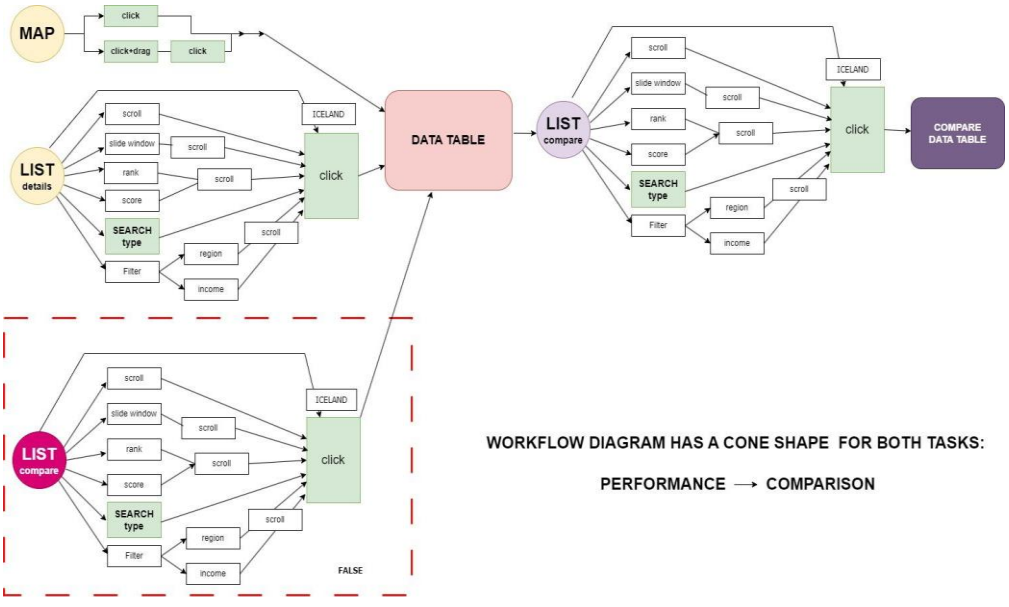


Figure 2: Hypertext registration of "The Green Future Index 2021", for the evaluation. (January 2023)

2- User's Cognitive walkthrough Thinking-Aloud - to define scenarios. Five computer experts were observed under the "Thinking-Aloud" method to spot the most representative countries to evaluate by tree test (Nielsen, 2012). Finally, for the performance task, Australia was chosen thanks to the separate huge spot on the opposite side of the map. Participants had to choose between list or map and what direct manipulation tool in order to appear Australia's Data Table. France and Italy were the two countries to combine performance for their neighborhooding spots, tempting users to click the map rather than the list to find the comparison. Participants were pleased to ask about well-known countries while comments started to reveal the problematic nodes. The two scenarios for the tree test were formed after several tool specifications (Optimal workshop, Usertest) as follows:

Task 1 - Performance: *You are at the homepage of our website. You want to have the overall ranking performance of Australia. Where will you find it?*

Task 2 - Comparison: *You are at the homepage of our website. You want to have the overall ranking performance of France and compare it with Italy's. Where will you find it?*

After the pre-research, an open invitation via Google forms, was forwarded to student association, where 10 postgraduate students of Graphic Arts and Multimedia accepted to participate in the Sorting, urging the sorting to evaluate visualization via design evaluation (fig.3). Usability experts clearly state that a limit of 50 participants is highly recommended to investigate a concept such as visualization, either for tree test or the cart sorting (Spencer, 2009:76; Tullis & Wood, 2004). The amount of 10 participants characterized the research as a pilot one, which led to Optimal Workshop usability platform for: Tree test and cart sorting in free open source has a limit of 10 participants, two tasks for the tree test plus 10 participants, 20 cards, unlimited categories for open or hybrid sorting. Both tests analyze data results with linked visualizations. Additionally, data and data analysis remains for use in the Optimal Workshop platform for a long time.

Card Sorting evaluation was conducted, in two (2) weeks (April 2023, 10-25), as follows:

A) Tree test: introduction to the website, short time interaction of the participants, running the tree test individually with the selected tool. A link of the tool tree test and a demo of the tree test procedure was separately forwarded.

B) After extensive interaction and individual investigation, a SUS for quantitative data gathering and Card Sorting was carried out individually. A Card Sorting tool and a google form link was separately forwarded.

Visual Art teacher 1
Visual Art teacher 2
Visual Art student 3
Graphic Art professional
Photographer professional
Technology professor 1
Technology professor 2
Computer Science teacher 1
Computer Science teacher 2
Computer Science teacher 3

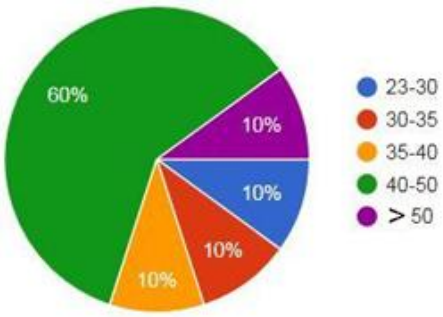


Figure 3: Demographic data of statistical sample.

Tree test is hard to evaluated big data visualizations

In order to settle the tree test, apprised a demand to register the most possible routes of hypertext for the scenarios. Furthermore, pilot tests were conducted with chaotic results without similarity to in-vivo interaction with the website. In addition, the real interaction looked less chaotic and more specific. In order to test the tree test, it was decided to contact two tree tests, under the same scenarios. The first one in-vivo with real interaction with the website under data recording. The following tree test by the tool. Both tree tests were conducted remotely via the Optimal workshop platform, moderately via WebEx. Moderator explained the scenarios verbally in Greek, observed and recorded the procedure. Participants proceed separately to interact with tree test tool or the website. Data record of the first tree test was carefully registered in the platform of Optimal Workshop, with added nodes the participants had visited (i.e.: Russia) (fig. 4, fig.20). Both tree tests data were analyzed with linked visualizations which had to be compared (fig.17). As soon as the tree test finished, verbal comments pointed out the problematic nodes (fig. 21). Tree test proved to be a fine preparation for the next phase of evaluation workflow: the Card sorting. The main scope of the two tree tests was the participants to cope with the website and form their mental models as designers and user' experience. The whole procedure plus the origin of the participants as postgraduate students of Graphic Arts and Multimedia, concluded that the Cards could represent the interfaces of the pages, while the categories the design situ.

Overall Ranking (GFI21)								
	⬇ View Data							
		dataset						
			overall					
	⬇ Download Report							
		pdf report						
	GEO MAP							
		scroll GEO MAP						
			zoom out GEO MAP					
			zoom in GEO MAP					
		India shape						
			Indonesia shape					
				Australia shape				
		South Aftrica shape						
			click+drag					
				Australia shape				
			delete South Africa data table					
				GEO MAP start point				
		France shape						
			data table					
				breakdown				
					data details			
				delete France data table				
					GEO MAP start point			
				mouse over				
					GEO MAP Italy shape			
					scroll country list			
						Iceland		

						Denmark		
						Norway		
						Ireland		
						Finland		
						Costa Rica		
						New Zealand		
						Belgium		
						Nedelands		
						Germany		
						Sweden		
						Luxemburg		
						Canada		
						Austria		
						Singapore		
						United Kingdom		
						Spain		
						Switzerland		
						Uruguay		
						India		
						Italy		
						Kenya		
						Chile		
						Colombia		
						Morocco		
						Ethiopia		
						Czech Republic		
						Thailand		
						Portugal		

						South Korea		
						Brazil		
						Kazakhstan		
						Poland		
						Australia		
						Mexico		
						Greece		
						Israel		
						Hungary		
				search/type				
					France			
					Italy			
					France, Italy			
		click +drag						
			click +drag					
				Australia shape				
			Kenya					
				click+drag				
					Ausralia shape			
		Italy shape						
		Russia shape						
			country list					
				search				
					France			
	country list							
		scroll country list						
			Iceland					
			Sweden					

			Luxembourg					
			Canada					
			Austria					
			Singapore					
			United Kingdom					
			Spain					
			Switzerland					
			Uruguay					
			India					
			Italy					
			Kenya					
			Chile					
			Colombia					
			Morooco					
			Ethiopia					
			Czech Republic					
			Thailand					
			Portugal					
			South Korea					
			Brazil					
			Kazakhstan					
			Poland					
			Australia					
			Mexico					
			Greece					
			Israel					
			Hungary					
			United States					

			Cameroon					
			United Arab Emirates					
			Philippines					
			Bulgaria					
			China					
			Taiwan					
			South Africa					
			Romania					
			Vietnam					
			Slovakia					
			Zambia					
			Angola					
			Nigeria					
			Uganda					
			Dominican Republic					
			Malaysia					
			Indonesia					
			Egypt					
			Argentina					
			Japan					
			Saudi Arabia					
			Ecuador					
			Ukraine					
			Hong Kong, China					
			Kuwait					
			Peru					
			Pakistan					
			Turkey					

			Bangladesh					
			Guatemala					
			Ghana					
			Algeria					
			Russia					
			Iran					
			Paraguay					
			Qatar					
			Denmark					
			Norway					
			France					
				data table				
					breakdown			
						data details		
					delete France data table			
						GEO MAP start point		
					mouse over			
						scroll country list		
							Iceland	
							Sweden	
							Luxembourg	
							Canada	
							Austria	
							Singapore	
							United Kingdom	
							Spain	
							Switzerland	
							Uruguay	

							India	
							Italy	
							Kenya	
							Chile	
							Colombia	
							Morooco	
							Ethiopia	
							Czech Republic	
							Thailand	
							Portugal	
							South Korea	
							Brazil	
							Kazakhstan	
							Poland	
							Australia	
							Mexico	
							Greece	
							Israel	
							Hungary	
							United States	
							Cameroon	
							United Arab Emirates	
							Philippines	
							Bulgaria	
							China	
							Taiwan	
							South Africa	
							Romania	

							Vietnam	
							Slovakia	
							Zambia	
							Angola	
							Nigeria	
							Uganda	
							Dominican Republic	
							Malaysia	
							Indonesia	
							Egypt	
							Argentina	
							Japan	
							Saudi Arabia	
							Ecuador	
							Ukraine	
							Hong Kong, China	
							Kuwait	
							Peru	
							Pakistan	
							Turkey	
							Bangladesh	
							Guatemala	
							Ghana	
							Algeria	
							Russia	
							Iran	
							Paraguay	
							Qatar	

						GEO MAP		
							Italy shape	
					search / type			
						France		
						Italy		
						France, Italy		
			Ireland					
			Finland					
			Costa Rica					
			New Zealand					
			Belgium					
			Nederlands					
			Germany					
		search / type						
			country list					
				Australia				
				France				
					data table			
						breakdown		
						search / type		
							Italy	
							France	
							France, Italy	
						GEO MAP Italy shape		
						delete France data table		
				Italy				
				France, Italy				
			compare					

		Filters						
			Region					
				East Asia, Pacific				
					New Zealand			
					Singapore			
					Thailand			
					South Korea			
					Australia			
					Philippines			
					China			
					Taiwan			
					Vietnam			
					Malaysia			
					Indonesia			
					Japan			
					Hong Kong			
				Europe, Central Asia				
					Iceland			
					Denmark			
					Norway			
					France			
						data table		
							breakdown	
							delete data table	
							Italy shape	
							scroll country list	
								Iceland
								Denmark

								Norwary
								Ireland
								Finland
								Belgium
								Nederlands
								Germany
								Sweden
								Luxemburg
								Austria
								United Kingdom
								Spain
								Switzerland
								Italy
								Czech Republic
								Portugal
								Kazahstan
								Poland
								Greece
								Hugnary
								Romania
								Bulgaria
								Slovakia
								Ukraine
								Turkey
								Russia
							search / type	
								Italy
								France

								Australia
								France, Italy
					Ireland			
					Finland			
					Belgium			
					Netherlands			
					Germany			
					Sweden			
					Luxemburg			
					Austria			
					United Kingdom			
					Spain			
					Switzerland			
					Italy			
					Czech Republic			
					Portugal			
					Kazakhstan			
					Poland			
					Greece			
					Hungary			
					Bulgaria			
					Romania			
					Slovakia			
					Ukraine			
					Turkey			
					Russia			
		Rank						

			change order 1-76 or 76-1					
		Score						
			change order 1-76 or 76-1					

Figure 4: In-vivo Tree test - 9 hierarchy levels - with the addition of the unexpected nodes of Russia, Kenya and Italy in red (.xls).

The Card Sorting - the timing

The procedure of tree test lasted a week. Following, each participant had a week to personally, at his own will, interact with the website to form their personal opinion and mental model about the usability and visualization of the latter. The tree test closed, so participants were invited to run the SUS and Card Sorting. Sorting conducted individually within the 45 minutes time limit of WebEx free tool. The participants had to sort a pill of 20 digital cards representing the interfaces of one page of the Green Future Index 2021 website, such as:

1.GEO MAP, 2.COUNTRY LIST, 3.FILTERS/CRITERIA FOR COUNTRY LIST, 4.SEARCH, 5.COMPARE, 6.OVERALL RANKING, 7.GREEN SOCIETY, 8.CARBON EMISSION, 9.ENERGY TRANSITION, 10.CLEAN INNOVATION, 11.CLIMATE POLICY, 12.SPONSORS, 13.ABOUT INDEX - HIGHLIGHTS OF INDEX, 14.ABOUT - CONTACT WITH - ADVERTISE WITH MIT TECH.REVIEW, 15.FB-IN-INSTAGRAM-TWITTER, 16.DOWNLOAD REPORT, 17.VIEW DATA, 18.DATA TABLE / COMPARE DATA TABLE, 19.TITLE Description, 20.SUBTITLE Description.

They had to pill the cards into categories under the situ name. A hybrid sorting was conducted, thus categories under the name of RIGHT, LEFT, TOP MENU, LEAVE IT AS IT IS, NOT IMPORTANT, CENTER guided the participants. The moderator explained each time the procedure that the categories are the situ of the interfaces / cards. Verbal comments were registered and participants were encouraged to name the categories however they wanted without guidance. In order to evaluate the color of the indice and the pillars plus the color and the graphic manipulation of the problematic nodes, the tool's following questionnaire was adjusted to a 12 standard multiple choice of basic and complementary colors as shown in fig.5. The multiple choices were: RED, GREEN, BLUE, MAGENTA, YELLOW, CYAN, GRAY, WHITE, LIGHT, DARK, BOLD, FRAMED, HIGHLIGHTED / BLENDED plus a final open question for further suggestions. The questions referred to the problematic nodes, pillars, indice as follows:

What color or graphic approach would you prefer for: *1. Overall Ranking (The Green Future Index), 2. Carbon Emission, 3. Energy Transition, 4. Green Society, 5. Clean Innovation, 6. Climate Policy, 7. Search, 8. Compare, 9. Data Table / Compare Data Table, 10. Title / Subtitle text, 11. Filters / Criteria.*

Questionnaire data was analyzed by the tool. Sorting Data were explanatory and statistically analyzed with connected visualizations.

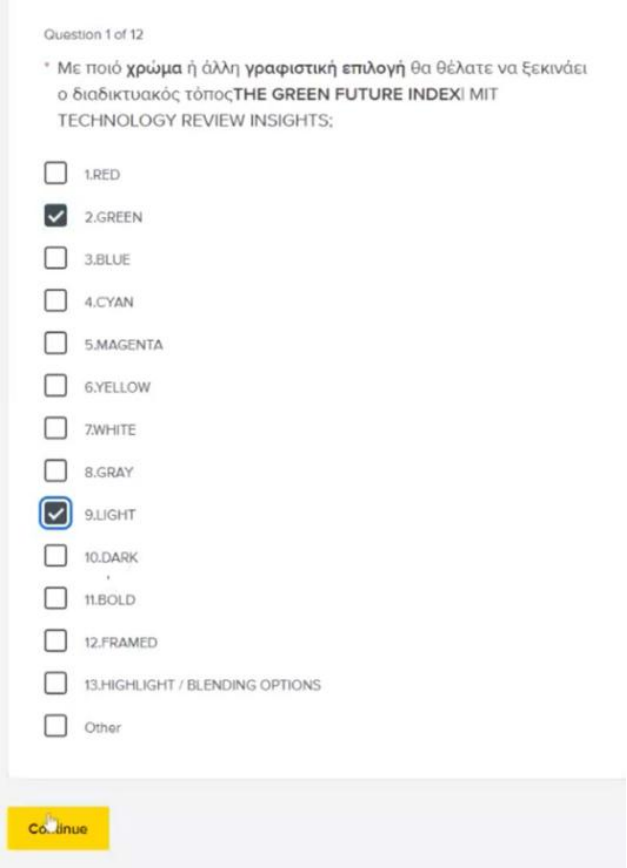


Figure 5: Screen from the Questionnaire about Graphics (in Greek).

Results: Mental models and homogenization

Through the sorting procedure, participants had the opportunity to pill the interfaces - cards into categories under the situ name, i.e.: FOOTER RIGHT, FOOTER CENTER, CATEGORY MENU, CENTER etc. Drag and drop procedure enabled the participants to place their categories to their physical position in order to visualize the sorting digital table in spatial mode, i.e.: to drag the category under the name RIGHT to the right side of the table, the category named FOOTER to the bottom etc. A participant's effort to visualize his mental model is depicted in fig.6. Additionally, participants freely created 42 situ - categories which had to be homogenized. Due to the small number of participants, moderator decided to sketch the mental models of participants - inspired by LLoyd's et al, making use of all the relevant data of sorting, questionnaire and participants comments (Lloyd et al., 2008) (fig.7). Few participants hesitate about the left or right position of the country list or map which led to multiple overwhelming mental models. The classification of interfaces-card among each situ, was of high importance, so had to be determined each time. The moderator had to verify whether, i.e.: in situ CATEGORY TOP MENU, which was prevailing among the generated categories, how the participants preferred the order of indice and pillars. 50% of the participants placed CLIMATE POLICY pillar next to GREEN FUTURE INDEX, in order to justify the 40% weighting.

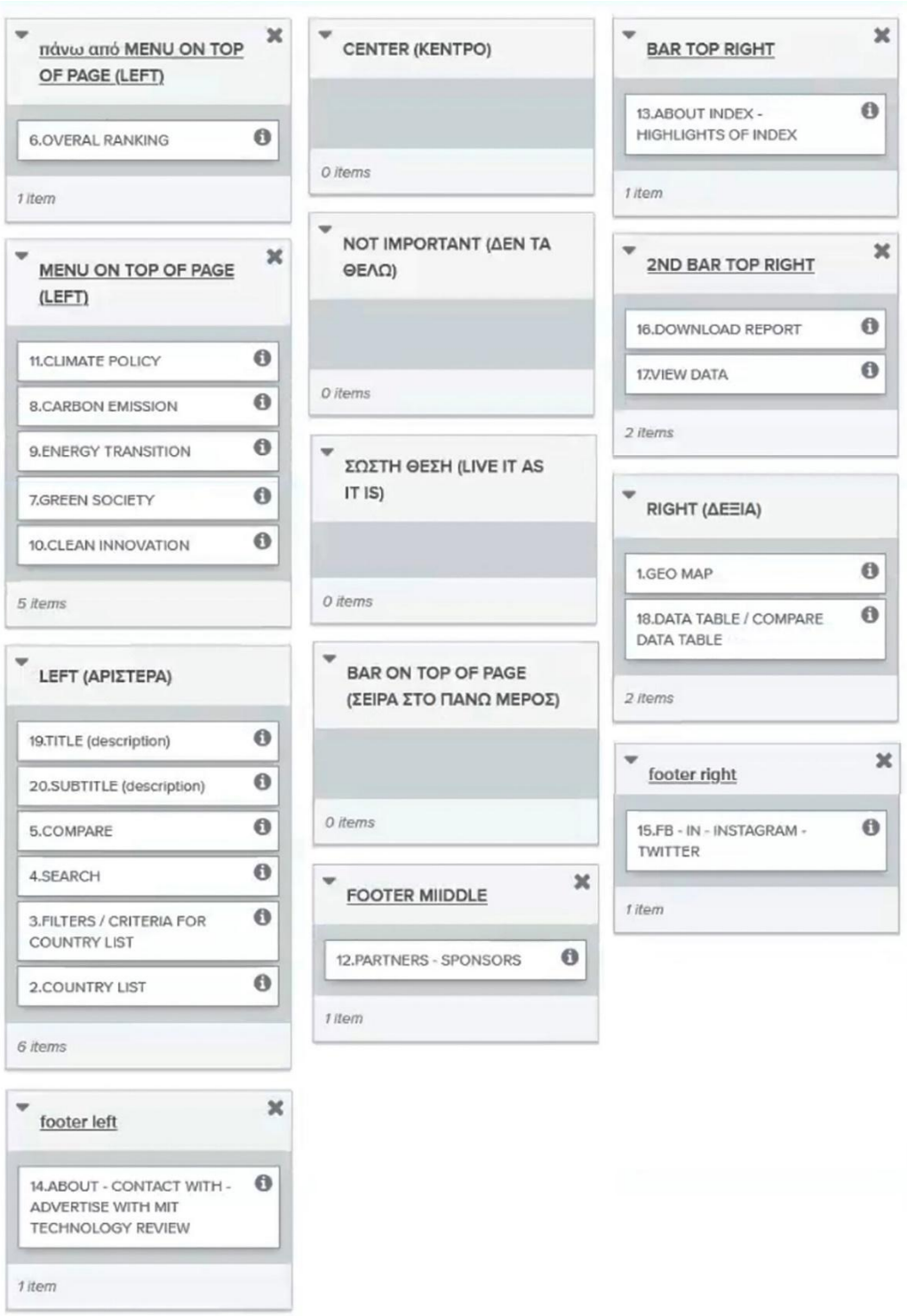


Figure 6: Visualization of a participant's Mendal model on the tool's screen

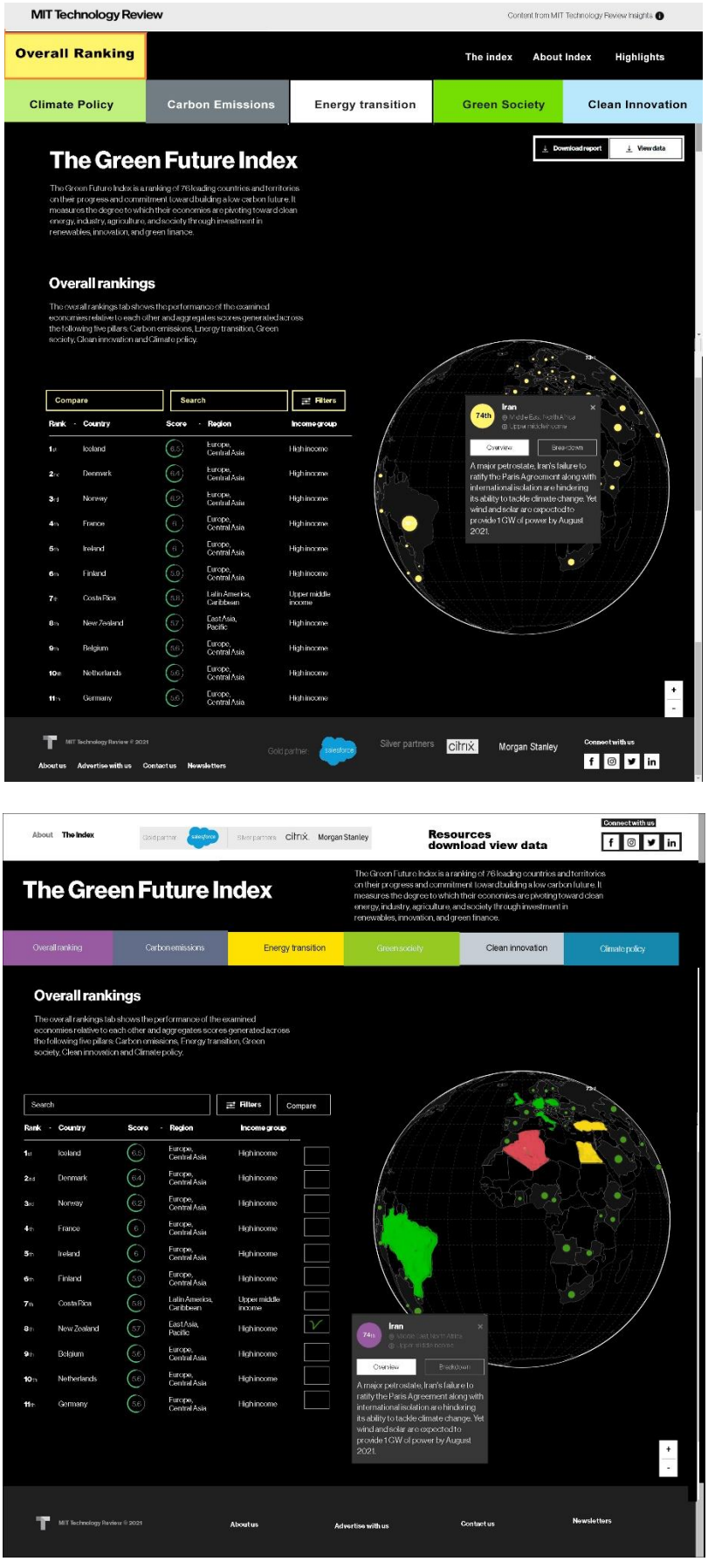


Figure 7: Visualizations of participant's mental models via pixel editing.

After consideration the 42 categories minimized to 18, thus 16 while two were NOT IMPORTANT and NOT HOMOGENIZED (fig.8). Labeling of the categories was in Greek but homogenized categories in English. What is well noted about the primary names of the categories - category's name in red (fig.8) - is the necessity to check page code and programming, i.e.: category name "be able to move via mouse", "always on sight top of page", "hover" etc.

UNSTANDARDIZED CATEGORY NAME	UNIQUE CARDS	STANDARDIZED CATEGORY NAME
ΠΙΟ ΔΕΞΙΑ ΕΚΕΙ ΠΟΥ ΕΙΝΑΙ	1	ABOUT INDEX PLACE
ΕΚΕΙ ΠΟΥ ΕΙΝΑΙ, ΠΙΟ ΚΕΝΤΡΟ	1	ABOVE LIST
ΠΑΝΩ ΑΠΟ ΤΗ ΛΙΣΤΑ	3	
BAR ON TOP OF PAGE (ΣΕΙΡΑ ΣΤΟ ΠΑΝΩ ΜΕΡΟΣ)	7	CATEGORY MENU
CENTER	8	CENTER TO PAGE
ΚΕΝΤΡΙΚΑ ΣΤΟΝ ΚΕΝΟ ΧΩΡΟ ΑΝΑΜΕΣΑ ΣΤΗ ΛΙΣΤΑ ΚΑΙ ΣΤΟ ΤΕΛΟΣ ΟΘΟΝΗΣ - ΚΕΝΤΡΑΡΙΣΜΕΝΟ ΜΕ ΤΗ ΓΗ	1	CENTER ALWAYS
ΜΕΤΑΞΥ ΑΡΙΣΤΕΡΗΣ ΛΙΣΤΑΣ ΚΑΙ ΧΑΡΤΗ		
ΝΑ ΒΓΑΙΝΕΙ ΔΙΠΛΑ ΣΤΟ ΚΟΥΜΠΙ COMPARE		
ΘΕΛΩ ΝΑ ΤΟ ΜΕΤΑΚΙΝΩ ΟΠΟΥ ΜΕ ΒΟΛΕΥΕΙ		
ΑΡΙΣΤΕΡΑ ΑΠΟ ΤΗ ΛΙΣΤΑ ΠΑΝΤΑ ΣΤΟ ΚΕΝΤΡΟ ΤΗΣ ΣΕΛΙΔΑΣ		
ΠΑΝΩ ΚΕΝΤΡΟ ΣΕ ΚΑΘΕ ΣΕΛΙΔΑ	1	CENTER TOP
ΚΑΤΩ ΔΕΞΙΑ	6	FOOTER
ΚΑΤΩ ΜΠΑΡΑ		
ΜΠΑΡΑ ΣΤΟ ΚΑΤΩ ΜΕΡΟΣ ΤΗΣ ΣΕΛΙΔΑΣ		
FOOTER RIGHT		
FOOTER LEFT		
FOOTER MIDDLE		
FOOTER ΣΕ ΤΡΕΙΣ ΣΤΗΛΕΣ		
ΚΑΤΩ ΚΕΝΤΡΟ		
ΚΑΤΩ ΑΠΟ ΤΗ ΚΑΤΩ ΜΠΑΡΑ ΜΕΣΗ		

UNSTANDARDIZED CATEGORY NAME	UNIQUE CARDS	STANDARDIZED CATEGORY NAME
HOVER BAR ON TOP	1	HOVER ON CATEGORY MENU
ΣΩΣΤΗ ΘΕΣΗ	20	LEAVE IT AS IT IS
LEFT	16	LEFT
RIGHT	6	RIGHT
MENU ON TOP OF PAGE(LEFT)	6	PORTRAIT CATEGORY MENU
ΠΑΝΩ ΑΠΟ MENU ON TOP OF PAGE (LEFT)	1	LEFT ABOVE CATEGORY MENU
2ND BAR TOP RIGHT	2	RIGHT UNDER CATEGORY
ΠΑΝΩ ΑΠΟ ΤΗΝ BAR ON TOP OF PAGE	6	STABLE MENU
ΚΕΝΤΡΙΚΟ ΜΕΝΟΥ (ΜΕΝΟΥ BAR))		
RESOURCES		
BAR TOP RIGHT		
ΣΤΑΘΕΡΑ ΣΤΟ ΠΑΝΩ ΜΕΡΟΣ		
ΣΤΑΘΕΡΑ ΣΤΟ ΠΑΝΩ ΜΕΡΟΣ ΔΕΞΙΑ ΚΑΤΩ ΑΠΟ ΤΟ ABOUT		
ΣΤΑΘΕΡΗ ΜΠΑΡΑ ΠΑΝΩ ΠΑΝΩ		
ΚΑΤΩ ΑΠΟ ΤΗΝ BAR ON TOP OF PAGE	3	UNDER CATEGORY MENU
ΑΚΡΙΒΩΣ ΚΑΤΩ ΑΠΟ ΤΗΝ ΜΠΑΡΑ, ΣΤΗ ΣΕΙΡΑ ΑΠΟ ΑΡΙΣΤΕΡΑ ΠΡΟΣ ΤΑ ΔΕΞΙΑ		
NOT IMPORTANT	3	NOT IMPORTANT
UNSTANDARDIZED		
ΟΠΩΣ ΕΙΝΑΙ ΑΛΛΑ ΣΕ ΚΑΘΕ ΠΕΡΙΠΤΩΣΗ ΝΑ ΚΙΝΟΥΝΤΑΙ ΤΟ ΕΝΑ ΔΙΠΛΑ ΣΤΟ ΑΛΛΟ ΚΑΙ ΟΧΙ ΑΝΕΞΑΡΤΗΤΑ ΚΑΘΩΣ ΣΚΡΟΛΑΡΕΙ Η ΣΕΛΙΔΑ	2	
ΣΤΗ ΛΙΣΤΑ ΠΑΝΩ ΣΤΗΝ ΕΠΙΛΟΓΗ ΤΗΣ ΧΩΡΑΣ ΜΕΤΑ ΤΟ ΟΝΟΜΑ ΤΗΣ ΧΩΡΑΣ	1	
ΤΕΛΕΥΤΑΙΑ ΣΤΗΛΗ ΔΙΠΛΑ ΑΠΟ ΤΟ INCOME GROUP ΜΕ ΔΥΝΑΤΟΤΗΤΑ CHECK ΠΑΡΑΠΑΝΩ ΑΠΟ ΔΥΟ ΧΩΡΕΣ	1	

Figure 8: Homogenization matrix.

Results: Explanatory and Statistic analysis

Table of arithmetical correlation in fig.9, links cards with homogenized categories, i.e.: interfaces with design situ (fig. 10). Color has been used to improve visual ability of the results (Lamantia, 2003). Results of the "LEAVE IT AS IT IS" category had to be added to results that verify the present design situ. After a controversy, it is clear that participants verified the present designing of the website, despite two crucial points. One about the situ of the data table, where 60% of the participants preferred to appear in the middle of the screen either to be mouse movable. The second finding was the overwhelming 70% of the participants, who were annoyed by the sponsors design situ, thus proposed to diminish their presence to the footer either center or right position.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1				1					2	2			4					1
2				1					2	3			2				1	1
3		1		1					3	3			2					
4		1		1					3	2			2			1		
5		1		1					2	2			1			1		2
6			5						3	1	1							
7			5						3	1		1						
8			5						3	1		1						
9			5						3	1		1						
10			5						3	1		1						
11			5						3	1		1						
12							7		2						1			
13	2						1		3						4			
14							4		5								1	
15							5		3						1		1	
16							1		4	1				1	3			
17			1				1		3	1				1	3			
18				1	5				2	1			1					
19				2					3	2					3			
20				1		1		1	3	2						2		

Figure 9: Matrix of Arithmetical Correlation (Altered Standardization Grid). (https://app.optimalworkshop.com/a/5ulk10o1/optimalsort/results/f5b04973-d18e-4741-8687-de29ac9a6a7d#/t/results/analysisTools/standardisationGrid)

CARDS	STANDARDIZED CATEGORIES
1.GEO MAP	1. ABOUT INDEX PLACE
2.COUNTRY LIST	2 ABOVE LIST
3.FILTERS / CRITERIA FOR COUNTRY	3.CATEGORY MENU
4.SEARCH	4.CENTER (KENTPO)
5.COMPARE	5.CENTER ALWAYS
6.OVERAL RANKING	6.CENTER TOP
7.GREEN SOCIETY	7.FOOTER
8.CARBON EMISSION	8.HOVER ON CATEGORY MENU
9.ENERGY TRANSITION	9.LEAVE IT AS IT IS (ΣΩΣΤΗ ΘΕΣΗ)
10.CLEAN INNOVATION	10.LEFT
11.CLIMATE POLICY	11.LEFT ABOVE CATEGORY MENU
12.PARTNERS - SPONSORS	12.PORTRAIT CATEGORY MENU
13.ABOUT INDEX - HIGHLIGHTS OF	13.RIGHT
14.ABOUT - CONTACT WITH - ADVERTISE	14.RIGHT UNDER CATEGORY MENU
15.FB-IN-INSTAGRAM-TWITTER	15.STABLE MENU
16.DOWNLOAD REPORT	16.UNDER CATEGORY MENU
17.VIEW DATA	17.NOT IMPORTANT
18.DATA TABLE / COMPARE DATA	18.NOT STANDARDIZED
19.TITLE Description	
20.SUBTITLE Description	

Figure 10: Cards and standardized categories

Explanatory analysis results were verified by statistical analysis. Key point is the differentiation of data approach analysis: Explanatory analysis copes with the numerical appearance of interfaces in several situ while statistical analysis determines whether interfaces appear together

in groups to relevant design situ. Optimal workshop platform offered the opportunity to test visualization of interface-situ combination:

Similarity matrix - represents by percentage how interfaces overlapped in situ: 100% pillars and indice found to have a presence together. COUNTRY LIST overlapped 80% with SEARCH, COMPARE and FILTERS interfaces, Search with COMPARE 50-80%, SOCIAL MEDIA - ABOUT MIT - SPONSORS 50-70%. On the contrary, GEOMAP had a low percentage in combination other than that with DATA TABLE in situ appearance on top of the map 30% (same as present). VIEW DATA overlapped with DOWNLOAD REPORT up to 90%. Similarity matrix has no reference to categories-situ.

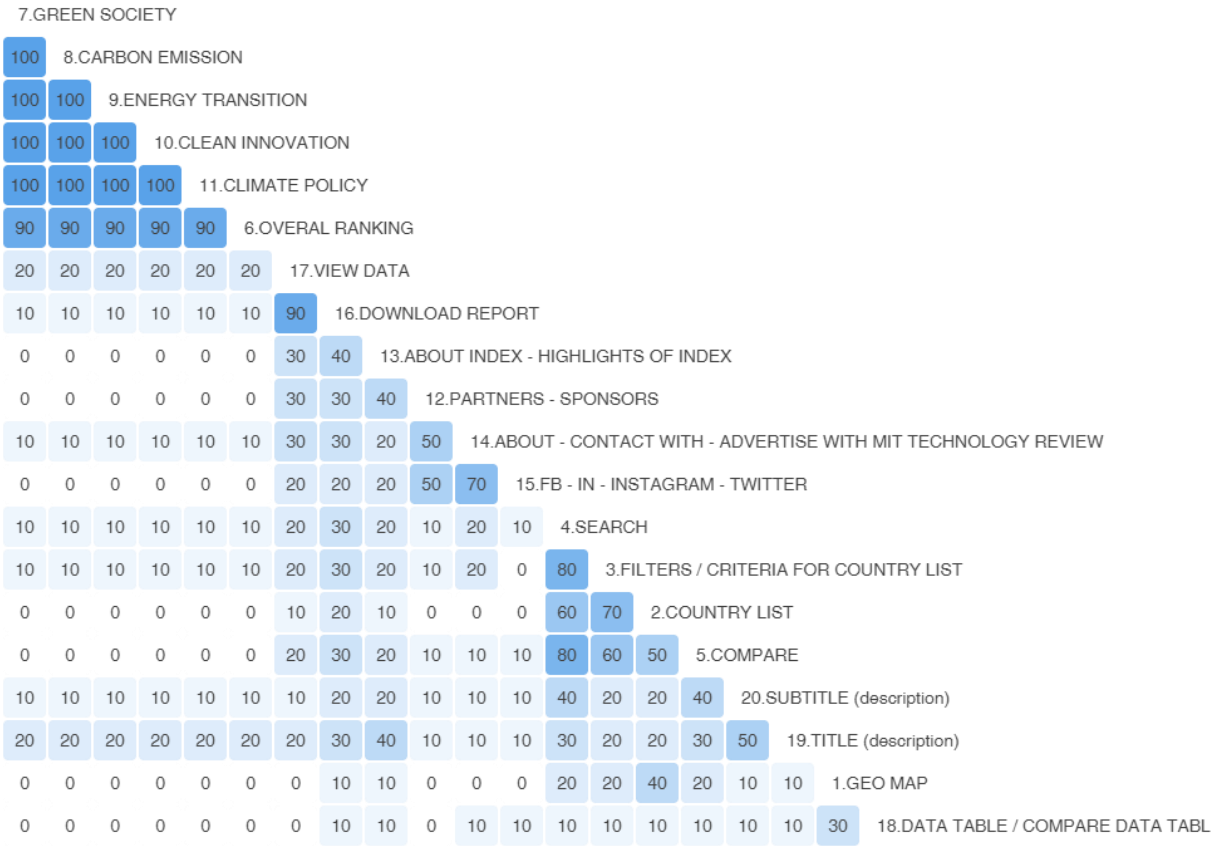


Figure 11: Similarity Matrix.
(https://app.optimalworkshop.com/a/5ulk10o1/optimalsort/results/f5b04973-d18e-4741-8687-de29ac9a6a7d#/t/results/analysisTools/similarityMatrix)

3D cluster view, had a different aspect of the interface- situ combination. Clusters represent the approximate number of situ a designer bears in mind to implement, while each cluster recites with a percentage, the possible combination of an interface to situ. Thus, for 7 different clusters-situ, a group of ABOUT MIT, SOCIAL MEDIA and SPONSORS interfaces seems to preferably appear to 100% in FOOTER, or 67% in LEAVE IT AS IT IS category (fig.12). 3D cluster view seems to offer an interesting exploration of design situ-interfaces linkage.

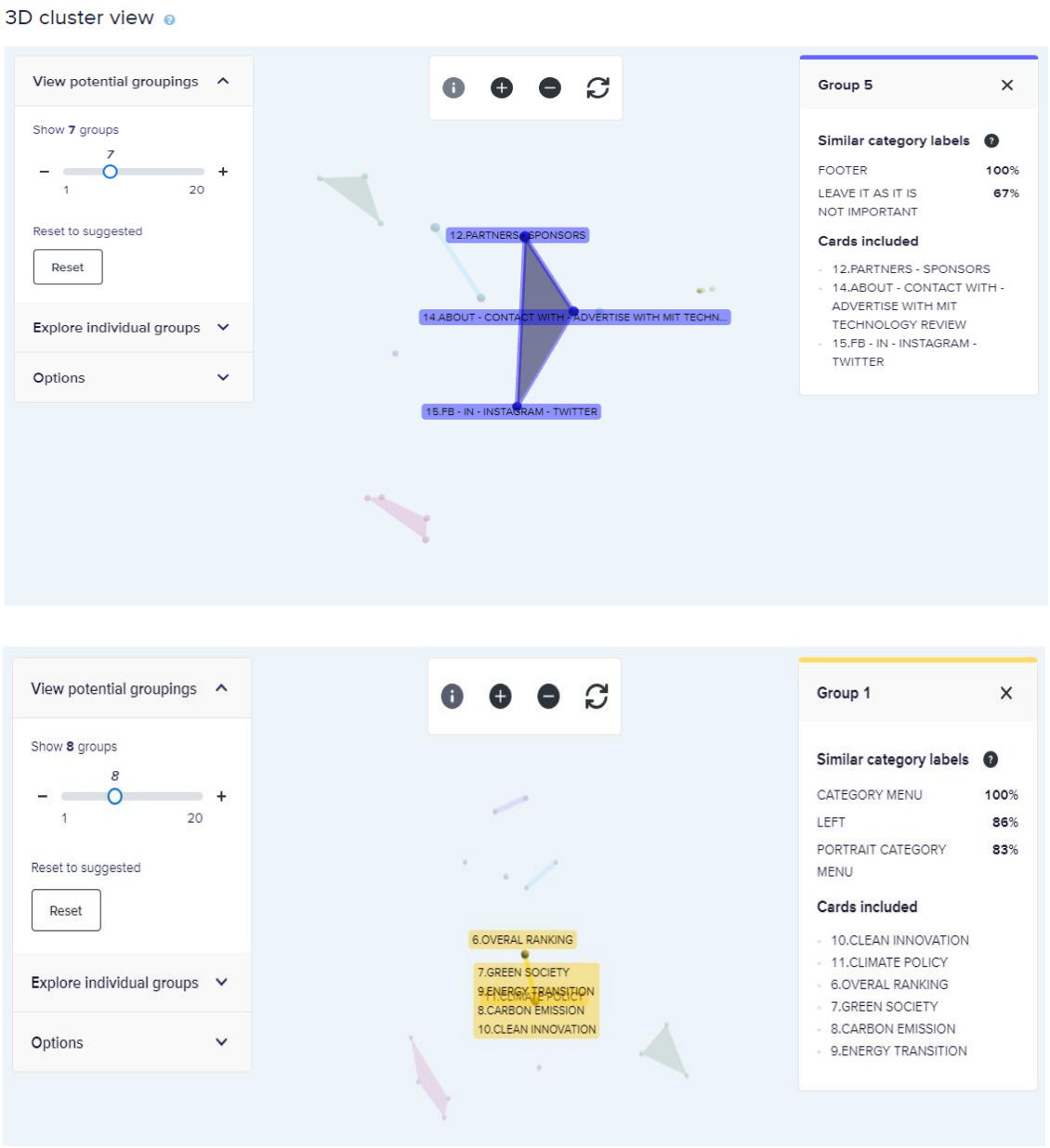
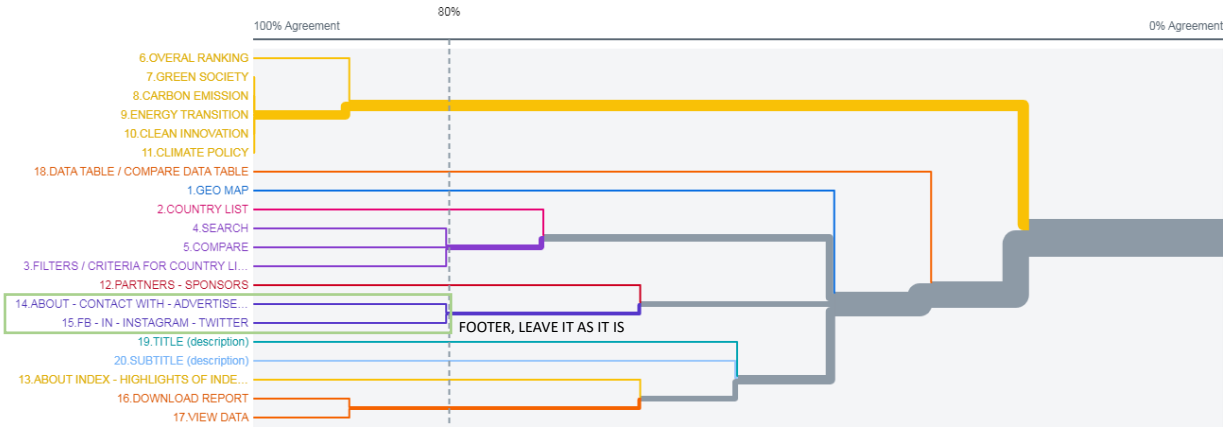


Figure12: 3D Cluster view.
(https://app.optimalworkshop.com/a/5ulk10o1/optimalsort/results/f5b04973-d18e-4741-8687-de29ac9a6a7d#/t/results/analysisTools/clusterView)

Dendrograms - were more specific than similarity matrix, as soon as reveal an opportunity to link a percentage of participants to a combination of interface - situ. Best merge method or actual agreement method offered by the tool have similarities (Laubheimer, 2021).



Best Merge. 80% of participants verified the present situ of ABOUT MIT and SOCIAL MEDIAL.

Actual Agreement. 30% of participants verified the present situ of GEOMAP and DATA TABLE

Best Merge. 90% of the participants verified the situ of VIEW DATA and DOWNLOAD REPORT

Figure 13: Screens from Dendrogram Analysis. (https://app.optimalworkshop.com/a/5ulk10o1/optimalsort/results/f5b04973-d18e-4741-8687-de29ac9a6a7d#/t/results/analysisTools/dendrograms)

Results of the questionnaire: Color

Raw data of the questionnaire were gathered in the matrix of fig14. Afterwards these were summed up to the interrelated matrix of fig.15. The preferred color either of indice and pillar/pages or graphical effects of problematic nodes: COMPARE, SEARCH and DATA-TABLE, is linked to percentage. Color has been used to visualize the relationships. It is made clear that: pillars of CARBON EMISSION, GREEN POLICY and CLEAN INNOVATION have a 90% agreement to more symbolic colors. Light gray for CARBON, light green for GREEN POLICY and light blue for CLEAN INNOVATION. ENERGY TRANSITION had a 60% and CLIMATE POLICY a 20% agreement of existing color. The GREEN FUTURE 2021 homepage color had a 40% agreement to sustainable green, though 40% accepted the existing purple stated to imply a consort of technology linked to MIT. Verbal comments pointed out that SEARCH as a problematic node had a visual flaw compared to the neighboring FILTER, as it lacked a hover command. In addition, the COMPARE interface was well hidden with a code error in emerging, with tiny letters on a dark background screen overwhelmed with information.

	GFI21	CARBON EMISSION	ENERGY TRANSITION	GREEN SOCIETY	CLEAN INNOVATION	CLIMATE POLICY	SEARCH	COMPARE	DATA TABLE	TEXT	CRITERIA
RED	-	10%	20%	-	-	10%	-	-	SAME	-	-
GREEN	40%	-	10%	90%	-	20%	20%	10%	SAME	-	-
BLUE	10%	10%	20%	-	30%	30%	-	-	SAME	-	-
CYAN	20%	-	10%	-	60%	10%	-	10%		-	-
MAGENTA	10%	-	10%	-	-	10%	-	-		-	-
YELLOW	10%	20%	40%	10%	-	20%	20%	10%		-	10%
WHITE	-	-	10%	-	10%	0%	40%	40%	LIGHTER MORE CONTRAST	100%	70%
GRAY	20%	70%	10%	-	30%	20%	30%	10%		-	20%
LIGHT	50%	40%	40%	50%	50%	50%	40%	10%		-	10%
DARK	-	10%	-	-	-	10%	10%	-		-	-
BOLD	20%	-	-	-	-	-	10%	10%		-	-
FRAMED	-	-	-	-	-	-	80%	50%		-	90%
HIGH/ED	10%	10%	-	-	-	-	-	-		-	-
OTHER	40%	-	10%	10%	20%	50%	40%	60%		-	30%
	MIXTURE OF MIDDLE GRAY BLUE	MIXTURE OR LIGHT GRAY BLUE	MIXTURE OF MIDDLE TONE GRAY GREEN	MIXTURE OF LIGHT GRAY GREEN	MIXTURE OF MIDDLE TONE	MIXTURE OF MIDDLE TONE	SAME COLOR TO CATEGORY	BACKGROUND SAME COLOR TO CATEGORY	ANOIXTO ME ANTIΘΕΣΗ		GRAY BACKWARDS
	SAME PURPLE				PURPLE LIGHT	LIGHT RED	COLOR BACKWARDS	SAME COLOR TO CATEGORY	MORE CONTRAST TO BACKWARD GEOMAP		HOVER
	SAME PURPLE					PETROL	GRAY BACKWARDS	SAME	MOVE DOWN TO INCREASE VISIBILITY		
	SAME PURPLE					SAME	HOVER	BACKGROUND SAME COLOR TO CATEGORY			
						LIGHT GREEN		HOVER			

Figure 14: Color questionnaire matrix
(https://app.optimalworkshop.com/a/5ulk10o1/optimalsort/results/f5b04973-d18e-4741-8687-de29ac9a6a7d#/t/results/questions)

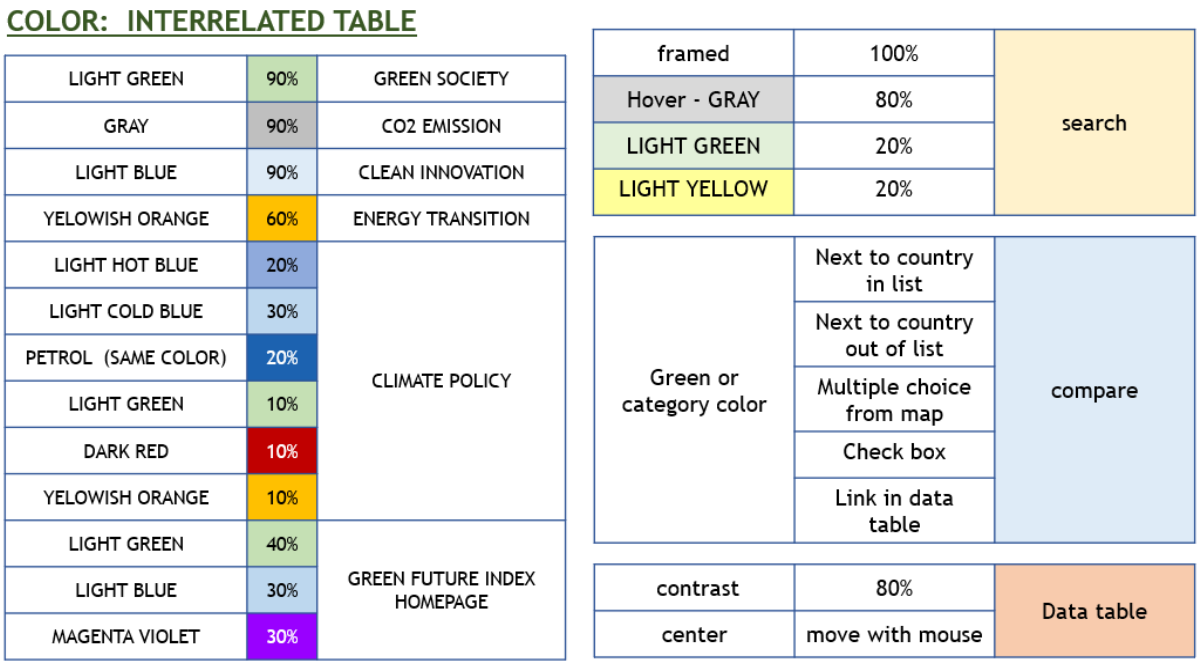


Figure 15: Color visualized with percentage

Results: SUS Scale

According to Katsanos et al., SUS scale has a lowest average of 12 participants to justify the results (Katsanos et al., 2012). Although, the 10 participants gave a score of 52,25 % which stands far away from the average 70%, what was most important was their written comments about the usability of the website. They run the SUS questionnaire altered with an open question for their suggestions, according to their mental models as student designers. Written comments verified the verbal ones (fig.16). The original Greeks was translated into English via Google translator. It is clearly stated that most of them had a difficulty with the detection of COMPARE, furthermore their proposals to improve usability are depicted in matrix fig15.

Written comments of participants:

- Unreasonably complicated site
- Difficult to compare between countries and poor choice of colors
- Search should be more visible (for example by using the corresponding color of the menu). I would prefer the menu with different colors that suits best each category. The comparison should be between more than two countries. I cannot find the way.
- I would prefer the colors on the map to match the colors green, orange, red as used for the score, in order to get a better overall picture of what is going on.
- The list of countries should be in a different box and color to stand out from the search option.
- I would also like a Greek menu
- The categories need to be better organized (colors, layout) and be able to compare data from more than 2 countries.
- 1) Difficult or even impossible to find a way to compare, 2) Why should there be a possibility to compare more countries? 3) Weak visualization of the navigation menu, maybe different colors.
- It has problem with scrolling and the choice of colors could be better
- There is no symbolic use of the categories color, black and white is tiring for the eye.
- The search is not visible and should go somewhere on the top right. Compare should be entered in the data table as an option.

Figure 16: Table of the Participant's scriben comments.(https://docs.google.com/forms/d/11m-iYPV5bkdejZu8G8ChHXD_G5PCHX-Mlk-E8DuErXw/edit#responses)

Results: Analysis with visualizations

Study results are mostly cascading, while the workflow: HYPERTEXT - THINK-ALOUD - TREE TEST - SUS - CARD SORTING, ladders via results to the upper levels of evaluation. In the beginning, Hypertext registration pointed out the information network of country performance and comparison. Afterwards, User observation Think-Aloud method revealed the best countries to spot the problematic nodes in workflow in order to verify with the tree test.

Tree tests had a key role in participants' mental model formation in order to reveal them in the following Card Sorting. On the other hand, linked analysis of Optimal Workshop Tree test, evaluated the architectural structure of the site (fig.17). First Click was found to share between interactive spatial visualization (GEOMAP) and interactive COUNTRY LIST. The results of the two tests were relevant 40%-60% (fig 18). The lowest First Click is 30% granted to the GEOMAP interface by the tool: it is not real while participants had already run an in-vivo comparison task, so they had realized that there was no point to search for comparison under the GEOMAP branch on the tool. None of the participants' first click in-vivo included DOWNLOAD REPORT & VIEW DATA interfaces, despite their situ (20% was their first click by the tool). The in-vivo tree test needed extra nodes that had not been predicted (fig.20).

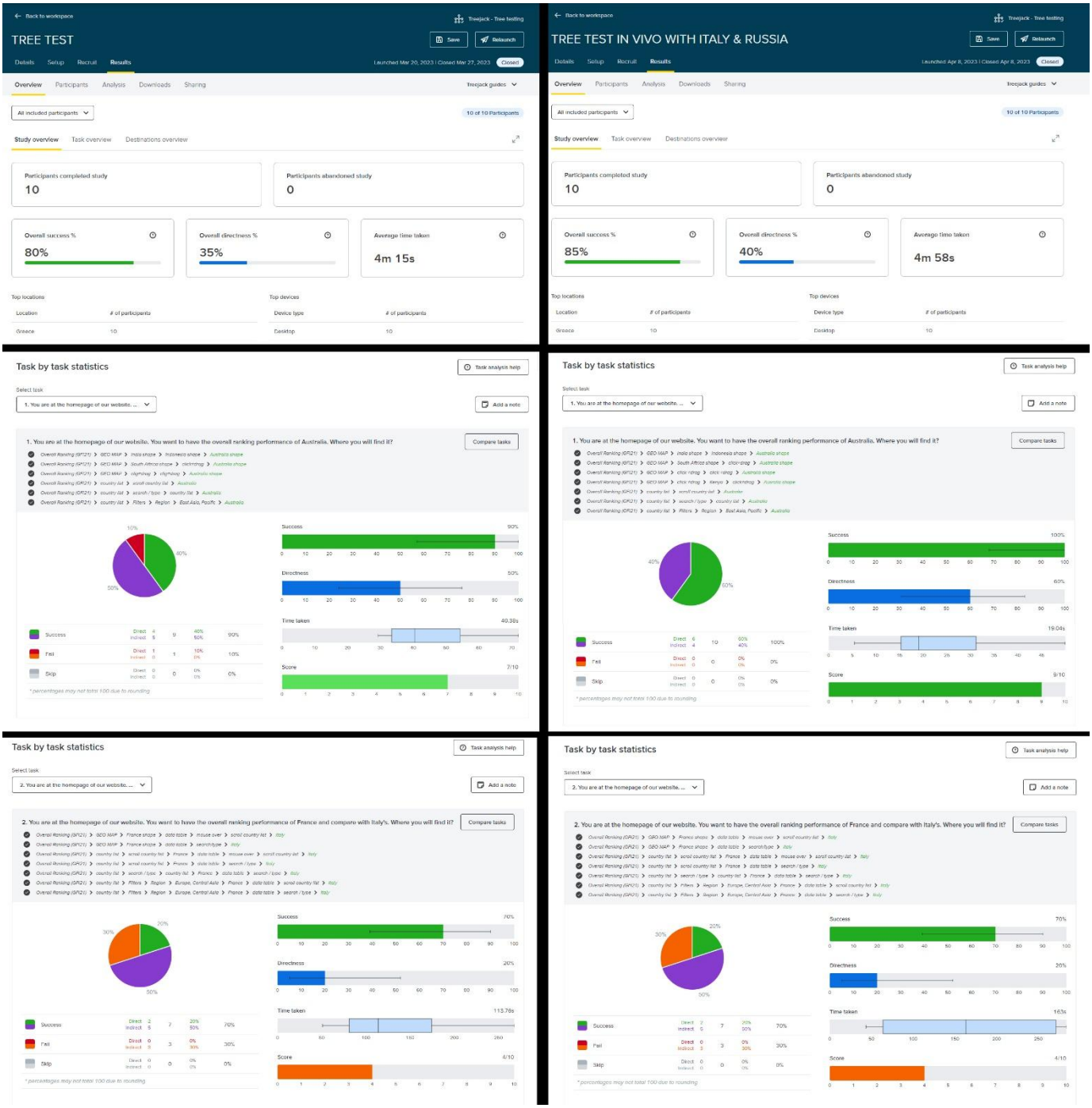


Figure 17: Tree Tests compared data analysis, as remain in Optimal Workshop platform. Compared results for both tasks.
(https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/04cd3480-cdbe-445e-9a42-50ad3729b2af#/t/results/overview/studyOverview)
(https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/f1d24ad6-b336-4bbb-bc5a-e649c4546c93#/t/results/overview/studyOverview)

First Click								
	Interaction by the tool				Interaction in-vivo			
	1st task		2nd task		1st task		2nd task	
	first	during	first	during	first	during	first	during
Download Report	-	-	-	10%	-		-	
View Data	20%	20%	-	10%	-		-	
Geo Map	40%	60%	30%	30%	40%	70%	50%	70%
Country List	40%	60%	70%	80%	60%	80%	50%	100%

Figure 18: First click.(https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/04cd3480-cdbe-445e-9a42-50ad3729b2af#/t/results/analysisTools/firstClick) (https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/f1d24ad6-b336-4bbb-bc5a-e649c4546c93#/t/results/analysisTools/firstClick

Success				
	Interaction by the tool		Interaction in-vivo	
	1st task	2nd task	1st task	2nd task
Direct Success	40%	20%	60%	20%
Indirect Success	50%	50%	40%	50%
Direct Fail	10%	-	-	-
Indirect Fail	-	30%	-	30%
Total success of Tree Test	80% success with 35% directness		85% success with 40% directness	

Figure 19: Success Analysis. (https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/f1d24ad6-b336-4bbb-bc5a-e649c4546c93#/t/results/analysisTools/taskResults) (https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/04cd3480-cdbe-445e-9a42-50ad3729b2af#/t/results/analysisTools/taskResults)

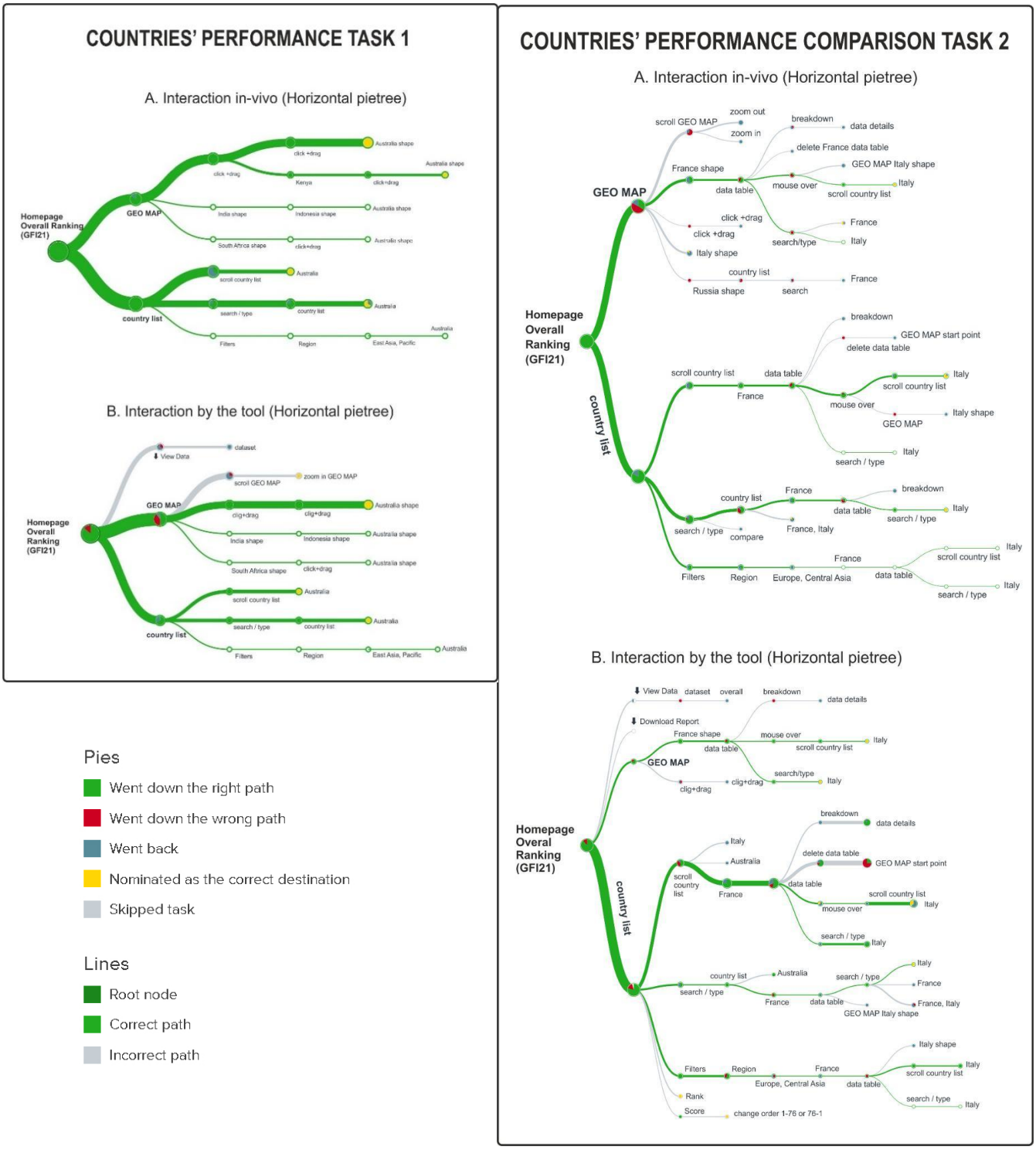


Figure 20: The pie visualizations of the destinations (horizontal) for both tree tests. (https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/04cd3480-cdbe-445e-9a42-50ad3729b2af#/t/results/analysisTools/pieTree) (https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/f1d24ad6-b336-4bbb-bc5a-e649c4546c93#/t/results/analysisTools/pieTree)

Visualizations via the pie tree of the destinations revealed the mental model way the participants used the offered tools to reach their goal. The performance task in-vivo interaction direct success destinations - after moderator's registration to Optimal Workshop platform tool - were:

> Overall Ranking (GFI21)>GEOMAP>click+drag>click+drag>Australia shape ----- 50% (30% direct)
>
> Overall Ranking (GFI21)>country list>scroll country list>Australia——————————20% (20% direct)
>
> Overall Ranking (GFI21)>GEOMAP>click+drag>Kenya>click+drag>Australia shape——----- 10% (10% direct)

The relevant direct success destinations by the tool were:

> Overall Ranking (GFI21)>GEOMAP>click+drag>click+drag>Australia shape ----- 50% (10% direct)
>
> Overall Ranking (GFI21)>country list>scroll country list>Australia——————————20% (20% direct)
>
> Overall Ranking (GFI21)>country list>search / type>country list>Australia——-----20% (10% direct)

For the second task, the countries' performance comparison, the relevant results for in-vivo interaction direct success were:

> Overall Ranking (GFI21) > country list > scroll country list > France > data table > mouse over>scroll country list > Italy—-40% (10% direct)
>
> Overall Ranking (GFI21) > country list > search / type > country list > France > data table > search / type > Italy——----20% (10% direct)
>
> Overall Ranking (GFI21) > GEO MAP > France shape > data table > mouse over > scroll country list > Italy——-----10%

While, for the interaction by the tool were:

> Overall Ranking (GFI21) < country list < scroll country list < France < data table < mouse over < scroll country list < Italy——-----20%
>
> Overall Ranking (GFI21) < country list < scroll country list < France < data table < search / type < Italy——----(10%) (10% direct)
>
> Overall Ranking (GFI21) < GEO MAP < France shape < data table < search/type < Italy——----(10%)
>
> Overall Ranking (GFI21) < GEO MAP < France shape < data table < mouse over < scroll country list < Italy——----(10%) (10% direct)
>
> Overall Ranking (GFI21) < country list < search / type < country list < France < data table < search / type < Italy——----(10%)

Overall Ranking (GFI21) < country list < Filters < Region < Europe, Central Asia < France , data table < scroll country list < Italy—---(10%)

(https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/f1d24ad6-b336-4bbb-bc5a-e649c4546c93#/t/results/analysisTools/destinations)
(https://app.optimalworkshop.com/a/5ulk10o1/treejack/results/04cd3480-cdbe-445e-9a42-50ad3729b2af#/t/results/analysisTools/destinations)

The comments of the participants during the tool-tree test reflected that the participants had no previous experience of relevant tools, beside the link of the demo tree test of Optimal Workshop. The textual description of nodes either helped (i.e. search) or disturbed them (i.e. scroll up, zoom in). High percentage of indirect success (50%) in fig.19, is verified by the visualizations of the preferred routes in fig.20. Especially for the comparison task, it is clear that there is a high possibility of user's drifting around the website until they reach their goal.

Comments of the participants were crucial to the Card Sorting procedure. Firstly, 3 participants revealed a relief about the countries involved in the query as well known, declaring their inconvenience with country spatial detection. Most important were the comments of the tree test, defining the problematic nodes, which could be arithmetically declared as:

A.	SEARCH	1/10	didn't see it at all
		2/10	used it automatically
B.	COMPARE	8/10	gone through without perception
C.	DATA TABLE	7/10	didn't realize that was the answer to task

Figure 21: The problematic nodes.

Thus, the problematic nodes were of high importance within card sorting. In order to enhance usability, the moderator insisted on their proposals as designers, which have been already depicted in fig.15 and fig.16.

During the Card Sorting, the procedure of drag & drop was found to be quite convenient to visualize the participant's mental models (fig.6). That participant stated that he needed extra time to tidy up his categories in order to visualize them in a real place. In addition, all participants paid attention to the order the pillar interfaces would appear in the category menu. 50% preferred the climate policy pilar interface to move next to indice interface for the 40% weighting.

Card sorting's two explanatory and statistical findings were considerate, with respect to the comments, to propose for the usability of the website. Color results could be taken under consideration for a more symbolic graphic approach of the website.

Conclusions

The Electronic Media participants used to investigate the web site were most crucial. Moderator suggested a 24/7 computer in contrast to a laptop wi-fi. Most of them accessed the site via Google Chrome browser, while laptop lacked site stability of visibility. Suggestions such as addition of multiple languages choice and modification of data / comparison table situ are omitted via Microsoft Edge Bing browser. In order to reach a conclusion for the 60% finding of Explanatory and Statistical Analysis of Card Sorting about the situ of data table, it was highly recommended for the moderator to insist in browser and media usage. In relevant research, a moderator besides the registration of the hypertext should investigate and conclude about the best media or browser to evaluate a website. Participants should operate under certain circumstances. The website operation under various media or browsers could be stated in the moderator's / evaluator's essay. To conclude, while Google Chrome is mainly used (64.38%), there is a suggestion to improve the visibility of data table, with respect to the appearance situ, for the specific browser (Statcounter, 2024).

Regarding the second finding of Card Sorting, sponsors lie on the header, following the MIT website's specifications - which was stated correctly by a participant. The overwhelming 70% for the sponsors to degrade to the footer situ is not the point. It is most possible the lack of site visibility (Nielsen usability law No.1) that confused the participants. It was stated several times "it is annoying for the sponsors to remain visible all the time if the category menu disappears after scrolling". Inferentially, there is a necessity to modify the stability of the category menu visibility. MIT had already altered the website design in the following versions of the Green Future Index (The Green Future 2022, The Green Future 2023).

The alteration in Card Sorting procedure to evaluate graphic design was well approved by participants, while the procedure interfered mainly with the subject of their curricular studies. It seemed they enjoyed much to suggest alternative situ for the interfaces being an MIT web designer themselves. Probably the procedure will fit among the members of usability groups or website designers' associations. Definitely a vast number of 50 participants will positively affect the results since visualization is a concept most controversary. Definitely moderator should be more specific and firmer: Participants should make use of the specific media and browser suggested, otherwise the results should be excluded from research. During the procedure categories could be proposed, in order to minimize the vast number of categories, to alleviate moderator's work (42 categories for 10 participants). A Delphic Card Sorting could work (Paul, 2008). On the other hand, the procedure may help the IT's, since category onomatology pointed out a necessity to improve programming code. Finally, in order to visualize the participant's mental models, it is recommended to encourage them to tidy up the visual or physical table according to their spatial suggestions. The alteration will certainly work under this special participant's ability of designer's aspect.

Furthermore, Card Sorting found to be able to work with indices workflow construction, among human centered participatory methods (Drago, 2022; Moreira, 2012). The method could work within specific scientific groups aware of the separate indexes construction theory each time. Results probably will be similar to that of questionnaire, or focus group other than Card Sorting linked visualizations offer a perspective of statistical analysis.

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