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Explaining the Cognitive Aspects of Elderly's Space Perception in Architecture based on Age, Gender and Length of Residence

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ABSTRACT: Space perception is the first step towards recognizing and communicating with the environment. Despite similar perception systems in human beings, the perception of surroundings is different from person to person. Therefore, different perceptions of similar objective spaces can result from several factors, and only one influential factor cannot determine the perceived subject. This study seeks to identify cognitive aspects of different areas of the elderly perception in architecture and determine the cognitive characteristics of independent elderly residents in Shahrak-e-Gharb of Tehran to obtain primary data and their perceptual, cognitive characteristics using cognitive maps. This is a theoretical-applied study with a qualitative-quantitative method. The library method was used for data collection, field observation to measure the status quo, and interview and cognitive maps technique to collect research data. The sample size of 38 persons was calculated using the Cochran formula. According to the findings, the average perceived cognitive paths of the men group were higher than that of women, and the average perceived cognitive places of the women group were higher than that of men. Aging and length of residence do not affect the number of perceived elements. As aging occurs, the number of perceived places decreases, and the number of perceived paths increases. Most recognized spaces in cognitive maps represent a place for people's memories. So, cognitive spaces should be improved before the cognitive abilities of the elderly decline

Keywords: *Cognition, Senior Citizens, Elderly perception, Cognitive Map.*

INTRODUCTION

People communicate with the built environment through psychological processes of perception and cognition. As transmitters, surroundings always send data about themselves in different dimensions and forms. The final product of the cognitive mapping process is a cognitive map. Over the past three decades, scientists and psychologists have conducted studies in various cognitive maps and their role in place identification and mental image building. The cognitive map may be defined as a scheme of the world we live in. For example, Garling points out that "long-term stored information about the relative place of objects and phenomena plays a role in the mind in the form of memory" (Garling et al., 1981). Therefore, the human mind remembers the information that reflects one's memories and mental images, which may be incomplete, more or less schematized, or distorted.

One of the essential issues that should be considered in architecture is the process of feeling, perception, and cognition of the environment that paves the way for humans to experience the place. To build spaces compatible with perceptual-behavioral needs, users need to understand the human-environment relationship accurately. In other words, in environmental design, understanding the relationship between perceived elements and environment properties and its effect on the user's behavioral, emotional, and perceptual levels is essential. Aging is a natural process every person encounters, along with consequent changes in their physical abilities and psychological needs that require serious attention. According

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*Corresponding Author Email: *hos.soltanzadeh@iauctb.ac.ir* to the available statistics, the aging rate in Iran is growing, and improvements in the social and economic situation and advances in medical sciences can reduce mortality and increase life expectancy and the elderly population growth. Due to the significant changes in humans' physiological and psychological characteristics in old age, the elderly perceive their surroundings differently from other age groups. Therefore, this study seeks to understand how to perceive the elderly space using cognitive maps. This research is essential in two aspects: first, theoretically, it allows for further evidence that spatial configuration is the root cause for the formation of cognitive maps. Second, experimentally, the methodological point of view allows the use of methodology as a valuable tool to perceive space. The importance of subjective representation of spatial configuration remains unknown in cognitive studies. The relationship between physical elements and spatial perception of the elderly reveals the necessity of paying attention to the role of space audiences in the physical-spatial construction of the environment. Therefore, as a challenge for designers in the promotion process of spatial quality, the role of space audience in space perception is neglected. In order to take effective countermeasures against multi-dimensional social problems resulting from old age, it is essential to implement projects which improve the cognitive abilities of living space in the present era for older people who have relatively low cognitive abilities. The present study seeks to respond to the components affecting the elderly's perception and understanding of their surroundings and measure the elderly's knowledge of their living environment through finding appropriate responses for the following questions:

The present study seeks to respond to the components affecting the elderly's perception and understanding of their surroundings, and measure the elderly's knowledge of their living environment through finding appropriate responses for some questions; specifically including: 'what are the factors affecting the elderly's space perception and cognition?', 'how do age and length of stay affect space perception?', 'how aware of the living environment are the elderly?', 'what components affect elderly's knowledge of their living environment?' and 'how do the elderly relatively recognize different parts of their living environment?'

Research Background

Researches into the elderly's space perception and cognitive maps are divided into two general categories:

The first category includes the studies on cognitive maps: For the first time, through a series of inventive experiments on rats trained to find food only from a single path, Tolman found that, when given a chance to go straight to food, the animal used that path and headed straight toward the food. According to Tolman, the rats gradually produced an image of their environment, which was later used to find a target. This image is the cognitive map (Tolman, 1948). Studying three cities, Lynch introduced five elements, including path, landmark, edge, node, and district, as the factors affecting citizens' image of the city (Lynch, 2004, 119). According to Kim, perception and cognition are the outcomes of human interaction and relationship with the environment as part of psychological processes (Kim, 1999, 39). Hart and Moore defined spatial cognition as "the knowledge and internal or cognitive representation of the structure, entities, and relations of space; or in other words, the internalized reflection and reconstruction of space in mind" (Hart & Moore, 1973, 248). According to Stea, cognitive mapping comprises a series of psychological transformations by which an individual acquires, stores, recalls, and decodes information about the relative places and attributes of the phenomena in their everyday spatial environment. So, cognitive mapping is a tool for building, interpreting, and dealing with complex sets of information in different environments. These are visible physical environments and a collection of memories experienced in the environment that influence our everyday experiences (Stea, 2017, 23). Appleyard believed that the use and form are factors affecting the mental image (Appleyard, 1970). Evans argued that cognitive mapping could be different from other cognitive representations of information such as signs, places, and maps. "Cognitive maps represent the spatial relationship between regions, relative distance, navigation and main directions from different parts" (Evans & Pezdek, 1980). Eraydin evaluated Lynch's elements and investigated continuity, complexity, diversity, integrity, and hierarchy in the environment (Eraydin, 2007, 14).

Bennett studied cognitive mapping and routing in animals and shortened their distance (Bennett, 1996). Vasudevan et al. studied cognitive mapping by mobile robots (Vasudevan et al., 2007). Shokoohi categorized the cognitive map elements of people aged 20-40 into five sets: spatial, mosaic, sequential, non-patterned, and incomplete, based on citizens' maps and Lynch's theory (Shokouhi, 2003). Based on Lynch's theory and cognitive maps, Zengin et al. examined perceptual differences according to distinctive places in the environment, irregularities, and rhythm (Zengin et al., 2013). In their research, Mahdzar and Safari found that Lynch's 2-D elements, i.e., paths, edges, and districts, influence perception of the environment. Spatial geometry creates spatial unity and better perception of the environment, so to develop spatial integration and ease of environment perception, appropriate spatial geometry is required (Mahdzar & Safari, 2014). According to Pei et al., human perception is essential feedback that designers can use to improve the design schemes. They also proposed an auxiliary method for pre-evaluating the architectural design goals and providing recommendations for architects to optimize the schemes (Pei et al., 2021). Park et al. maintained that humans are adept at learning the latent structure of the relationship between abstract concepts and can build a cognitive map from limited experiences. However, they included examining the cognitive map's internal representations because they are unobservable and differ across individuals (Park et al., 2021). Jamshidi and Pati proposed four categories of theories on human wayfinding in interior environments: theories of perception, theories of spatial knowledge development, theories of mental representation of spatial knowledge, and theories of spatial cognition (Jamshidi & Pati, 2021).

The second category includes the studies on cognitive maps of the elderly: Kwon et al. used cognitive mapping to identify and analyze the cognitive status of the elderly's residential environment (Kwon et al., 2018). Iaria et al. stated the effect of age on the representation of cognitive maps and spatial orientation skills in the elderly and the youth (Iaria et al., 2009). Gary et al. examined personal knowledge of the elderly about their surroundings and age-related differences in environmental cognition using cognitive mapping (Evans et al., 1984). Borella and Meneghetti conducted studies on urban route learning using cognitive mapping to investigate the effect of age on building cognitive maps (Meneghetti et al., 2012). Finally, Rivero Jimenez et al. evaluated the phenomenon of loneliness in old age using De Jong Gierveld Loneliness Scale through monitoring a group of elderly's social interactions and mapping their daily loneliness/interaction patterns (Rivero Jimenez et al., 2021).

Researches on the elderly's space perception using cognitive mapping focus on perceptual differences among the elderly and young people, and the only variable studied is age. In contrast, this study focuses only on the elderly over 60 and their age, gender, and length of residence.

MATERIALS AND METHODS

This study is theoretical-applied. The research method is qualitative and quantitative in two different parts. The qualitative research method is used to draw and investigate cognitive and perceptual maps. In the analysis of cognitive maps, the qualitative-quantitative research method is used according to the defined variables. Therefore, multiple mixed research methods are used in this study.

The Population

The study consists of the elderly aged 60-80 with general consciousness and movement abilities and willingness to participate, and a high perceptual and cognitive function level. Members of this group could communicate without problems and live independently (without the help of children or nurses). The sample size was determined using the Cochran formula. (Formula 1)

$$n = \frac{NZ^2pq}{Nd^2+Z^2pq-d^2}$$

Formula 1: Cochran formula

Placing the obtained values into the formula, we had:

$$n = \frac{40.3368}{1.0629} = 37.94976 \approx 38$$

Therefore, the sample required for this study includes 38 people.

In order to conduct assessment studies, field observation was carried out. So that, in the study area, the elderly were asked to draw a cognitive map of their surroundings. Their sketches were classified based on the type of knowledge and cognition using the classification table of various Appleyard cognitive maps. Drawing mental images and basic maps required learning how the elderly perceived space and identified their surroundings. The sketches and cognitive maps were classified into two groups based on the type of cognition. Then the cognitive characteristics of the elderly were compared and analyzed based on age, gender, and length of residence. Age and the number of perceived elements specified in maps (dots and lines) were analyzed to investigate their correlation with each other. Statistical analysis was performed using M.S. Excel, SPSS, and scatterplot. The tests used in this study included the Chi-Square Test of Independence, Pearson and Spearman Correlation Coefficients.

Study Area

The study area is in District 2 of Tehran (Fig. 1), which includes eight sub-districts (Fig. 2), located in Sub-district 8, Shahrak-e Gharb, Derakhti area including Sepehr Park, part of Dadman Boulevard, Derakhti Street, and part of Sepehr Street along with alleys and commercial uses connected to the main streets listed. According to the statistics provided, the study area has a higher average age than other areas (Fig. 3). As mentioned earlier, the classification of cognitive maps into two groups of dots and lines is based on the Appleyard classification. Fig. 4 displays the dot and line maps in the study area, developed by the authors to explain the two map types. According to the statistics on the elderly population provided by the Director-General of Health Domain of Tehran Municipality, Iran has an elderly population of 8231000, one million of which live in Tehran, that is 10.3% of the people of Tehran. According to the statistics, districts 3 with 21%, districts 1 and 6 with 17%, and districts 1,2,3,4 and 5 have the highest elderly population. (Tasnim News Agency, 2020).

RESULTS AND DISCUSSION

Appleyard (1970) categorized cognitive maps according to the types of cognitive maps he obtained from Venezuelans. According to the Appleyard classification, maps are mainly composed of two main sequential elements (paths) or spatial elements (single buildings, places). More complete maps use a combination of both. In sequential maps, the sections are connected, and connections are dominant. In spatial maps, the sections are often scattered on the map, and connections are accidental. In each of these maps, four subgroups are identified. The classification of different types of cognitive maps is displayed in Table 1 (Appleyard, 1970).

Based on the Appleyard classification, cognition by dot and line

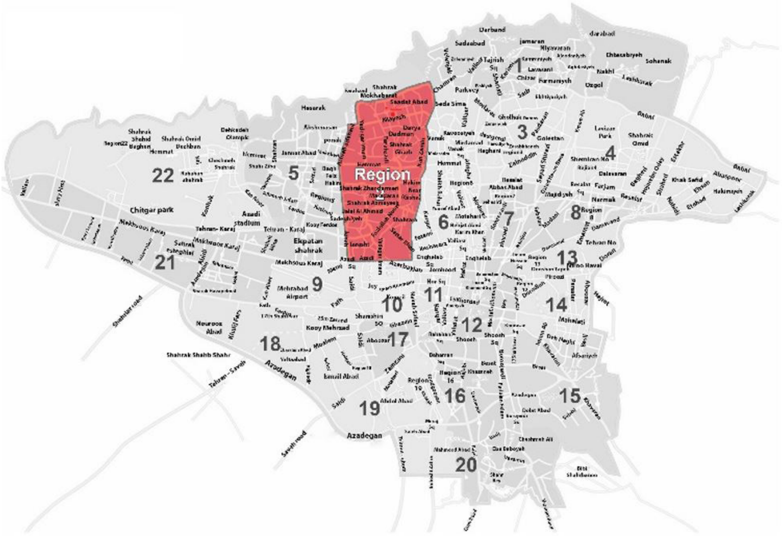


Fig. 1: Districts of Tehran (Vakil, 2021)

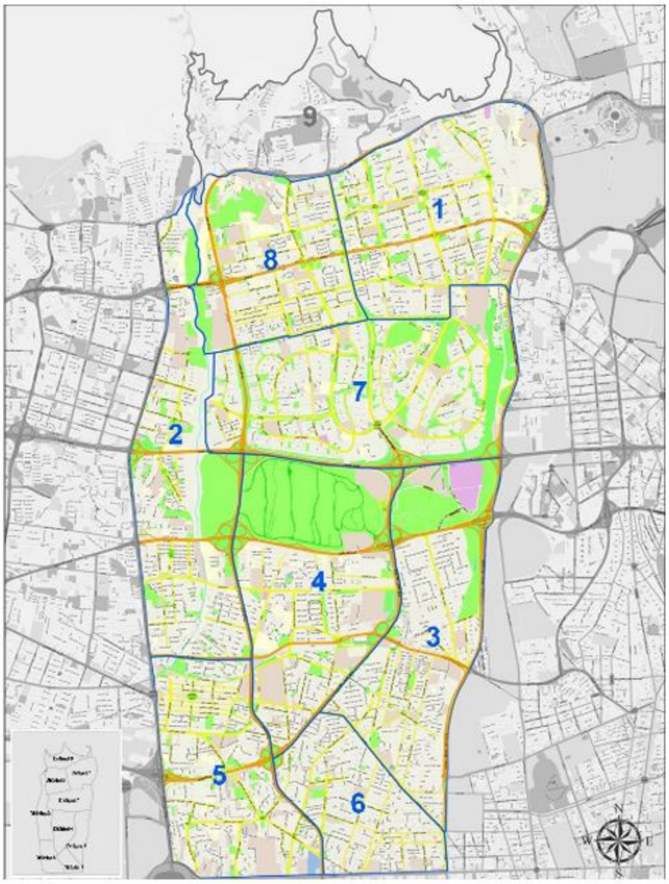


Fig. 2: Sub-districts of District 2 of Tehran (Vakil, 2021)

Fig. 3: The study area (Vakil, 2021)

Fig. 4: Cognitive maps of the study area in two dot and line types according to the Appleyard classification (adapted from Appleyard, 1970)

is classified as a refined concept. Accordingly, line maps that focus on roads and paths and dot maps that are location-based were separated. 2 examples of maps drawn by the elderly are listed in Table 2, which are classified into dot and line maps.

Table 3 shows that 52.6% of the male participants drew a line map, and 47.4% of the female participants drew a dot map.

In the following, some descriptive statistics on quantitative variables such as age, number of paths, number of places, and number of perceived elements detected by the elderly are investigated.

According to Table 4, based on the information obtained about age, the age range of the elderly participants was 15, the minimum age was 61, and the maximum age was 76. Thus, the average age was 67.7105. Standard deviation and age variance were 4.34280 and 18.860, respectively. The analysis of other variables showed relatively similar results.

In the following, the expected average of quantitative variables in the research needs to be ensured. Since the population

Table 1: Classification of cognitive maps by Appleyard (Appleyard, 1970)

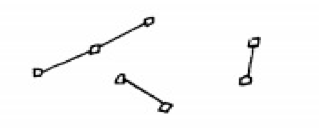
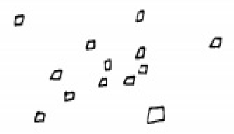
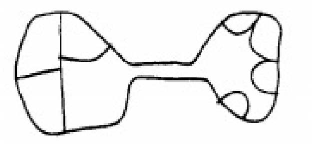
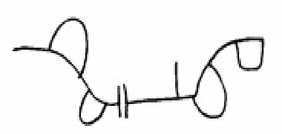
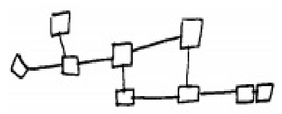
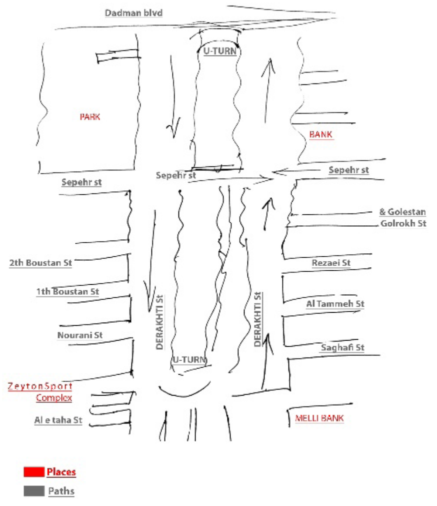
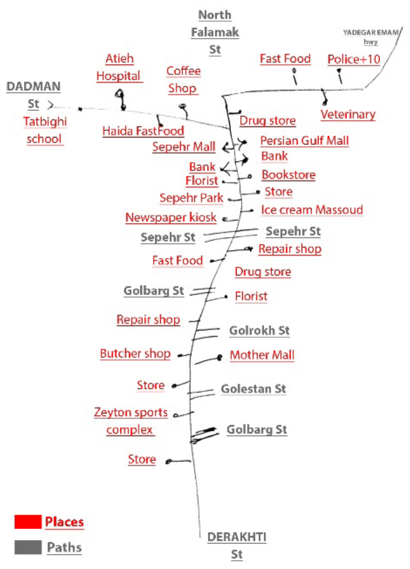
Sequential elements	Spatial elements
	
Fragmented	Scattered
	
Chain	Mosaic
	
Branch-ring	Connected
	
Grid	Patterned

Table 2: Author's Appleyard-based Classification of cognitive maps drawn by participants

Line map	Dot map
	

number of 38 is above 30, the assumption of normality of the average score of the research variables is not rejected, so parametric tests are used. First, the average age of men and women is compared using an independent t-test. Then, before the test, the age variance is compared at gender level using the nonparametric Levene test. The results are listed in Table 5.
According to Table 5, because the significance level is higher than 0.05, variance equality is confirmed. Therefore, an independent t-test needs to test the average age, assuming the equality of variances. The results of the average age test based on gender and using the t-test of two independent samples are reported in Table 6.
According to Table 6, the average age of women and men is 67.2778 and 68.1, respectively. Since the significance level of t-test=-0.577 is calculated as P=0.567, which is above 0.05, there is no significant difference between the average age of men and women. Therefore, considering the map type and gender, the Chi-Square Test of Independence investigates the relationship between the type of map and gender.
According to Table 7, 14 elderly women drew a dot map, but according to gender independence assumption and the type of map, the value of 8.5 was expected.
According to Table 8, because the test (0.001) significance level contains less than 0.05, there is a significant relationship between map type and gender with a 5% error. Therefore, based on Table 7, it is concluded that women tend to draw dot maps and men tend to draw line maps. According to Appleyard's studies, dot maps convey place-based cognitive memory focusing on remembering the places. In contrast, line maps convey path-based cognitive memory with a focus on referring to streets and paths.
In the following, the average number of paths used by men and women is compared.
Because the significance level below 0.05 is calculated, variance equality is not assumed. Therefore, an independent t-test with the assumption of variance inequality is used to test

Table 3: Scatterplot of participants based on qualitative variables

Variable	Item	Frequency	(%) Ratio
Gender	Female	18	47.4
	Male	20	52.6
Map type	Dot	18	47.4
	Line	20	52.6
Total		38	100

Table 4: Some descriptive statistics of quantitative variables of the research

Variable	Number	Range	.Min	.Max	Average	SD	Variance
Age	38	15	61	76	67.7105	4.34280	18.860
Length of residence	38	37	3	40	18.2895	10.50073	110.265
Number of paths	38	13	1	14	5.1316	3.98084	15.847
Number of places	38	18	0	18	7.7632	4.94529	24.456
Number of perceived elements	38	29	2	31	12.8947	5.71763	32.691

Table 5: Results of comparison test on age variance in terms of gender

Variable	Levene test value	Significance
Age	0.445	0.509

Table 6: Results of comparison test on average age in terms of gender

Variable	Gender	Average	SD	T-Test value	Degrees of Freedom	Significance	Confidence interval 95% of the difference	
							Lower limit	Upper limit
Age	female	67.2778	4.08448	-0.577	36	0.567	-3.70988	2.06543
	male	68.1	4.63283					

the average number of paths (Table 9)

According to Table 10, the average number of paths for women and men was 3.3333 and 6.75, respectively. Because the significance level of t-test =-3.015 is P=0.006, which is lower than 0.05, there is a significant difference between the average number of perceived paths between men and women, which is significantly higher for men than women. Similarly, the average number of places used by men and women is compared.

According to Table 11, variance equality is confirmed.

According to Table 12, the average number of perceived places for women is 10.9444, and for men, it is 4.9. Because the significance level of t-test=4.722 is P=0.001, i.e., below 0.05, there is a significant difference between the average number of perceived places for men and women. Thus, the average places are significantly higher for women than men.

The average age is compared considering dot and line map types.

According to Table 13, variance equality is confirmed.

According to Table 14, the average age is 67.3333 for dot map and 68.05 for line map. Because the significance level of t-test=-0.503 is calculated as P=0.001, the average age for line and dot maps is not significantly different.

According to Table 15, variance equality is confirmed.

According to Table 16, the average length of residence is 15.6667 for the dot map and 20.65 for the line map. Since t-test=-1.484 has a significance level of P=0.146, there is no significant difference between the average length of residence in the two types of maps.

Using correlation coefficient, the relationship between quantitative and rank variables of the research is investigated. Due to quantitative age and length of residence, the Pearson correlation test investigates the relationship between the two variables.

Table 17 shows that the correlation coefficient between age

Table 7: Observed and expected frequency of gender in terms of map type

Crosstable of gender and map type			**Type of Map**		**Total**
			Dot	**Line**	
Gender	Female	Observed Frequency	14	4	18
		Expected Frequency	8.5	9.5	18
	Male	Observed Frequency	4	16	20
		Expected Frequency	9.5	10.5	20

Table 8: Results of independence test between map type and gender

Parameter	**Values**
Chi-square Statistics	12.685
Degrees of freedom	1
A significance level of test	0.001

Table 9: Results of comparison test on the variance of the number of paths in terms of gender

Variable	**Levene test value**	**Significance**
Number of paths	8.845	0.001

Table 10: Results of comparison test on the average number of paths in terms of gender

Variable	**Gender**	**Average**	**SD**	**t-test value**	**Degrees of freedom**	**Significance**	**Confidence interval of 95% the difference**	
							Lower limit	**Upper limit**
Number of paths	female	3.3333	1.71499	-3.015	0.006	24.367	-5.7530	-1.08004
	male	6.75	4.73370					

Table 11: Results of comparison test on the variance of the number of places in terms of gender

Variable	**Levene Test value**	**Significance**
Number of placeS	0.003	0.958

Table 12: Results of comparison test on the average number of perceived places in terms of gender

Variable	Gender	Average	SD	t-test value	Degrees of free-dom	Significance	Confidence interval of the 95% difference	
							Lower limit	Upper limit
Number of places	Female	10.9444	3.70170	4.722	36	0.001	3.44857	8.64032
	Male	4.9	4.14094					

and length of residence (r=-0.153) has a significance level of P=0.358, higher than the error value of 0.05. Therefore, the correlation between age and length of residence is negative, but the relationship with 5% error is not significant. In other words, there is no statistically significant relationship between age and length of residence.

Figure 5 shows a negative relationship between age and length of residence (negative slope). This means that older people have a lower length of residence, but this relationship is not statistically significant.

According to Table 18, the correlation coefficient of r=-0.025 has a significance level of P=0.881, i.e., the correlation between age and number of perceived elements is negative but weak and, therefore, non-significant.

According to Fig.6, there was a negative relationship between age and the number of perceived elements (negative slope). Older people have fewer perceived elements, but the relationship is statistically non-significant.

Table 13: Comparison of age variance in terms of map type

Variable	Levene test value	Significance
Age	0.001	0.984

Table 14: Results of average age comparison test in terms of map type

Variable	Map type	Average	SD	*t*-test value	Degrees of freedom	Significance	confidence interval of the 95% difference	
							Lower limit	Upper limit
Age	dot	67.3333	4.44575	-0.503	36	0.618	-3.60754	2.17420
	line	68.05	4.33438					

Table 15. Results of comparison test on the variance of the length of residence in terms of map type

Variable	Levene test value	Significance
Length of residence	0.840	0.365

Table 16. Results of comparison test on the average length of residence in terms of map type

Variable	Map type	Average	SD	t-test value	Degrees of freedom	Signifi-cance	confidence interval of 95% the difference	
							Lower limit	Upper limit
Length of residence	dot	15.6667	4.44575	-1.484	36	0.146	-11,79260	1.82953
	line	20.65	4.33438					

Table 17: Correlation coefficient between age and length of residence

Variable	Parameter	Length of residence
Age	Pearson correlation coefficient	-0.153
	Significance	0.358
	Number	38

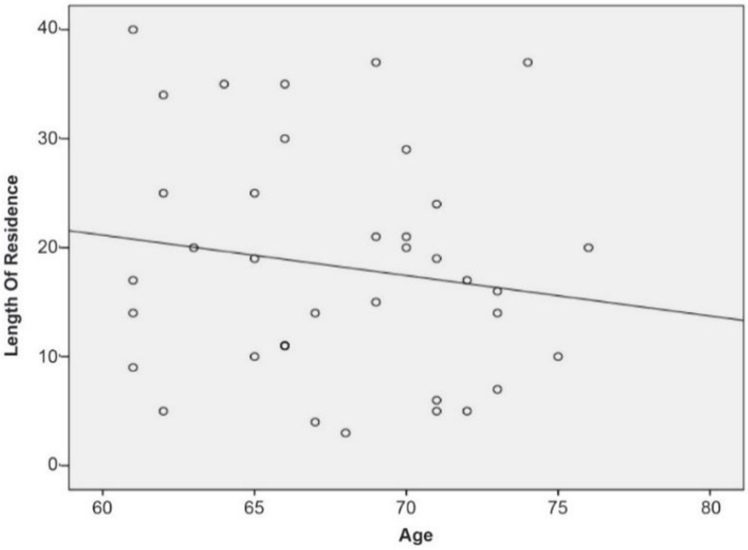


Fig. 5: Scatterplot of age vs. length of residence

Table 18: Correlation coefficient between age and number of perceived elements

Variable	Parameter	Number of perceived elements
Age	Pearson correlation coefficient	-0.025
	Significance	0.881
	Number	38

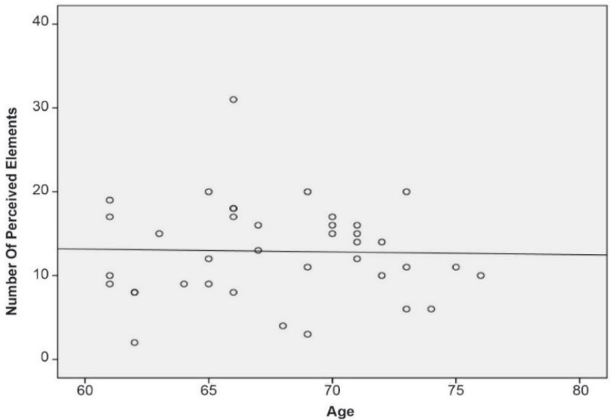


Fig. 6: Scatterplot of age vs. number of perceived elements

Table 19: Correlation coefficient between age and number of perceived places

Variable	**Parameter**	**Number of perceived places**
Age	Pearson correlation coefficient	-0.343
	Significance	0.035
	Number	38

According to Table 19, the correlation coefficient of r=-0.343 has a significance level of P=0.035, i.e., the correlation between age and the number of perceived places is negative and significant.

According to Fig. 7, the number of perceived places decreases with age. Also, the relationship is statistically significant.

According to Table 20, the correlation coefficient of r=0.390 has a significance level of P=0.016, i.e., the correlation between age and number of paths is positive and significant. This means that as aging occurs, the number of perceived paths increases.

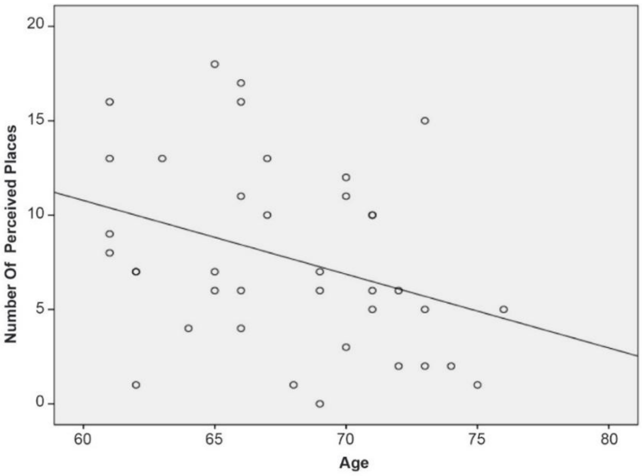


Fig. 7: Scatterplot of age vs. number of places

Table 20: Correlation coefficient between age and number of paths

Variable	Parameter	Number of paths
Age	Pearson correlation coefficient	0.390
	Significance	0.016
	Number	38

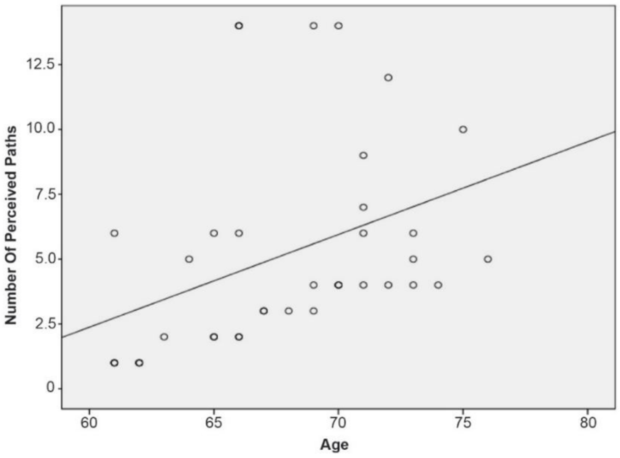


Fig. 8: Scatterplot of age vs. number of perceived paths

Table 21: Correlation coefficient between the length of residence and number of perceived elements, places, and paths

Variable	Parameter	Length of residence
Number of perceived elements	Pearson correlation coefficient	-0.052
	Significance	0.758
	Number	38
Number of perceived places	Pearson correlation coefficient	-0.210
	Significance	0.206
	Number	38
Number of perceived paths	Pearson correlation coefficient	0.187
	Significance	0.262
	Number	38

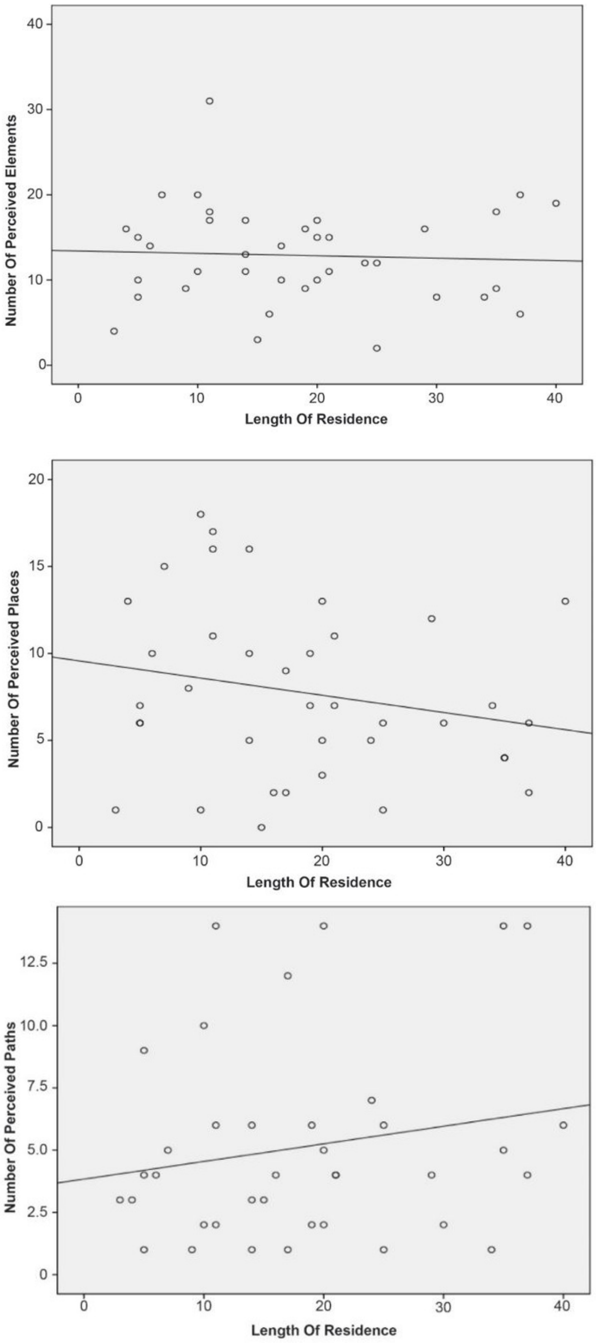


Fig. 9: Scatterplot of the length of residence vs. number of perceived elements, places, and paths

According to Figure 8, older people have more paths, which is statistically significant.

According to Table 21 and Figure 9, people with more extended residence have fewer perceived elements and places but more paths; however, none of the relationships are statistically significant.

CONCLUSION

This study aims to investigate the cognitive characteristics of the elderly and the perception of the living environment by the independent elderly residents in Shahrak-e-Gharb, Tehran. To improve the living conditions of the elderly, independent elderly living should be taken into care, as the number of elderly households with 1 or 2 members is increasing. The elderly have their psychological, physiological, and social needs due to old age. Most older people, despite such limitations, handle themselves very well, and their capabilities are still extensive, and if they are provided with a suitable environment, they can maximize their capabilities. To create an independent life more and more, it is essential to use cognitive and physical residual abilities. In line with the research goals, 42 elderly people aged 60 to 80 were asked to determine where they lived. Meanwhile, 38 valid samples were analyzed for variables such as gender, age, length of residence, type of cognitive map, and several cognitive elements (places and paths). In contrast, the relationship between nominal variables (type of cognitive maps, gender) was cross-analyzed.

The maps indicate that men tend to perceive space and create a mental image based on paths, while women's space perception is based on places, including commercial places. The number of perceived places for the female group was higher than that of men, but the number of men's perceived paths was higher than that of women's. Aging did not affect the use of cognitive maps of line and dot types.

The results from cognitive maps were unexpected in some aspects. It was assumed that with increased length of residence, the number of perceived elements, i.e., places, and paths would increase while increasing the length of residence did not affect the mentioned cases. Also, aging did not affect the number of cognitive elements. However, it impacted a correct perception of places and paths, i.e., more errors occurred in perceiving parallel and cross streets and locating the places. With aging, the number of places mentioned on the map decreased while the number of paths mentioned on the map increased. So, it is concluded that with aging, space perception and the mental image are forms of paths, and less attention is paid to places. According to the maps, as communal spaces, parks had a positive effect on the space perception of the elderly. All the elderly pointed to parks and connected streets and places, and when locating those spaces to draw their cognitive maps, they had fewer mistakes. It is concluded that green and communal spaces positively affect the minds of the elderly in recalling the surrounding spaces. Therefore, in designing unique spaces for the elderly, the determinant factors are cognitive and perceptual characteristics of the elderly, formation of mental schemes of the elderly from space, and distinguishing the paths using perceived elements for the space to be welcomed and changed into a familiar place.

Although architects try to design spaces from user's insights, the point noted in this research is the differences in the elderly's perception of a similar objective space. Users with no professional experience have limited knowledge and ability to perceive space, so obtaining feedback from users and evaluating the design objectives makes the designing difficult for architects and designers. This research collected the elderly's bio-feedback from their living environment using cognitive maps to provide a visual presentation for understanding the perceptual differences of the elderly. In improving the project, designers no longer need to empirically examine or describe the vague and non-quantitative minds of the elderly since the cognitive data and bio-feedback can provide more scientific and objective evidence to optimize the unique scheme for the elderly. This method is expected to help improve the design and provide evidence-based recommendations to designers.

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