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Review Paper

The Interactive Architecture for the Improvement of Urban Health during COVID-19 Crisis: A Review

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Abstract
The damages of COVID-19 to people's lives have highlighted the need for the usage of technologies to improve health. For this purpose, the identification of available technologies could facilitate the fight against COVID-19. This study aims to explore effective technologies existing in the literature on Interactive Architecture because these technologies are embedded in the daily life of individuals to respond to the real-time needs of people. Therefore, we conducted a scoping review in the Web of Science and Scopus databases, with no time and paper type limitations. The selected papers were categorized based on their content. Also, the guidelines for combating COVID-19 (based on the WHO and the national government tips) were reviewed and categorized. Afterward, the papers that shared the same themes by guidelines were selected to extract the technologies introduced in them. Finally, usage has been proposed for each of the technologies. Also, we examined the effectiveness of the technologies in the proposed sectors by asking about the experts' viewpoints. As result, we found that interactive ventilation, flexible walls, and eHealth technologies could be effective for the promotion of physical health during COVID-19. In that vein, interactive installations (such as interactive furniture) could improve mental health during quarantine by extending the space and providing the opportunity to connect with the outside world. Also, the virtual education environment was the most effective technology for education challenges during the COVID-19 pandemic.

Keywords: *Coronavirus, Mental Health, Physical Health, Quarantine, Interactive Technologies*.

1. INTRODUCTION

According to the World Health Organization (WHO), the health and well-being of citizens are perhaps a city's most significant asset, which has a pivotal effect on urban health (WHO, 2020c). Today, the COVID-19 crisis, however, has affected the two. Therefore, experts in different disciplines try to develop smart technologies to combat the COVID-19 pandemic. Of smart technologies, interactive technologies (I.T.), which had the potential of interacting with the real-time needs of people, seem to be a powerful tool to encounter this crisis.

However, the use of I.T. in health issues is not new. Reuzel et al. (2001; 1999) wrote on the suitability of interactive technology assessment for the normative bias in health technology assessment (HTA) and its positive effect on the ethical problem. While Glasgow et al. (2010) developed effective and cost-efficient diabetes self-management (DSM) programs, Shoup et al. (2015) reduced parental concerns about vaccination. Further, in a recent study, an interactive technology was introduced to solve the problem of low physical activity of students, which can be easily integrated into the school environment (Mo et al., 2020). Likewise, I.T. is a powerful tool for architects and urban designers, known as Interactive Architecture (I.A.). Therefore, we decided to find I.A. technologies that could be effective in combating COVID-19. Since interactive architecture is an

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essential part of smart cities, this type of study seems to have a central role in developing healthy cities in the future.

The primary aim of this study is to present the available useful I.A. technologies that could be useful in preventing the spread of COVID-19. The secondary aim is the exploration of experts' perspectives to assure the efficiency of these technologies. The research question is:

Which technologies of interactive architecture can be effective in preventing and controlling COVID-19?"

The innovation of the present research is in the proposal of technologies that can facilitate the implementation of the health protocol provided by the World Health Organization and the local government. Notably, we used the SQUIRE guideline in the organization of this study (Ogrinc et al., 2020). This study is structured as follows:

After the introduction, Section 2 describes the research methodology in detail; in this section, the technologies are extracted from the literature, and usage is defined for each of them. Also, the efficiency of technologies is examined. Section 3 presents the results. Section 4 discusses the experts' view on the efficiency of selected technologies. Section 5 presents the conclusions, and additionally, reveals research gaps in the literature on interactive architecture.

2. METHOD

We conducted the study in two phases. The method used for the first phase was a scoping review of Interactive Architecture literature. Scoping review was selected to address less specific research questions with a potentially broad range of topics, and to reduce the emphasis on quality assessment (Arksey & Malley, 2005; Provoost, Lau, Ruwaard, & Riper, 2017). In this paper, we applied the Arksey and O'Malley framework (2005). Notably, a scoping review protocol and author checklists were used to guide the review process and ensure consistency, transparency, and reproducibility. The protocol was in accordance with Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines with scoping review extension (PRISMA-ScR) (Tricco, Straus, & Moher, 2018). Using this method, we extracted the technologies from selected literature and suggested a usage (a sector) for each of them based on the WHO and national government of Iran tips for the prevention of coronavirus.

In the next phase, we used the Q methodology to empirically study the expert's view about the efficiency of extracted technologies in the suggested sector.

2.1. First Phase: Extract Available Interactive Technologies

To extract the technologies, first, a scoping review was conducted. Then, the selected articles were categorized based on the purpose of the authors to develop the technology introduced. Also, we have categorized COVID-19 prevention guidelines provided by WHO and the national government. In the next step, the categories were compared to find the thematic relationship between papers and guidelines. Then, the articles that share the same theme as the guidelines were selected, and their technology was extracted. Finally, we offer some suggestions for the usage of the extracted technologies.

2.1.1. Scoping Review on Interactive Architecture

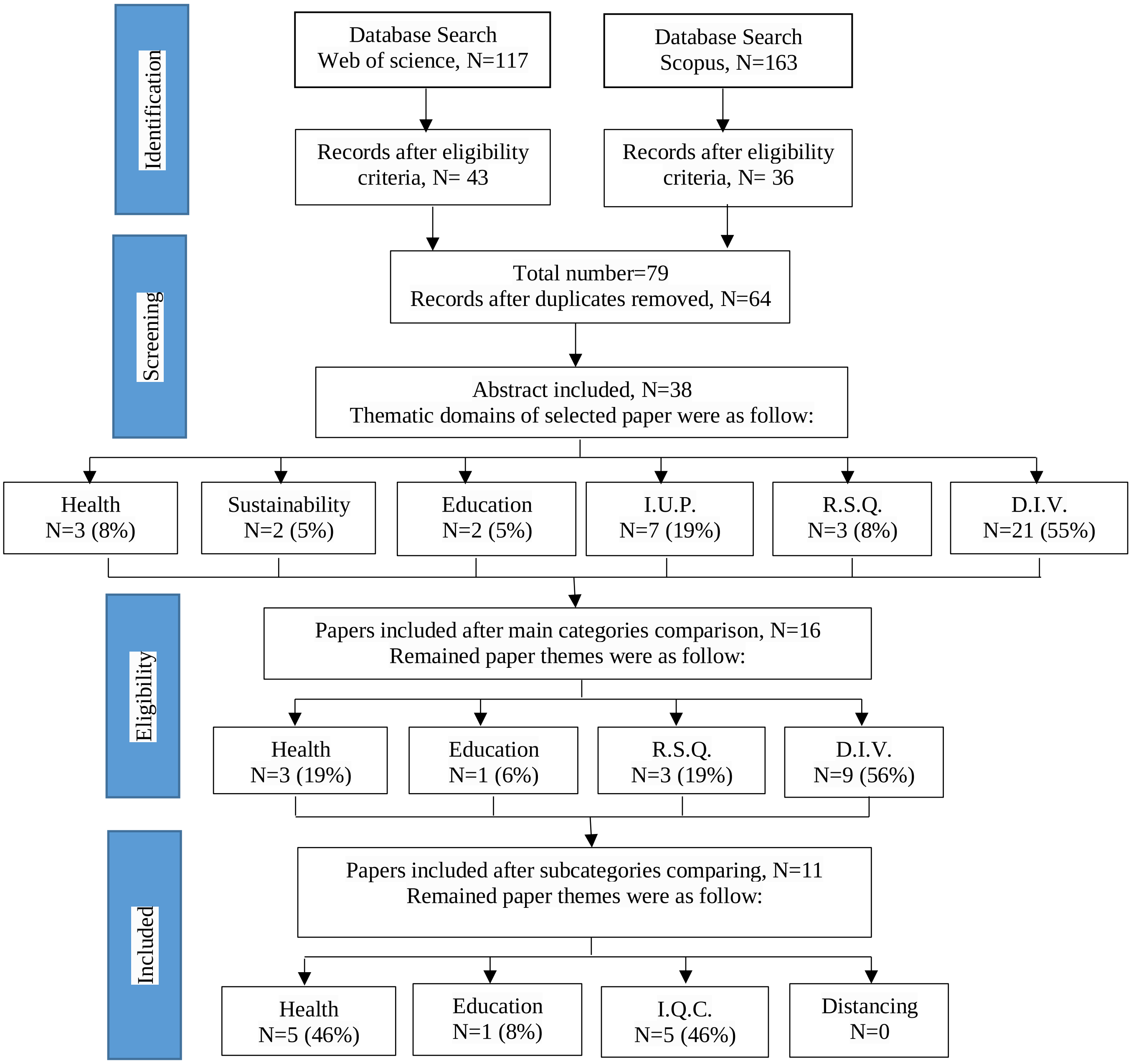
We conducted a keyword search in Web of Science (WoS) and Scopus, as major scholar databases in engineering, by ("interactive" And (architecture OR space OR environment)) keywords. This resulted in 117 articles on WoS and 163 articles on Scopus. The Searching for relevant databases was conducted with the guidance of a research librarian. There were no time and paper-type limitations to investigate the field in-depth, and the final cut-off date for published studies was 26 December 2020. After the topic screening, we selected 43 and 36 articles from WoS and Scopus, respectively. Removing the duplicates, a total of 64 articles were selected. The bellow protocol was prepared to select a subset of journal articles from this collection:

- Explicitly deal with constructing or designing interactive technologies.
- Only interactive systems should be considered.
- The "interactive architecture/ environment/ space" terms should not be mentioned only in the references.

An initial analysis of the selected papers led to the identification of additional protocols as follows:

- Since theoretical justifications are not decisive in the applications of I.A. (Maia & Meyboom, 2015), only empirical research should be selected. PRISMA diagram of the review was shown in Figure 1.

Consequently, we selected 38 papers for full-text screening. Screening involved using Mendeley software to manage and retrieve full texts. The final articles were categorized according to their content The main categories showed in Figure 2 (Down). As shown in the Figure 2, health, sustainability, education, the improvement of user participation, rising space quality (R.S.Q.), and the development of interactive technologies (D.I.T) were the thematic domains of the studies.



Fige 1. Scoping Review Flow Diagram

2.1.2. The General Strategies for the Prevention of Coronavirus

In this step, we extracted COVID-19 prevention strategies related to building spaces or urban environments from World Health Organization (WHO) tips and Iran National Action Plans (Government of The Islamic Republic of Iran, 2020a, 2020b; Headquarters, 2020; Iranian Health Education & Promotion Association, 2020; Tabnak, 2020a, 2020b; WHO, 2020b, 2020a) (Appendix A).

The main categories were shown in Figure 2 (up). This structure was the result of an agreement between the authors based on the grounded approach. The results indicated that the improvement of health, quarantine conditions (I.Q.C.), social distancing, and education were the thematic domains of tips to combat COVID-19.

2.1.3. Finding Thematic Relationship

To identify the final articles, the result of previous sections has been compared (Figure 2). The possible links were shown in Figure 2, in which the continuous and dashed lines indicated the possible strong and weak relations, respectively. As a result, 16 papers included in the categories of health, education, rising space quality, and development of interactive technologies were selected to compare their sub-categories with the sub-categories of COVID-19 prevention strategies (Figure 3). Consequently, 11 papers were selected to extract technologies (see Appendix B for final articles). The agreement between the evaluators is 84.6% and the Kappa coefficient is 0.67, which demonstrates the substantial agreement between the evaluators.

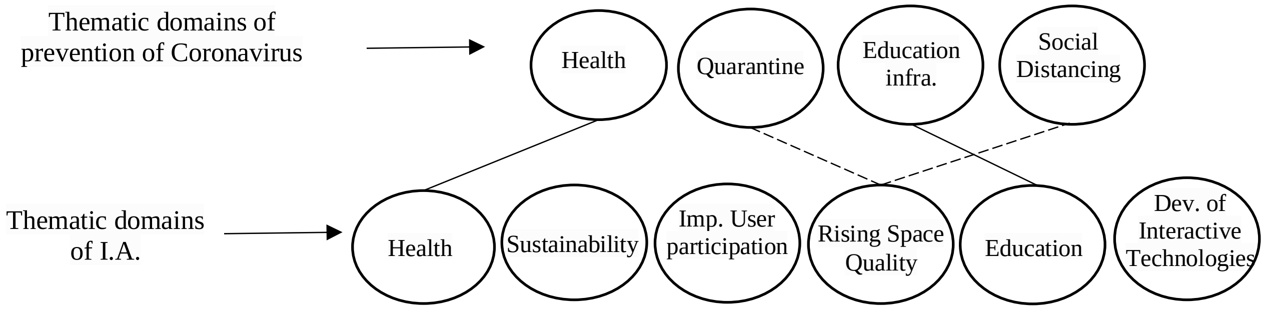


Fig 2. Comparison of Thematic Domains of I.A. and Prevention of Coronavirus

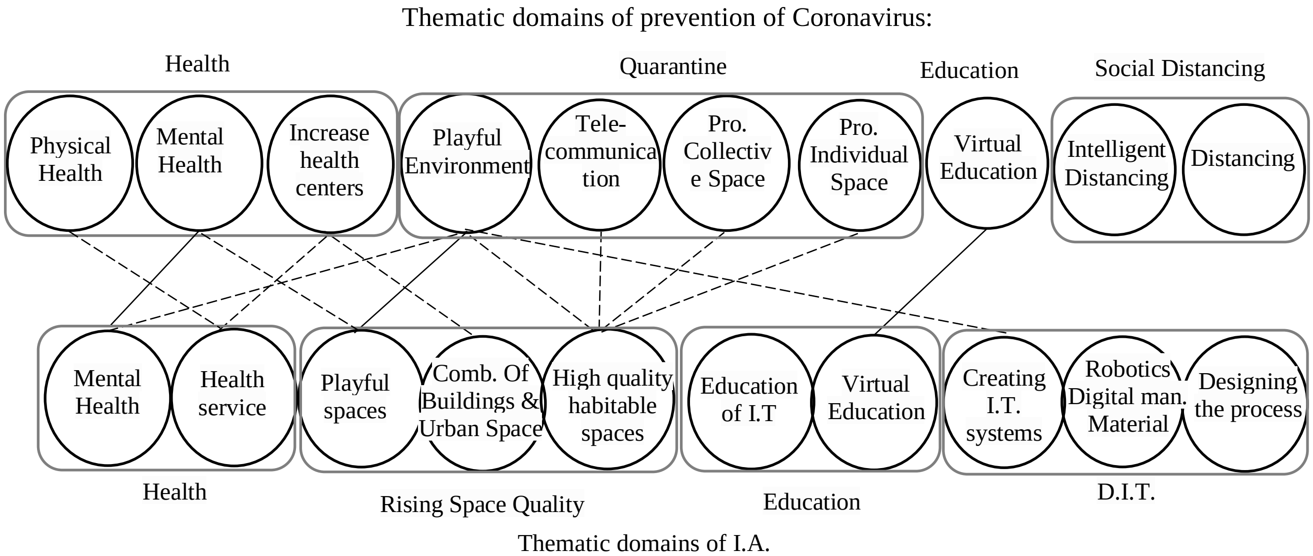


Fig 3. Sub-categories of Thematic Domains of I.A and the prevention of Coronavirus

2.1.4. Extracting Technologies

The extracted technologies were introduced in this section. Applications were suggested based on the primary goal of technology development. However, some suggestions have been made according to their potential to fight the pandemic.

Health Sector

Five technologies were considered for use in the health sector. Two of them can be used to promote mental health, and the rest can be used to improve physical health. For example, Naz et al. (2017) designed an interactive technology to affect the emotional status of individuals by changing the light, color, and texture of walls in the living space. They argued that this technology could affect the mental health of individuals positively (Naz et al., 2017). Therefore, it could be used to improve the mental health of individuals during quarantine (Figure 4).

As another example, combining the space and eHealth service, Talantikite and Chaouch (2018) developed an intelligent environmental technology that improves healthcare delivery in hospitals. E-Health can also be used to monitor the emotional and physical state of COVID-19 patients at home or in hospitals.

In the case of physical health, we found several I.T. systems. The idea in Abramovich and Achten's paper (2016) lay in the design of new building structures which are put inside an urban context. It included several 7*7 cubes which could be opened and shut in different conditions based on multiple needs. It had the potential to be used as a removable field hospital during the pandemic (Figure 5).

In another project, the shading device, ventilation, and display screens were interactively merged into one landscaping element. When a viewer was approaching, a proximity sensor triggered embedded fans and display screens. Therefore, the building was integrated with an interactive ventilation system (Ron, 2012). This technology is applicable in buildings to improve ventilation interactively. Besides, interactive walls, opened and closed by similar sensors, were the other I.T. system introduced in the buildings by Biloria (2012) that could be used to make flexible space at home, especially when a temporary isolated room is needed.

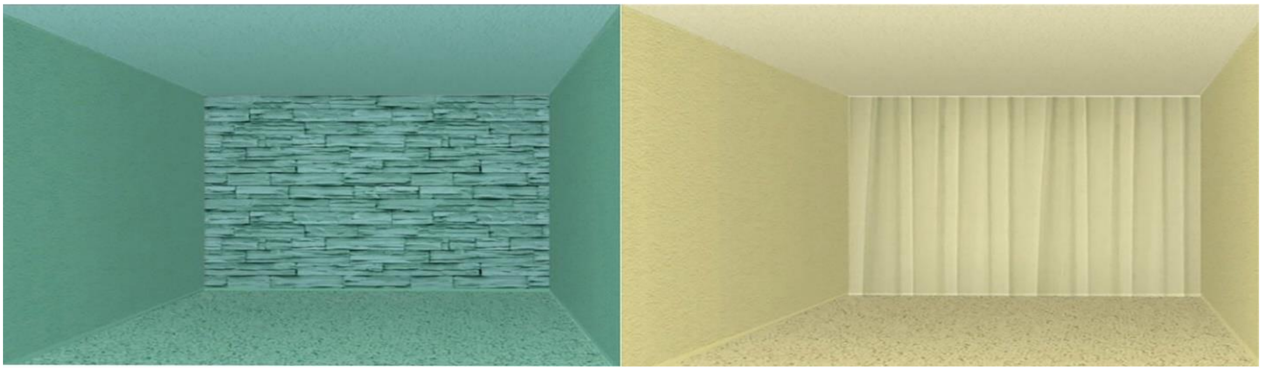


Fig 4. Affecting the Emotional Response of Persons by Projecting Different Light, Color, and Texture (Naz et al., 2017)

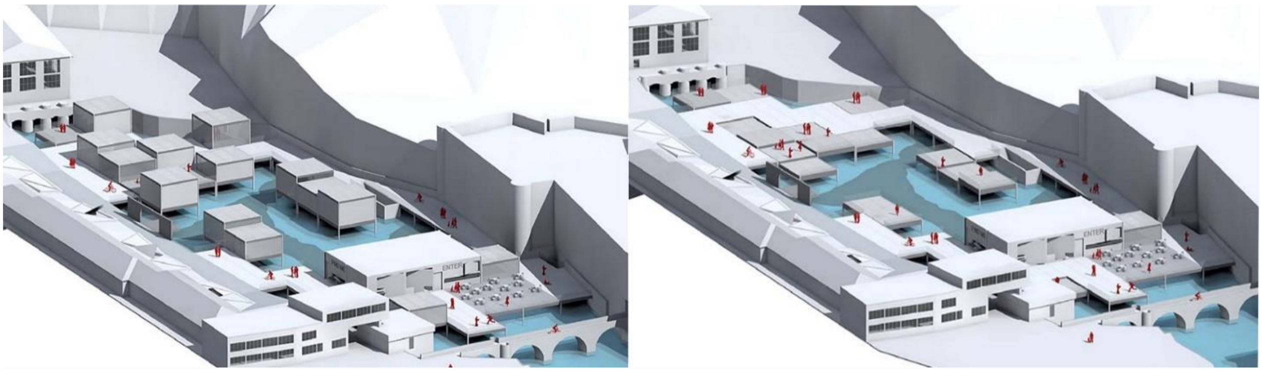


Fig 5. The Folding Cubes Technology (Abramovic & Achten, 2016)

Improvement of Quarantine Conditions (I.Q.C.)

We extracted several interactive technologies that could be considered to use in quarantine. While some provided telecommunication possibilities, others were useable for entertainment. For example, MyGreenSpace, MeeringMeEating, and ubiGUI technologies were interactive display walls that could extend the space and create the perception of a larger room (Röcker & Kasugai, 2012). MyGreenSpace was a display wall on which a forest scene was rendered. This display wall adjusted itself to the position of the viewer. Additionally, it could notify the user about events or could be a reminder to take medication (Figure 6). Similarly, ubiGUI is an interface that allows multiple input methods such as reminders, several games, etc. However, it is optimized for large screens.

MeetingMeEating enabled two persons, both sitting alone in front of a large screen, to dine together over a distance. The display walls showed the video streams of the dining partner and a part of the partner's table. It used head tracking to adjust the perspective and used background segmentation to overlay the video content with virtual three-dimensional content (Figure 7).

Notably, it is essential to stay at home during an airborne pandemic such as COVID-19. For this purpose, people must have fun in their homes. Some interactive technologies developed with this objective were interactive furniture shaped by the user's body or emotional state (Biloria, 2012). Similarly, Viny et al. (2018) have created two interactive systems. One of them was made of open and closed petals and another was made of twisted fabric cones. Both of these systems acted based on the average mood of inhabitants (Figure 8).

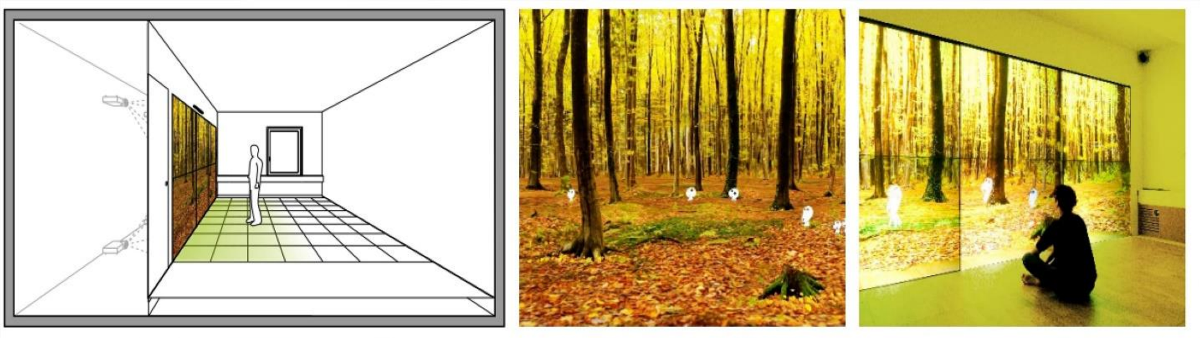


Fig 6. My Green Space (Röcker & Kasugai, 2012)

Fig 7. Meeting Me Eating (Röcker & Kasugai, 2012)

Fig 8. The Opening and Closing Petals (Left), the Twisting Fabric Cones (Right) (Viny et al., 2018)

Likewise, Liu et al. (2017) developed an interactive virtual installation, changed by users' moods. In this technology, the data from social media was the source of reforming the installation. It is important to note that the possibility of translating emotion into the virtual environment not only entertains users but also affects their mental health (Figure 9).

Another installation, designed by Change, et al. (2019) was opened and closed by motion-sensing. It was a responsive component that acts by changing shape through kinetic motion (Figure 10).

In addition, interactive paper walls (Nabil et al., 2017) and displays (Rozhen K, von Mammen, & Boyd, 2013) were the other interactive technologies suitable for interior spaces. Both of them were suitable for improving the quarantine conditions (Figure 11).

Fig 9. The virtual Strips Changed by Users' Moods (Liu et al., 2017)

Fig 10. The Adaptive Component Triggered Closed and Open States through Motion (Chang et al., 2019)

Fig 11. Interactive Wallpaper (Left)(Nabil et al., 2017), Interactive Displays (Right) (Rozhen K et al., 2013)

Education Sector

Relevant to this sector, we only found one paper, describing a virtual environment for international creative education. This technology presented the current potential of virtual worlds as an efficient learning environment (Z. Liu, 2017). The author declared that the interactive features used in this environment enabled learner-centered education. Besides, it could actively lead to a pleasant learning process, the sharing experience, and a better understanding of the art and design concepts. Given the importance of distance learning during the pandemic, this technology offers appropriate opportunities for virtual education (Figure 12).

2.2. Second Phase: The Efficiency of Extracted Technologies

To explore the efficiency of extracted technologies in suggested sectors, the Q-methodology was used. Rather than finding the average opinions in a group, the idea of the Q method is finding different perspectives emerging from a population (Barry & Proops, 1999). The essence of the Q-method factor analysis is to group people with similar viewpoints. In Q-methodology, a factor (i.e. viewpoint) should be defined by at least 4 or 5 persons (Dennis, 1986). In determining which sets of people should be clustered together, the sorts were factored by rotating the matrix. Assuming there are mental similarities among people, we used the Direct Oblimin method for the rotation.

The concourse was the literature on interactive architecture, collected and analyzed in previous steps. Also, the Q-sample included 14 technologies extracted from the literature (see Appendix C). We had more than four technologies for the health and I.Q.C sectors which were desirable based on Schwartz's paper (2010). Although there was just one technology for the education sector, it was sufficient based on Donner's paper (2001). Because of the disease, the Q-sorts were carried out by an online questionnaire. A detailed description and pictures were provided beside each question. Also, it was made possible for respondents to add a description where needed.

In this study, we focused on urban planners and architects as participants because this group has a pivotal role in shaping public spaces. The participants were selected by convenience sampling method from masters or Ph.D. students. The experts were asked to rank-order the statements from “most agree” to “most disagree" on a seven-point Likert scale. We used the free distribution of statements in this study. It is notable that the range and shape of the Q-sort distribution have no effect on the statistical results (Brown, 1993, 2009; Cottle & McKeown., 1980; Giannoulis, Botetzagias, & Skanavis, 2010).

Of distributed questionnaires, fifty answers were acceptable. This was justified by the fact that the Q-analysis did not reveal all the possible perspectives. However, the patterns revealed truly exist (McKeown & Thomas, 1988). After numerous rotations, a total of 5 viewpoints were selected. The total variation in the Q-sort cards reached approximately 61 percent. Each viewpoint involved at least six individuals with factor loading greater than 0.4, and the loading of at least 4 individuals was significant with $p<0.05$ or $P<0.01$, (Eq. (1), see PQMethod manual (Schmolck, 2014)).

Eq. (1): $$a > \frac{1.96}{N}$$

Where “a” is the factor loading and “N” is the number of statements. After selecting the Factors, the factor scores for each statement were calculated based on the weighted scores and the ranks given by each participant included in the viewpoint. Since we have used the free distribution, the pattern of statement distributions for each viewpoint has been generated by taking the percentage of the number of votes in each range (-3, +3) (Table 1).

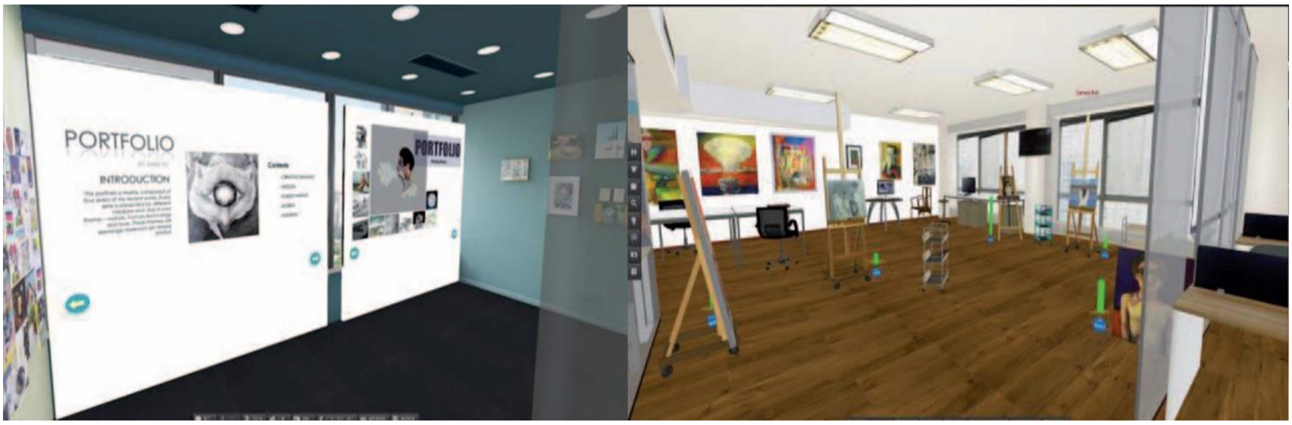
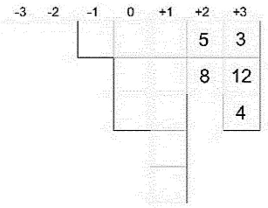
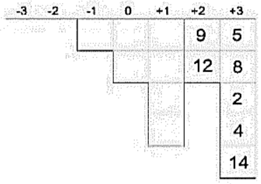
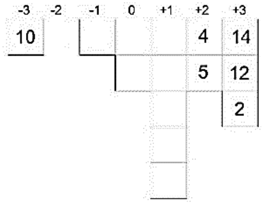
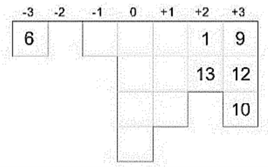
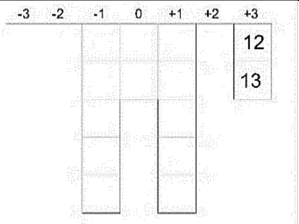


Fig 12. Studio of Virtual Environment for International Creative Education (Z. Liu, 2017)

Table 1. Viewpoint Groups Revealed by Cluster Analysis

 Viewpoint 1 Agreement & strong agreement (+2, +3): *Health Sector:* (3) Cubes with the ability to open and close (4) Interactive Ventilation, and Display Screens (5) Interactive Walls *Imp. of Quarantine Conditions:* (8) MeetingMeEating	 Viewpoint 2 Agreement & strong agreement (+2, +3): *Health Sector:* (5) Interactive Walls (2) E_health technology (4) Interactive Ventilation, and Display Screens *Imp. of Quarantine Conditions:* (8) MeetingMeEating (9) ubiGUI *Education Sector:* (14) Virtual Education	 Viewpoint 3 Agreement & strong agreement (+2, +3): *Health Sector:* (2) E_health technology (4) Interactive Ventilation, and Display Screens (5) Interactive Walls *Education Sector:* (14) Virtual Education Strong Disagreement (-3): (10) Interactive wall-paper
 Viewpoint 4 Agreement & strong agreement (+2, +3): *Health Sector:* (1) Flexible physical environment based on users' emotion *Imp. of Quarantine Conditions:* (9) ubiGUI (10) Interactive wall-paper (13) Automatic Interactive installations Strong Disagreement (-3): (6) Flexible shapes in a virtual environment	 Viewpoint 5 Strong agreement (+3): *Imp. of Quarantine Conditions:* (13) Interactive installations	

Finally, statements ranked at both extreme ends of viewpoints were selected to describe the collective views of the individuals included in the viewpoints (Exel & Graaf, 2005). Notably, because of sharing strong agreement over all of the perspectives, the 12th phrase – interactive furniture- was not a separate statement. Thus, it was removed from the analysis.

3. RESULTS

According to Table 1, there were five different views on the efficiency of the extracted technologies.

3.1. Viewpoint 1: Health-Centered Attitude

The number of health technologies outnumbered the I.Q.C. ones 3 to 1. Thus, it was reasonable to surmise that the emphasis of this group was on the effectiveness of health-oriented technologies.

The health seekers especially emphasized physical health technologies which provide health facilities on the scale of a house or urban space. They stated that *folding cube* technology was the most efficient health technology, especially for creating a field hospital during the COVID-19 crisis (statement 3, score 41/48[3]). Besides, the *interactive ventilation along with display screens* (4, 39/98) and *interactive walls* (5, 38/40) were the other efficient technologies for this group. This group was fairly neutral about other technologies from I.Q.C. or education sectors.

3.2. Viewpoint 2: Holistic Attitude

Although the distribution of terms was approximately similar to the first approach, the various technologies of all three sectors were considered here. Of health technologies, the *interactive ventilation plus screen displays* (3, 199/82), *interactive walls* (5, 197/03), and *eHealth* were the most efficient technologies for this group. *MeetingMeEating* (8, 196/3) and *ubiGUI* of I.Q.C., and *virtual education* of the education sector (14, 195/63) were selected too. Notably, there was a combination of various technologies from three sectors at the relatively same scores in this viewpoint.

3.3. Viewpoint 3: Education-Health-Centered Attitude

Along with health-seekers, the education-health actors also shared the view that health technologies were so efficient. According to Table 1, there were five different views on the efficiency of the extracted technologies. However, the main difference between the first viewpoint and the third was that the latter was keenly informed by the effectiveness of virtual education technology. While the highest score in the former group was for health, education technology was the most efficient technology for the latter (14, 33/28).

Of health technologies, *eHealth* was the second for this group (6, 32/65). *Interactive ventilation* and *interactive walls* were the next with 28/24 and 27/38 scores, respectively. On the other hand, I.Q.C. technologies were in the neutral range except for *interactive wallpaper*, in the strongly disagreed position.

3.4. Viewpoint 4: The I.Q.C. Centered Attitude

Despite removing the 12th statement, the number of I.Q.C. technologies outnumbered the health ones 3 to 1. Thus, it was reasonable to surmise that the emphasis of this group was on the technologies from the I.Q.C. sector.

This group stated that *ubiGUI* was the most efficient technology to improve quarantine conditions (9, 11/39). The second rank went to the *interactive wallpapers* (10, 6/47), *the flexible environment* (1, 5/06), and *automated interactive installations* (13, 4/95). Notably, three out of four technologies mentioned were of I.Q.C. and only one was a health technology. Similar to the first viewpoint, *virtual education* did not score highly in this group. On the other hand, similar to the third view, experts disagreed with one of the I.Q.C. technologies (i.e. the *flexible shapes in the virtual environment*).

3.5. Viewpoint 5: The Neutral Attitude

By contrast, the neutral viewpoint was neutral to all the examined technologies. The distribution of statements in this attitude indicated that this group felt that interactive technologies were not efficient enough to be introduced in their future works. This group ranked all the statements among the range (-1, +1), at scores [-14/60, 7/08].

4. DISCUSSION

This study summarized some interactive technologies embedded in the environment to facilitate the challenges that emerged during the COVID-19 crisis. For this purpose, we conducted a scoping review and investigated any paper types including journal and proceeding papers. After the full screening, we found 11 relative papers that share the same themes with the WHO and Iran national government guidelines to combat COVID-19. After extracting the technologies, we found 14 technologies in three general scopes (namely health, I.Q.C, and education sectors) and suggested the possible usage for each technology. It is notable that despite the importance of social distancing in controlling disease infection, we could not find any interactive technology to facilitate it. We also surveyed the efficiency of extracted technologies in suggested sectors from experts' viewpoints.

The first sector was health, both physical and mental. Related to these fields, technologies such as *Folding-Cubes*, *interactive ventilation plus screen displays*, *interactive walls* for physical health, and *flexible environment* and *eHealth technology* for mental health were found. Also, this sector emerged in the 3 out of five viewpoints (namely, *Health, Educational-Health, and Holistic viewpoints*) that indicate its importance among experts. In measuring the efficiency of these technologies, interactive ventilation and interactive walls were evaluated as the most efficient technologies for three viewpoints, and eHealth was the most effective for two. Various studies have indicated the importance of ventilation to decrease the COVID-19 infection risk (Fadaei, 2021; Sha, Zhang, & Qi, 2021; Sun & Zhai, 2020). On the other hand, flexible walls could provide flexible space such as an isolated room in quarantine conditions. The importance of eHealth technologies during the COVID-19 outbreak was surveyed in other studies too (Brørs, Norman, & Norekvål, 2020; Thulesius, 2020).

The second was the I.Q.C. sector that could facilitate the quarantine conditions and the well-being of individuals during the outbreak of COVID-19.

Likewise, *Flexible forms*, *MyGreenSpace*, *MeetingMeEating*, *ubiGUI*, *interactive wallpaper*, *interactive displays*, *interactive furniture*, and *interactive automatic installations* were the technologies found for improving quarantine conditions. Of these technologies, *interactive furniture* was the most favorable technology among all viewpoints. *ubiGUI, MeetingMeEating, and Interactive-installation* were the other effective technologies in increasing the well-being of individuals (by counting 2 out of 5 points). While MyGreenSpace, MeetingMeEating, and ubiquity could extend the space and have telecommunication possibilities, the function of the others was for the entertainment of users.

We also found a virtual interactive environment for the education sector that was effective from two viewpoints. These technologies are essential during the quarantine because they could provide a virtual interactive environment for education (Gelineau-Morel & Dilts, 2021; Sabol, 2021).

In addition, while the large body of research on interactive technologies was aimed to entertain the users, the present study showed the high potential of these technologies for use in critical situations.

Notably, we faced some limitations in this survey. First, because of the pandemic, our access to manual resources was limited and we mostly used internet resources. Second, because of free distribution, the research method was slightly different from the forced one. Therefore, to avoid bias and intervention in the research path, statistical and percentage methods were used to find out the shape of the arrangement of expressions. However, this in itself yielded interesting results in terms of viewpoints. Also, for the same reason, we had to use SPSS, instead of the PQmethod app, to analyze the data.

5. CONCLUSION

In this study, state-of-the-art Interactive Architecture was introduced as a new way of promoting public health in urban or domestic spaces, especially for future smart cities. We introduced several interactive technologies in the health, I.Q.C., and education sectors that could be useful to facilitate life during COVID-19. Interactive furniture was the most effective technology in quarantine conditions. In the Second level, interactive ventilators and flexible walls could enhance the physical health of individuals by providing a better system of ventilation and making multiple uses from the same space, respectively. Afterward, eHealth technology (electronic health), the virtual education environment, and the technologies that extend the living space and provide a virtual connection with the outside world were most impressive in promoting mental health, education, and quarantine conditions, respectively. Overall, it could be concluded that effective interaction with the built environment based on the real-time needs of individuals could increase the life quality during COVID-19, and interactive architecture has a great potential to present more applicable technologies for the crisis. The present study could also clarify the orientation of future research in the field of interactive technologies. This study targets not only architects and urban planners but also interactive technology developers or biomedical engineers who are interested in the integration of health technologies with the environment.

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DECLARATION OF CONFLICTING INTERESTS

The authors declare that there is no conflict of interest with respect to the research, authorship, and/or publication of this article.

ENDNOTES

[1] It is notable that since we only found one technology in the education sector, our results in this section are not as strong as the other steps. However, based on Donner's opinion, this does not disturb the results.

[2] The use of free distribution led to a different pattern for each factor. Therefore, the factor scores were not normalized in the range (-3, +3) and were placed in the arrangements, respectively.

[3] It is notable that scores are just comparable in the domain of each viewpoint, not between the two.

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Appendix A. The Final Category of Coronavirus Prevention

N.	Organ.	Extracted Subjects	Thematic Domains (Open Coding)	Thematic Domains (Axial Coding)
1	S.A.H a, tip27	Coping with stress Playful Activities	Mental Health	Health
2	S.A.H, tip28	Isolating and appropriate ventilation Washable Surface	Physical Health	Health
3	S.A.H, tip29	Predicting Entrance Space	Physical Health	Health
4	S.A.H, tip 33	Individual-level Physical Distancing	Physical distancing	Distancing
		Exercising at Home	Mental & Physical Health	Health
		Appropriate Ventilation	Physical Health	
		Meeting with Video Conference	Tele-communication	Quarantine conditions
5	S.A.H, tip 34	Identifying individual's Differences and Similarities	Mental Health	Health
		Video Chat with Family	Telecommunication	Quarantine conditions
		Collective Activities	Providing Collective spaces	
		Individual activities	Providing Individual Spaces	
6	WHO	Hand hygiene, Respiratory etiquette & individual physical distancing.	Physical Health Physical Distancing	Health Distancing
7	WHO	Isolating, providing appropriate care, and quarantining, and supporting all contacts.	Physical Health Quarantine	Health Quarantine conditions
8	WHO	Appropriate clinical care, continuity of essential health and social services	Physical Health	Health
9	WHO	Physical distancing, and restrictions on non-essential domestic and international travel.	Physical Distancing Quarantine	Distancing Quarantine conditions
10	WHO	Focus on large-scale public health capacities	Increase health centers Physical Health	Health
11	WHO	Coping with stress	Mental Health	Health
12	C.N.H [b]	Encouraging people to stay at home and closing down busy centers	Playful Environments to Quarantine	Quarantine conditions
13	C.N.H	Working at home	Telecommunication	Quarantine conditions
14	C.N.H	Closing schools and holding virtual education courses	Virtual-education	Education
15	C.N.H	Intelligent social distance	Intelligent Distancing	Distancing
16	C.M [c]	Increasing the number of medical centers (establishment of field hospitals in high-risk areas)	Increase health centers Physical Health	Health

a Scientific Association of Health (S.A.H)
b Corona National Headquarters (C.N.H).
c Council of Ministers (C.M.).

Appendix B. The Final articles according to their Themes

Themes / Author/year		Health		Education	R.S.Q			D.I.T.
		Mental Health	Health Services	Virtual education	Playful spaces	Combination of Buildings & Urban Space	High Quality Habitable spaces	Creating I.T. Systems
Ushigome et al	2008							■
Cardoso et al	2009							■
Biloria	2012							■
Rocker, Kasugai	2012						■	
Rozhen K. et al	2013							■
Ron	2013							■
Datta, Andrei,Chang	2016							■
Liu zh	2017			■				
Liu, Ch. et al	2017	■						
Nabil et al.	2017							■
Nabil et al.	2017							■
Naz A	2016	■						
Abramovic and Achten	2016					■		
Talantikite, Chaouch	2018		■					
Viny, A. et al	2018				■			
Chang, et al	2019							■

Appendix C. Final technologies and their potential application in the three general sectors

Themes	Statements (Technologies)							
Health	N.1. Flexible physical environment based on user's emotion	N.2. Folding Cubes with the ability to open and close	N.3. Interactive Ventilation, and Display Screens	N.4. Interactive Walls	N.5. ehealth technology			
I.Q.C.	N.6. Flexible shapes in virtual environment	N.7. MyGreen Space	N.8. Meeting MeEating	N.9. ubiGUI	N.10. Interactive wall-paper	N.11. Interactive displays	N.12. Interactive Furniture	N.13. Interactive installations (open and shut automatically)
Education	N.14. Virtual Education							

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