The Effects of Greenery in Balconies of Apartments on People's Well-Being: Using Virtual Reality

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Abstract

The issue of well-being in the built environment has received considerable critical attention in recent years. Especially during COVID-19, when people had to stay indoors and stay away from green spaces, the importance of balconies increased. The paper will in particular focus on the potential to design balconies with sufficient greenery in buildings that contributes to people's well-being. To test this hypothesis, virtual reality (VR) technology and experiments were conducted with 45 participants. Virtual reality is a tool that provides the conditions for users to immerse themselves in their surroundings. Participants were randomly assigned to three separate groups, each consisting of two different VR environments and asked them oral questions based on a standard questionnaire (well-being in the built environment) to test which balcony is more effective in increasing well-being. The importance and originality of this study is that it evaluates well-being on balconies via virtual reality.

The results show that greenery on the balcony could affect people's well-being. The most obvious finding to emerge from the analysis is that greenery on balconies has significant differences in well-being. In such balconies, people feel happier, satisfied, connected to others, have independence and have the ability to do something successfully, which leads to better mental health. Further analysis showed that the amount of greenery on the balcony makes no difference. In other words, with a small number (for instance, number of pots), the well-being can be improved. Moreover, the tests revealed that individuals of different ages and gender have no major significance in well-being on balconies.

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1. *Introduction*

The issue of well-being in the built environment has received considerable critical attention in recent years. The increase in the population and the price of housing and land in urban life, especially in big cities, has led to living in apartments, which has caused many problems over the years [1]. Among the problems, exposure to bad conditions of the built environment has been shown to be related to adverse effects on mental health [2].Whereas, today it is less taken into account during the designing progress[3]. An inappropriate physical condition in buildings is associated with increased risk of stress which leads to mental disorders and depression [4] Mental health includes two aspects: the first aspect is called negative mental health, which includes mental disorders and second is named positive mental health, which includes optimal functioning and general well-being. Despite their correlation, these two aspects are different.[5][6] and evidence supports the fact that high well-being has beneficial points for general health, longevity, productivity and social relationships[7]. Well-being, which is given a lot of attention nowadays, is divided into objective (Eudemonic) and subjective (Hedonic) groups[8].Subjective well-being includes satisfaction with life, positive emotions and the absence of negative emotions, and objective well-being related to individuals' goals and their ability to perform properly in line with one's goals.[9]Previous studies have agreed that subjective well-being is a broad topic that refers to evaluations of the quality of one's life and includes both affective and cognitive[10].Increased subjective well-being correlated with improved sleep quality and decreased blood pressure, so it can be said that subjective well-being affects physical health, mental health, reduces the risk of death and increase better social relations. Consequently, well-being plays an important role in quality of life[11].Subjective well-being also has an impact on how individuals perceive their profession. A number of studies show that higher subjective well-being can increase higher income, and increase productivity and reduce fatigue or stress in work. The data suggests that people's satisfaction with the residential setting in housing is dependent, at least in part, on the effective use of the open spaces nearby one's residential building [12] and affects their social interaction.

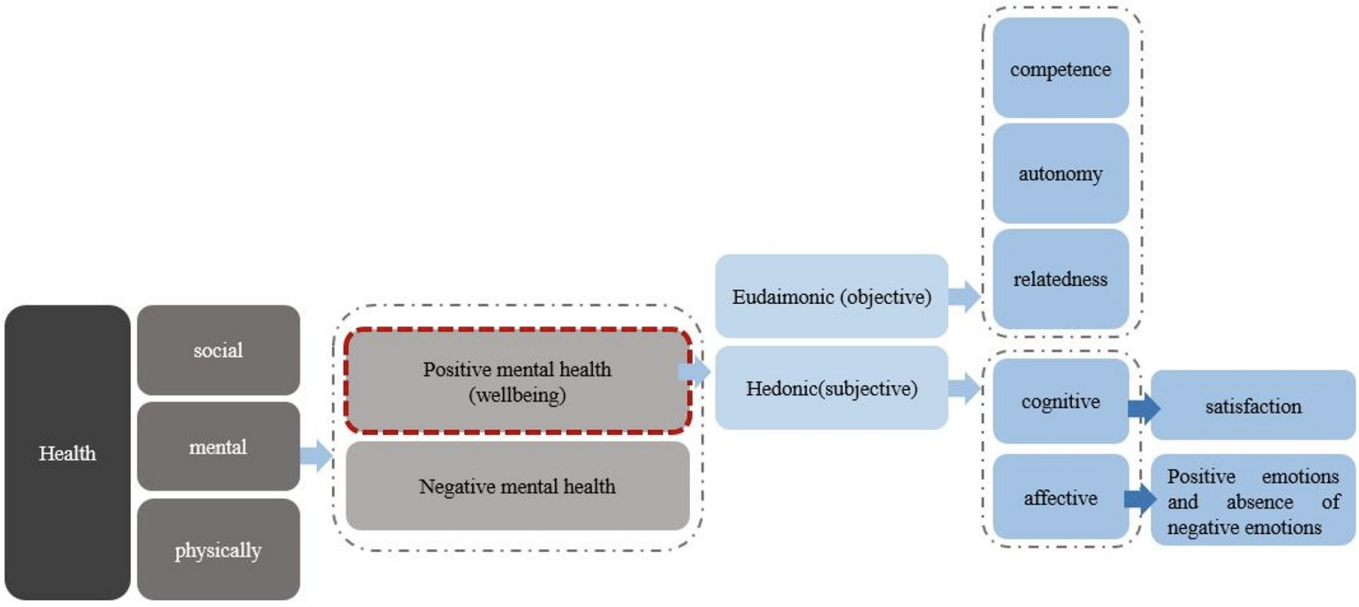

Figure 1. mental health's subsets

Previous studies have shown that many factors can affect mental health and well-being, but we have limited our research to green spaces, which are an important physical factor. The reason is that findings have been reported that people with the most access to nature have higher well-being.[13] Moreover, the landscape has received enough attention as a continuum between wild nature and designed environment such as urban and rural forests, green spaces, parks, gardens, waters, and neighborhood areas[14]The researches demonstrate that increasing green spaces can notably improve the environment temperature in summertime[15].Another literature has emphasized the importance of green spaces within and near neighborhoods which can help to cope with public health emergencies[16]. During covid19 most governments issued stay-at-home orders for a long time. Therefore, this limitation to the outdoors caused serious problems like depression, insomnia, stress and mental illness [17].Therefore, the balcony's importance, as a place where private buildings can open up to the fresh air, natural light and community interaction, has been highlighted in the recent emergence of public space's indisposition during the COVID-19 pandemic. In addition, in contrast to outdoor and indoor places, there is much less information about the effect of semi-open space, especially balconies, on mental health. Taken together, the evidence suggests that balconies could be helpful in improving[18], and its effect on mental health has not been addressed.

Therefore, this study has three key aims. Firstly, to focus on the potential to design balconies in the built environment that contribute to people's well-being. Secondly, address the question of whether or not the greenery on the balcony will affect residents' well-being and finally, how much greenery is suitable for well-being in balcony's buildings. The importance and originality of this study is that, instead of traditional methods, it uses virtual reality to explore balconies.

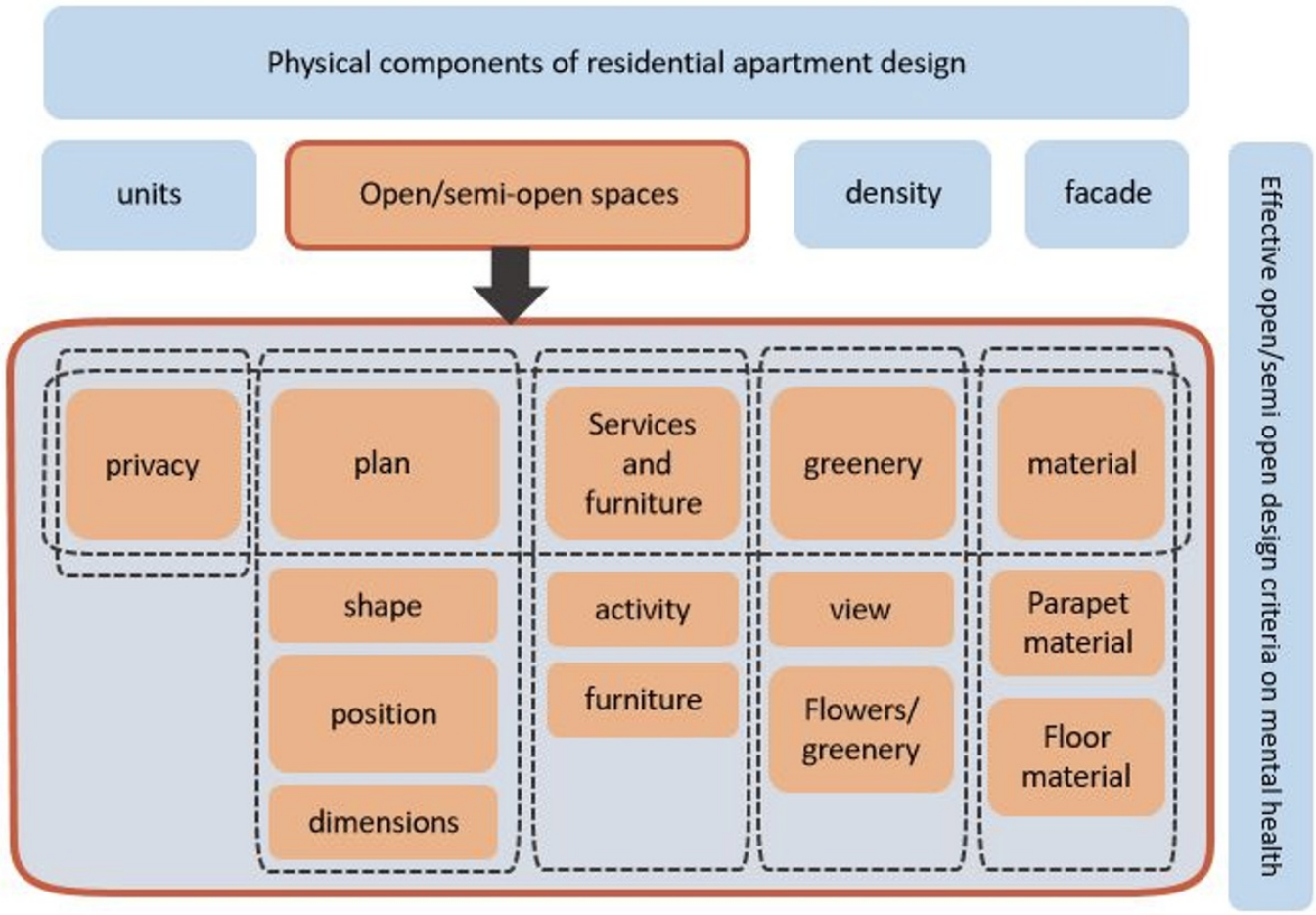

Figure 2. physical factors of apartment design

2. *Method*

2.1. *Research process*

This study uses a quantitative case study approach to evaluate the effectiveness of designing balconies on users' well-being.

In this research, participants were randomly entered into the VR scenario separately to test the effect of greenery in balcony environments on human well-being. We randomly divided people into three groups (group A/B, group A/C and group A/D), and in each group we showed only two environments, one of which in each group was similar. There are two reasons for this between-subject design. Firstly, each participant only experienced the test twice to ensure the best effect and avoid the potential for residual effects. Secondly, in order to reduce the negative effects of wearing the VR device on the participants, such as headache, this way can reduce the wearing time of the VR Environment simulation. Data is collected through the "Building Well-being scale" questionnaire which was asked orally [19]. For each test, the environments were shown to the users while they were sitting on a chair and were free to explore all 360-degrees of each environment during the trials. All environments presented on the OCULUS QUEST 1 at a resolution of 1440 × 1600

pixels, and a 110◦ field of view (FOV). Each candidate had to answer the questions while being immersed in space. This included providing basic personal information and checking for VR related simulator sickness symptoms before the test. The immersed virtual environment test took place in a neutral test room, containing all the VR equipment, a headset and a desk for the researcher conducting the experiment. The cases were familiarized with the head mounted VR equipment and given instructions for the VR viewing and questionnaires. They were asked to stay during the test within a color-marked floor of 1m *1 m. This zone was covered by the VR spatial location sensors communicating with the VR headset. Finally, data analysis is conducted by statistical product and service solutions (SPSS).

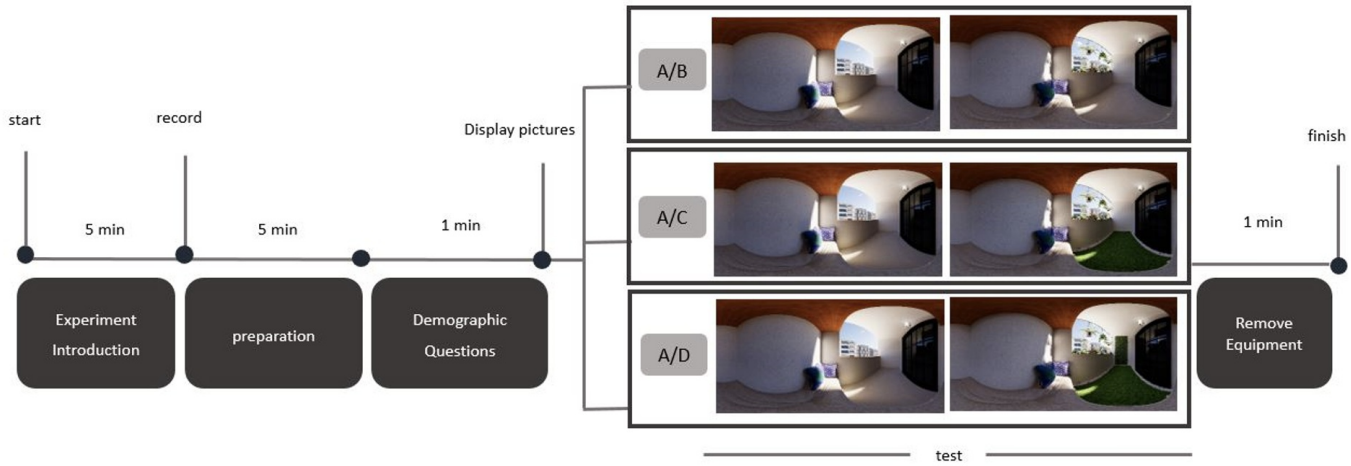

Figure 3. Overview of the experiment procedure from start to the end test.

2.2. *Research tools*

2.2.1. *Virtual reality*

Traditionally, researches have been assessed by visualization methods (e.g., images and photos), which cannot provide respondents with a holistic perspective to evaluate the built environment accurately. Whereas, in this study we use VR technology, which has shown enormous potential in architecture, education, commerce, and medication and many other areas. In addition, previous research has also shown that human psychological perception and physiological reactions are similar in VR and real scenarios. Existing research found participants' subjective and objective visual responses are almost the same in the real and virtual environment[20].The three conditions of immersion, interaction and imagination can be provided by VR [21][22]. Moreover, the experience of walking in or around a structure that does not exist can be enhanced by VR. Also, virtual reality technology helped to eliminate some of the interference factors in the experiment, such as auditory perception, olfactory system, and interaction with surrounding people [23].

2.2.2. *Questionnaire*

The questionnaire was based on previous studies by Kelly j Watson, which introduces a novel well-being valuation approach consisting of a multi-item scale to measure and quantify the well-being outcomes of building users[19].This

building well-being scale is made up of five components: Satisfaction, Affect, Relatedness, Autonomy and Competence. It was developed in reference to two existing, academically developed and validated, multi - item scales for measuring well-being in individuals or populations, not in relation to the built environment. The first scale is the Warwick - Edinburgh Mental Well-being Scale (WEMWBS), and the second is the Questionnaire for Eudaimonic Well-being (QEWB). The final Building Well-being scale, a combination of two questionnaires named, represents an accessible and effective method to quantify the well-being experienced by the end users of a built environment, including well-being scores for each individual user, an overall well-being score for the building, and a score for each measure of well-being. In this study, the participants were asked orally. The present research tests, for the first time, 'the well-being scale in the built environment' questionnaire in the balcony. Participants were also asked demographic questions, such as their age, gender, marital status and their education.

Table 1. The Building Well-being scale

variable	statements	Questionnaire	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
affect	I feel optimistic when I'm in this building.	WEMWBS	-2	-1	0	1	2
satisfaction	I have purpose when I'm in this building.	QEWB	-2	-1	0	1	2
affect	I feel at ease when I'm in this building.	WEMWBS	-2	-1	0	1	2
relatedness	I feel interested in other people when I'm in this building.	WEMWBS	-2	-1	0	1	2
autonomy	I can be myself well when I'm in this building.	QEWB	-2	-1	0	1	2
competence	I deal with problems well when I'm in this building.	WEMWBS	-2	-1	0	1	2
competence	I think clearly when I'm in this building.	WEMWBS	-2	-1	0	1	2
satisfaction	I feel useful when I'm in this building.	WEMWBS	-2	-1	0	1	2
relatedness	I feel close to other people when I'm in this building.	WEMWBS	-2	-1	0	1	2
satisfaction	I feel fulfilled when I'm in this building.	QEWB	-2	-1	0	1	2
autonomy	I can make up my own mind about things when I'm in this building.	WEMWBS	-2	-1	0	1	2
relatedness	I feel valued when I'm in this building.	WEMWBS	-2	-1	0	1	2
competence	I can apply myself to what I'm doing when I'm in this building.	QEWB	-2	-1	0	1	2
autonomy	I feel in control of my own decisions when I'm in this building.	QEWB	-2	-1	0	1	2
affect	I feel energized when I'm in this building.	WEMWBS	-2	-1	0	1	2

2.2.3. *Participants*

The resulting total sample size, estimated according to a global effect size of 0.96[24] with a type error of 0.05 and a power of 0.8 was 36. Though to ensure more than a few people were tested. The random sample of 45 participants was recruited from building users in the city where the experiment took place. Participation was voluntary and eligible participants were selected based on criteria of normal vision, age between 20 and 60 years old (M=21, F= 24).

2.3. *Study environment*

The VR environments were created by SKETCHUP and ENSCAPE engine. First, we investigated and grouped the existing balconies in the city. An initial interview was conducted and the existing damages were identified. Then five balconies were designed based on the needs and preferences of the residents. Afterwards, a re-interview was held and the best balcony was chosen for the final test. The final balcony was designed into 4 final models. In other words, as shown in Figure 1. We designed a balcony with four different amounts of greenery and, in order to allow for fair comparison all of them were constructed with equal visual quality (sharpness and resolution).

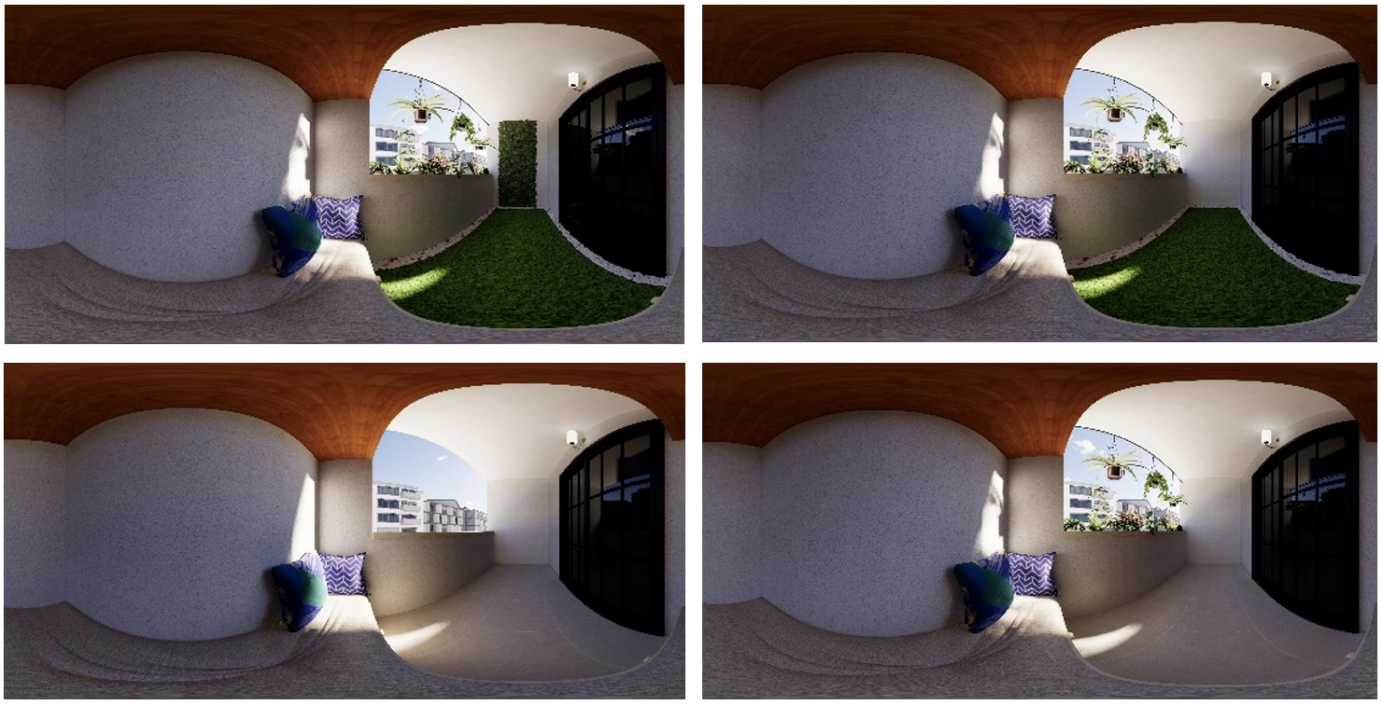

Figure 4. Environment A, B, C and D

3. *Results*

A total of 45 samples were tested and analyzed. The research test was set based on the PLS test. Regarding their education level, all the participants had university education. Table1 shows the demographic characteristics of the participants.

Table 2. Characteristics of the participants

		Overall (n=45)	
		n	%
Age(years)	20-40	15	34
	40-60	30	66
Gender	Male	21	47
	female	24	53
Marital status	single	15	34
	Married	30	66
education	diploma	4	9
	Bachelor degree	20	45
	Master degree	17	37
	Ph.D.	4	9

Source: the authors

To test the hypotheses of this research, first, the normality of the research variables is measured, and then the correlation between them is calculated. Finally, the research hypotheses are tested based on the partial least squares method. Table2 shows the descriptive statistics indicators including mean, standard deviation, skewness, kurtosis related to research variables.

Table 3. The results of multivariate analysis of variance and descriptive statistics indicators

IN	WS(EFS)	BG	L test (F)	SD	M	SK	KU	Picture	group	Var.
0.16**(0.001)	80.77*(0.65)	2.26**(0.97)	2.38	1.18	2.62	0.32	-0.59	A	A/B	affect
				0.83	3.91	-0.48	-0.75	B		
				1.02	2.77	-0.63	-0.61	A	A/C	
				0.48	4.20	0.49	-1.19	C		
				1.33	3.28	-0.52	-0.91	A	A/D	
				0.62	4.51	-1.20	0.69	D		
1.30**(0.05)	82.21*(0.66)	0.79**(0.03)	5.94	1.17	2.91	-0.43	-1.06	A	A/B	Satisfaction
				1.01	3.82	-0.60	-0.57	B		
				0.88	2.77	-0.70	-0.21	A	A/C	
				0.39	4.11	1.07	0.59	C		
				1.18	3.02	-0.23	-1.23	A	A/D	
				0.64	4.42	-0.97	0.13	D		
0.47**(0.02)	62.94*(0.60)	1.32**(0.05)	0.48	1.11	2.88	-0.71	-0.82	A	A/B	Relatedness
				0.82	3.73	-0.19	-0.44	B		
				0.95	2.82	-0.54	-0.65	A	A/C	
				0.65	3.93	-0.71	0.34	C		
				1.29	3.22	-0.52	-0.67	A	A/D	
				0.69	4.33	-0.55	-0.96	D		
0.03**(0.001)	40.38*(0.49)	1.61**(0.07)	2.10	1.04	2.71	0.38	0.32	A	A/B	Autonomy
				0.89	3.35	-0.15	-0.11	B		
				0.94	2.88	-0.35	-0.96	A	A/C	
				0.61	3.60	0.33	0.51	C		
				0.99	3.24	-0.18	-0.74	A	A/D	
				1.00	3.93	-0.39	-1.03	D		
1.87**(0.08)	34.70*(0.45)	3.27**(0.13)	2.09	1.05	3.20	-0.36	0.00	A	A/B	Competence
				0.92	3.57	-0.11	-0.90	B		
				0.87	2.95	-0.99	-0.17	A	A/C	
				0.56	3.86	0.42	-0.38	C		
				0.95	3.64	-0.36	-0.91	A	A/D	
				0.70	4.40	-0.77	-0.50	D		

0.001 0.05** var.: variables M: mean SD: Standard L test(F): Levene's Test BG: between group WS: within group IN: interaction*

Nevertheless, the values of skewness and kurtosis of variables are in the range between 1.96 and -1.96 Therefore, the normality of the research variables is accepted. In this way, parametric tests can be used to analyze the data. The results of multivariate analysis of variance shows that there is a significant correlation between pictures(environments) in each

group. However, no statistical differences between the groups and the environment*group were found.

Table 4. Provides the results of multivariate analysis of variance.

Table 4. The results of multivariate analysis of variance

Partial Eta Squared	SIG.	F	MS	DF	SS	Measure	source
.097	.117	2.260	3.098	2.000	6.195	Affect	
.036	.458	.795	1.048	2.000	2.096	Satisfaction	
.059	.276	1.328	1.911	2.000	3.822	Relatedness	group
.071	.211	1.616	2.359	2.000	4.719	Autonomy	
.135	.048	3.274	3.875	2.000	7.751	Competence	
0.65	0.001	80.775	38.678	1.000	38.678	Affect	
0.66	0.001	82.215	33.205	1.000	33.205	Satisfaction	
0.60	0.001	62.941	23.511	1.000	23.511	Relatedness	environment
0.49	0.001	40.387	10.449	1.000	10.449	Autonomy	
0.45	0.001	34.709	10.449	1.000	10.449	Competence	
.008	0.85	0.16	0.07	2.000	0.15	Affect	
.059	0.28	1.305	0.52	2.000	1.05	Satisfaction	
.022	0.62	0.47	0.17	2.000	0.35	Relatedness	Group*environment
.002	0.96	0.03	0.00	2.000	0.01	Autonomy	
.082	0.16	1.874	0.56	2.000	1.12	Competence	
			0.47	42.000	20.111	Affect	
			0.40	42.000	16.963	Satisfaction	
			0.37	42.000	15.689	Relatedness	Error
			0.25	42.000	10.867	Autonomy	
			0.30	42.000	12.644	Competence	

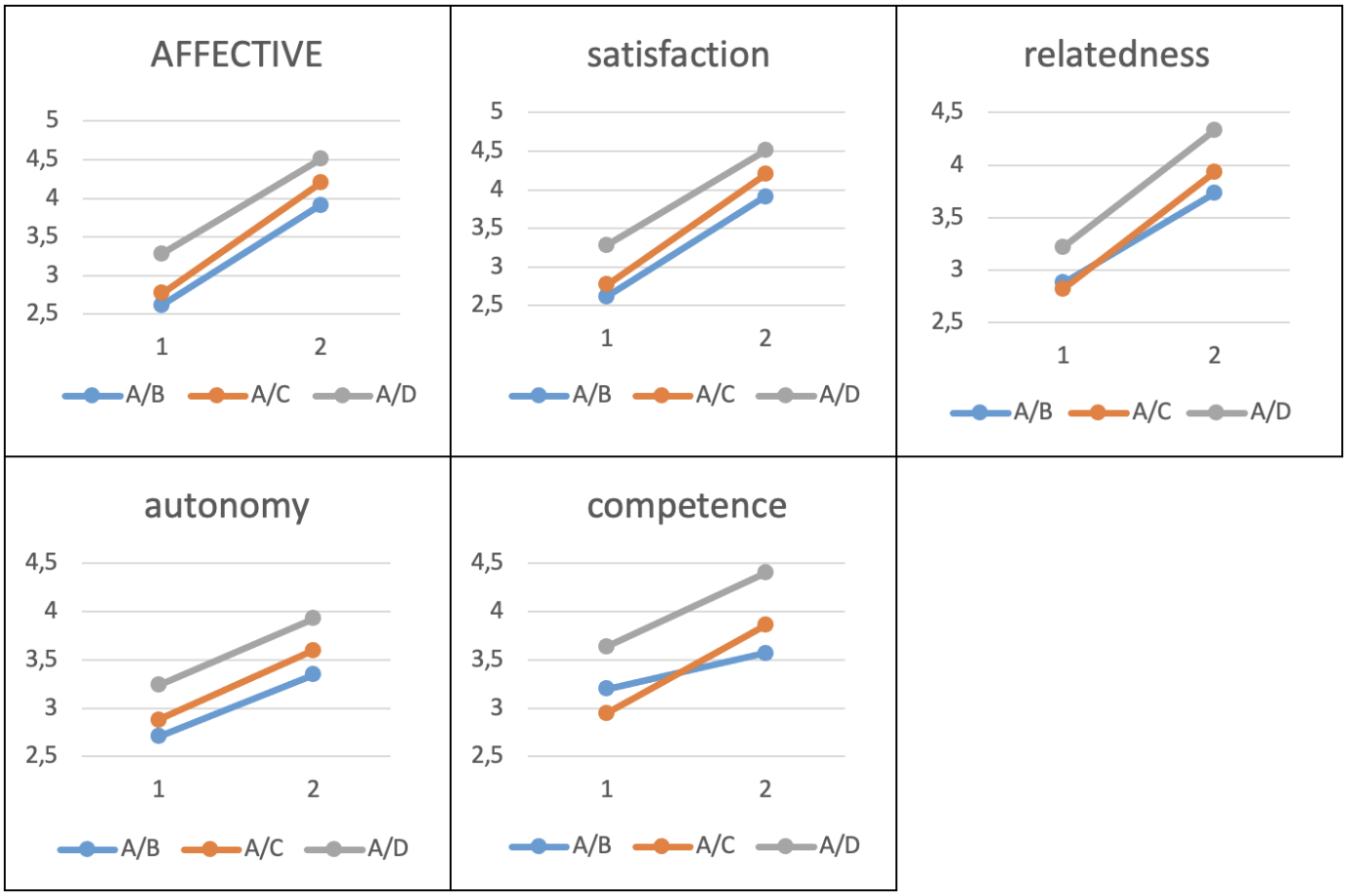

Figure 5. the mean changes of each variable.

Surprisingly, the competence figure is different from others. The reason for this is not clear, but a possible explanation could be that other factors like personal, housing and neighborhood factors are correlated with well-being and its variables [25].

Additionally, the results of Table3 show that the significance level of the test for the variance is more than 0.05, so the use of greenery is the same among males and females and also is the same among different age groups.

Table 5. The results of multivariate analysis of variance between different ages and gender

Partial Eta Squared	SIG.	F	MS	DF	SS	Measure	source	
.624	.000	54.796	18.403	1.000	18.403	Affect		
.651	.000	61.466	20.245	1.000	20.245	Satisfaction		
.527	.000	36.741	11.930	1.000	11.930	Relatedness	Environment	
.508	.000	34.089	8.509	1.000	8.509	Autonomy		
.286	.001	13.248	4.295	1.000	4.295	Competence		
.031	.315	1.042	.350	1.000	.350	Affect		
.011	.552	.361	.119	1.000	.119	Satisfaction		
.000	.905	.014	.005	1.000	.005	Relatedness	Environment*Age	
.032	.305	1.087	.271	1.000	.271	Autonomy		

.015	.481	.507	.164	1.000	.164	Competence	
.025	.659	.423	.142	2.000	.284	Affect	
.134	.092	2.561	.844	2.000	1.687	Satisfaction	
.009	.855	.158	.051	2.000	.102	Relatedness	Environment*group
.022	.693	.370	.092	2.000	.185	Autonomy	
.036	.548	.612	.199	2.000	.397	Competence	
.010	.572	.326	.110	1.000	.110	Affect	
.006	.650	.210	.069	1.000	.069	Satisfaction	
.030	.323	1.007	.327	1.000	.327	Relatedness	Environment*gender
.003	.756	.098	.024	1.000	.024	Autonomy	
.001	.841	.041	.013	1.000	.013	Competence	
.091	.206	1.659	.557	2.000	1.115	Affect	
.136	.089	2.606	.858	2.000	1.717	Satisfaction	
.047	.449	.819	.266	2.000	.532	Relatedness	Environment*age*group
.025	.664	.415	.104	2.000	.207	Autonomy	
.065	.332	1.140	.369	2.000	.739	Competence	
.055	.177	1.905	.640	1.000	.640	Affect	
.164	.016	6.480	2.134	1.000	2.134	Satisfaction	
.076	.110	2.700	.877	1.000	.877	Relatedness	Environment*age*gender
.003	.756	.098	.024	1.000	.024	Autonomy	
.074	.113	2.648	.858	1.000	.858	Competence	
.088	.220	1.584	.532	2.000	1.064	Affect	
.045	.468	.778	.256	2.000	.512	Satisfaction	
.054	.401	.938	.305	2.000	.609	Relatedness	Environment*group*gender
.073	.288	1.292	.322	2.000	.645	Autonomy	
.045	.468	.777	.252	2.000	.504	Competence	
.167	.049	3.306	1.110	2.000	2.221	Affect	
.061	.353	1.076	.355	2.000	.709	Satisfaction	
.105	.159	1.945	.632	2.000	1.263	Relatedness	Environment*age*group*gender
.158	.058	3.100	.774	2.000	1.547	Autonomy	
.002	.969	.031	.010	2.000	.020	Competence	
			.336	33.000	11.083	Affect	
			.329	33.000	10.869	Satisfaction	
			.325	33.000	10.715	Relatedness	Error
			.250	33.000	8.237	Autonomy	
			.324	33.000	10.698	Competence	

4. *Discussion*

The aim of the present research was to examine whether greenery in the balcony could affect people's well-being. The

most obvious finding to emerge from the analysis is that greenery in balconies has significant differences in well-being. In such balconies, people feel happier, satisfied, connected to others, become independent and have the ability to do something successfully. Contrary to expectations, this study did not find a significant difference between well-being and different amount of greenery. It means that well-being can be improved even with a few pots and there is no need for more green. Therefore, one way to reduce the symptoms of low well-being is to be exposed to green spaces in balconies, which is less taken into account. Our finding broadly supports the work of other studies in this area linking green spaces to well-being [14]. Also, this finding consists with that of Dzhambov (2021) who found that the students who spent most of their time at home during the COVID - 19 epidemic had better mental health when exposure to greenery [17]. This also accords with our earlier observations, which showed that a high percentage of dwellers asserted the importance of having a balcony in an apartment and its far-reaching impact on boosting mental health[26]. In this research, it was shown that the greenery on the balcony has an effective relationship with the increasing tendency of people to have social connections, which consists with that of Huang (2006) who found that space design and the existence of greenery and plants can have an important role in increasing social interaction[27].Another research shows that indoor and outdoor greenery connected with fewer depressive symptoms during COVID-19 lock downs while gender, education, and income did not modify relationships between green spaces and depressive symptoms [28].

Moreover, in this research no significant differences were found between greenery and different ages or gender. It is encouraging to compare this with that found by Khaledi (2022) who found that the use of green spaces and the rate of depression and anxiety are the same among males and females and also at different ages[29]. This study supports evidence from research on students in India during COVID–19 to evaluate built environment attributes that found gender has no significant associations with mental health[30]. In accordance with the present result, previous studies demonstrated that there are no significant differences between gardeners and non-gardeners in gender in assessing garden use and mental well - being in the elderly.[31] This outcome is contrary to that of Roe et al. (2013) who found a notable interaction effect between gender and percentage green space on mean cortisol concentrations, demonstrating a positive effect of higher green space concerning cortisol measures in women but not in men [32].

Although the current study is based on a small sample of participants, it is possible to hypothesize that people's expectation of a balcony, as a semi-open place to relax in, could be somehow the same. The present study has a number of strengths. The key strengths of this study are its method. In this research we used virtual reality as a tool and as mentioned before, to create more accurate results than traditional methods, as VR provides a situation that helps candidates to immerse [21][22].

5. *Conclusion*

Residents who spent most of their time on balconies experienced better well-being when exposed to greenery. Experiencing greenery on balconies was associated with feeling happier, satisfied, connected to others, independence and having the ability to do something successfully which led to higher well-being.

References

1. ^*Behrad, B. and B. Bahrami, The impact of public spaces physical quality in residential complexes on improving user's social interactions; case study: Pavan residential complex of Sanandaj, Iran. Journal of Civil Engineering and Urbanism, 2015. 5(2): p. 89-93.*
2. ^*Núñez-González, S., et al., Overview of "systematic reviews" of the built environment's effects on mental health. Journal of Environmental and Public Health, 2020. 2020.*
3. ^*Han, M.J.N. and M.J. Kim, Green environments and happiness level in housing areas toward a sustainable life. Sustainability, 2019. 11(17): p. 4768.*
4. ^*Zarghami, E. and D. Fatourehchi, Impacts of Islamic-Iranian Identity on Mental health outcomes in traditional houses. Naqshejahan, 2018. 7(4): p. 30-46.*
5. ^*Deci, E.L. and R.M. Ryan, "Facilitating optimal motivation and psychological well-being across life's domains": Correction to Deci and Ryan (2008). 2008.*
6. ^*Keyes, C.L., D. Shmotkin, and C.D. Ryff, Optimizing well-being: the empirical encounter of two traditions. Journal of personality and social psychology, 2002. 82(6): p. 1007.*
7. ^*Yun, Y.H., et al., The satisfaction with life scale and the subjective well-being inventory in the general Korean population: psychometric properties and normative data. International journal of environmental research and public health, 2019. 16(9): p. 1538.*
8. ^*Schönfeld, P., et al., The effects of daily stress on positive and negative mental health: Mediation through self-efficacy. International Journal of Clinical and Health Psychology, 2016. 16(1): p. 1-10.*
9. ^*Tennant, R., et al., The Warwick-Edinburgh mental well-being scale (WEMWBS): development and UK validation. Health and Quality of life Outcomes, 2007. 5(1): p. 1-13.*
10. ^*Diener, E., et al., Subjective well-being: Three decades of progress. Psychological bulletin, 1999. 125(2): p. 276.*
11. ^*Saputra, A. and F. Tentama, Construction of the subjective well-being scale. International Journal of Scientific and Technology Research, 2020. 9(2): p. 38-42.*
12. ^*Abu-Ghazzeh, T.M., Housing layout, social interaction, and the place of contact in Abu-Nuseir, Jordan. Journal of environmental psychology, 1999. 19(1): p. 41-73.*
13. ^*Anders, C., I. Hooley, and D.M. Kivlighan III, The nature of a pandemic: Testing the relationship between access to nature, nature relatedness, wellbeing and belonging in nature using polynomial regression with response surface analysis. Journal of environmental psychology, 2023. 85: p. 101949.*
14. a, b*Abraham, A., K. Sommerhalder, and T. Abel, Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. International journal of public health, 2010. 55(1): p. 59-69.*
15. ^*Yu, H., et al., The effect of landscape configuration on outdoor thermal environment: A case of urban plaza in Xi'an, China. Building and Environment, 2023. 231: p. 110027.*
16. ^*Guo, X., et al., Urban greenspace helps ameliorate people's negative sentiments during the COVID-19 pandemic: The case of Beijing. Building and Environment, 2022. 223: p. 109449.*
17. a, b*Dzhambov, A.M., et al., Does greenery experienced indoors and outdoors provide an escape and support mental*

health during the COVID-19 quarantine? Environmental Research, 2021. 196: p. 110420.

18. ^*Omrani, S., et al., On the effect of provision of balconies on natural ventilation and thermal comfort in high-rise residential buildings. Building and Environment, 2017. 123: p. 504-516.*
19. [a, b]*Watson, K.J., Establishing psychological wellbeing metrics for the built environment. Building Services Engineering Research and Technology, 2018. 39(2): p. 232-243.*
20. ^*Abd-Alhamid, F., et al., Developing an innovative method for visual perception evaluation in a physical-based virtual environment. Building and Environment, 2019. 162: p. 106278.*
21. [a, b]*Li, Z., X. Huang, and M. White, Effects of the Visual Character of Transitional Spaces on Human Stress Recovery in a Virtual Reality Environment. International Journal of Environmental Research and Public Health, 2022. 19(20): p. 13143.*
22. [a, b]*Bhagavathula, R., et al. The reality of virtual reality: A comparison of pedestrian behavior in real and virtual environments. in Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2018. SAGE Publications Sage CA: Los Angeles, CA.*
23. ^*Bakr, A.F., Z.T. El Sayad, and S.M.S. Thomas, Virtual reality as a tool for children's participation in kindergarten design process. Alexandria engineering journal, 2018. 57(4): p. 3851-3861.*
24. ^*Cohen, J., Statistical power analysis. Current directions in psychological science, 1992. 1(3): p. 98-101.*
25. ^*Huebner, G.M., et al., The relationship between the built environment and subjective wellbeing–analysis of cross-sectional data from the English Housing Survey. Journal of Environmental Psychology, 2022. 80: p. 101763.*
26. ^*Molaei, P., P. Hashempour, and L.M. Tang, Semi-open spaces of apartments considering COVID-19 pandemic: General expectations of balcony design in the post-pandemic world. Architectural Engineering and Design Management, 2022. 18(5): p. 705-722.*
27. ^*Huang, S.-C.L., A study of outdoor interactional spaces in high-rise housing. Landscape and urban planning, 2006. 78(3): p. 193-204.*
28. ^*Zhang, J., et al., Is indoor and outdoor greenery associated with fewer depressive symptoms during COVID-19 lockdowns? A mechanistic study in Shanghai, China. Building and Environment, 2023. 227: p. 109799.*
29. ^*Khaledi, H.J., M. Faizi, and M. Khakzand, The effects of personal green spaces on human's mental health and anxiety symptoms during COVID-19: The case of apartment residents in Tehran. Frontiers in Built Environment, 2022. 8: p. 981582.*
30. ^*Asim, F., P.S. Chani, and V. Shree, Impact of COVID-19 containment zone built-environments on students' mental health and their coping mechanisms. Building and Environment, 2021. 203: p. 108107.*
31. ^*Corley, J., et al., Home garden use during COVID-19: Associations with physical and mental wellbeing in older adults. Journal of environmental psychology, 2021. 73: p. 101545.*
32. ^*Roe, J.J., et al., Green space and stress: Evidence from cortisol measures in deprived urban communities. International journal of environmental research and public health, 2013. 10(9): p. 4086-4103.*