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Modeling an Interactive Interior Design Mechanism, Depending on the User's Desires

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ABSTRACT

This study introduces an innovative paradigm for the development of interactive, user-responsive interior spaces. Historically, the design of interior spaces has been largely disconnected from the preferences and requirements of their occupants, necessitating user adaptation. However, advancements in technology, nanomaterials, and intelligent materials have paved the way for the customization of spaces to align with the individual needs and desires of users. Despite these technological advancements, a practical mechanism for the application of intelligent materials and technologies in the design of user-responsive spaces remains elusive. This study aims to address this gap by developing a novel software solution for the creation of color-responsive interactive spaces. The proposed software employs interactive smart materials, particularly thermochromic pigments, to enable spaces to engage with inhabitants in a dynamic manner. Preliminary findings from the Thermochromic Interior Design (TID) program indicate a consistent physiological response across different environments. Yet, the distinct color dynamics within each space foster a unique interactive experience. This study thus extends the current understanding in the field by proposing a proactive approach to interior design that capitalizes on smart materials and technologies. Furthermore, the research highlights the potential of these technologies in crafting adaptive and personalized spaces, posing a paradigm shift in our interaction with our environment. The adaptability and interactivity facilitated by such spaces could enhance user satisfaction and engagement across various contexts, from residential to commercial.

1. INTRODUCTION

The potential for interior design to enhance human experience by augmenting architectural spaces, with a keen focus on user needs as the design's foundation, is well-documented [1]. This emphasis on user-centricity has precipitated the emergence of interactive spaces, engendering environments that can engage in a dialogue with users. The constituents of interior spaces have evolved, extending beyond static objects intended for human use to entities capable of sensing, recognizing, and interacting with users, and adapting to their needs in a manner that optimizes space utilization and maximizes customer satisfaction [2]. The current technological landscape has seen the proliferation of smart materials, which when interfaced with a data source through a digital network, can facilitate a two-way information exchange with humans and other physical components, as evidenced by [3]. The ability of these materials to respond to external stimuli and modify their properties accordingly ensures programmability. The advent of interactive design and smart materials has effectively bridged the gap between the environment and the user, adding new dimensions to this relationship. As a result, the conceptualization of space and its function have undergone a novel reinterpretation. This suggests that an Interactive Interior not only influences the implementation of the design but also its final form.

Considering the transformative potential of this technology and its capacity to make architectural designs more responsive to user needs at the design stage, the current research aims to address the existing lack of a mechanism or strategy that architects can utilize to design smart interactive technologies that cater to users' desires. In this context, the implications of smart materials and interactive design in transforming user experience through personalized and adaptive spaces will be explored.

2. RELATED WORK

Many studies focused on the effect of color in interior design and its physiological importance on the functional nature of space and its users [4-6]. Some studies also provided tools on the application of colors in interior spaces and choosing the appropriate color for the interior environment and previewing the color at the time of design [7]. Zhu et al. [8] put an approach, which is a color suggestion Tool for fournitures and Interior's parts compatible with the overall color picture of the interior scene. These works reduce the burden of interior designers in choosing the appropriate colors for the interior spaces. However, all of these studies deal with colors and their effects separately.

Our software offers the possibility of linking color and its physiological effect and its relationship with the nature of the function of space as a tool to assist in the design. It employs smart interactive materials in the first design stage to apply them to the architectural structure (such as a wall) provide a special internal environment for each individual and compatible with his physiological desires.

3. INTERIOR INTERACTIVE ARCHITECTURE

Interaction as an architectural feature in interior spaces provides a solution for adapting and allocating buildings [9]. Crippa [10] explained that based on technological development, the concept of traditional space with its expected use and associated with a specific function and a fixed relationship with neighbors will become a thing of the past. Therefore, the central idea of designing "Interactive Interior Spaces" in transforming elements of interior spaces and surfaces (walls, floors, ceilings) to become interactable and responsive to interactions with or between space occupants through the capabilities of intelligent technologies (embedded in the material itself) and responding to people, motions, physical manipulation, or other physiological and psychological data. Interactive indoor environments have the ability to be more adaptable to personal preferences and behavioral patterns. These modifications can be changes in their appearance, shape, color, pattern, luminosity, or texture [11].

4. INTERACTIVE SPACES FUNCTIONS

The built environment through the concept of interactive interior spaces contributes to the organization of social processes and plays a role in the establishment and stability of the social order and acts as a form of communication. Through the following:

- Communication with the interactive space

Interactive architecture is characterized by multiple qualities that represent a new type of built environment, such as the ability to communicate with users and interact with them, which provides immersion in the built environment. The ultimate goal of this interaction is to provide an interactive experience and allow all users to feel comfortable and communicate. Therefore, the continuous analysis of user behavior allows the building to understand them and creating a beneficial and enjoyable relationship with them [12].

- Understanding users' behavior

By evaluating the user's behavior, which is one of the characteristics of interactive architecture in understanding the behavior, learning and development, it provides the possibility of anticipating the activities of the individual to some extent, allowing the environment to adapt proactively. This facilitates and allows the implementation for user activities that have not yet occurred, which makes the interactive space more enjoyable to use [9].

- Learning from users

The bulk of interactive space behavior depends on users' performance and other external stimuli using learning and development by tracking the environment of users and evaluating their response to cues, thus learning how to communicate with them effectively. An interactive environment can provide cues to users about how to act within it and make choices about using space [9, 13].

- Multiple user adaptations

The uses of the architectural environment differ according to the type and number of users, it may be used by one or a number of users participating in one or more activities [14, 15]. The role of spatial adaptation is not limited to meeting the individual needs of its users rather, it provides a solution between a group of users by giving priority to some activities or some users at the expense of others. The priority of activities can be determined based on various criteria such as the well-being of the people, the importance of an activity, or the purpose of the activity. These criteria can change over time [9].

Smart interactive indoor spaces can reflect social performance in several ways, including [16]:

- Changing the shape of the space as desired by users.
- Adaptation to different types of activities.
- Linking the physical environment with the virtual environment.

5. INTERACTIVE ARCHTECTURE AND ARCHITECTURAL DESIGN

The purpose of interactive design is to achieve a level that creates a kind of balanced interrelationship between the different aspects affecting the design. Balance does not necessarily mean equality between forces, but rather achieving a level where different forces and factors are neutralized by each other. The interactive architecture will analyze all aspects of architectural design and establish a mutual relationship between its various aspects [17] producing a final design that has the maximum and optimum adaptation to all factors and parameters. This makes the interactive architectural approach an effective and practical model for achieving sustainability in architecture and urban development, as well as its great potential for creating places with a sense of belonging [18]. The design based on the concept of interactive architecture, is an interactive building (the mechanism in which the building and users are involved) where the built environment is determined by the dynamic behavior, the needs of its users, and the internal and external changing conditions [19].

6. RESEARCH DESIGN

From a review of previous studies in terms of concepts, processes, methods, etc., the following can be noted:

- Despite the fact that smart interactive technologies seek to improve the quality of life and individual well-being and achieve sustainability, flexibility, etc. However, most of the research in the field of architecture dealt with the concept in a theoretical way, with no mechanism for their practical application.
- Most of the research focused on the technical and technological side and how to achieve interaction technically and only referring to the user as a stimulative for this interaction.
- Referring to smart interactive technologies as an addition to any space in the post-use stage, without mention to its role from the beginning of the designing process, which will contribute, especially in small spaces, to creating adaptive and sustainable environments.

Most studies indicate that smart technologies, smart materials and technical expertise are already available, but there is a lack of the mechanism adopted by the architectural designer.

Accordingly, the research problem is there is no clear method or mechanism to use the smart interactive materials that can be used by the architect and designer in achieving interactive interior spaces during the designing stage.

The aim of this study is an attempt to develop a software that the architect can adopt in achieving the desires of the user by using smart interactive thermochromic pigments material in their interior spaces.

6.1 Smart interactive materials

Technological advances and the miniaturization of components to the nanoscale such as sensors, processors, and actuators have led to the development of new classes of materials influenced by computing, the Internet of Things (IoT), and information and communication technologies that have promoted knowledge exchange and collaboration between different disciplines [20]. These materials outperform traditional smart materials through additional degrees of intelligence and interaction and are called interactive materials, connected, and smart (ICS) [3, 21] or Organic User Interface (OUI) [22] or smart materials that interact sensibly with the surfaces (utrasurface) without the need for keyboards, buttons or touch screens, but through stimulation of the senses. These programmable materials can be used in many sectors (transportation, electronics, wearable things, smart objects, and architecture), showing huge potential for sustainability and resource reduction [20]. These materials help designers to design new environments that are stimulating and meaningful to people's daily lives through the performance of materials by movement, changing colors, lighting and many other interaction [21]. In general, it can be said that smart interactive materials are more advanced as they can be programmed at every stage of manufacturing and using [20].

6.2 Color-change materials

Color-changing materials or color-changing smart materials are materials that react to external stimuli by changing color or intensity. This is caused by subtle structural changes in these materials causing their optical properties (transparency or diffraction) to change in response to physical or chemical stimuli in the surrounding environment [23]. Thermochromic pigments are most commonly used in architectural applications as they are widely available nowadays in the form of ready-to-use pigments in a variety of colors where the reaction time and threshold are determined not only by the properties of each material but also by the mixture of chemicals [22], which makes it easy to apply to different types of materials covering both rigid and flexible surfaces [24]. In addition, color change by heat can be programmed electronically using heating factors underneath, while other color changing dyes are not easily controlled electronically, such controlled color change is of particular importance for designing and creating interactive environments. It stimulates interior designers in creating environments with changing appearance and changing interior elements, in addition to the possibility of slow interaction that suits the interior spaces, as mentioned by the study [22]. This is because it takes a few seconds to transform from one color to another depending on the heating factors underneath.

6.3 Effect of color-changing materials in the internal environment

Since thermochromic pigments provide the advantage of color change in the internal environment, it is necessary to refer to the determinants required by the application of color in the internal environment, which are architectural determinants and the determinants of its psychological impact. The color has a great impact on interior design with its effects on the perception of the nature of space and architectural elements in it (visual effect) besides its psychological effects on the people who use the space in terms of their feelings. The different mixture of colors can exert different effects and create a comfortable or uncomfortable living environment. The basic colors of the solar spectrum were used in addition to some colors that were referred to in the literature with the basic color group and divide into three categories warm, cool and neutral colors.

7. SOFT-WARE MECHANISM

In order to put in use, the engineers and interior designers in interactive design and to involve the user in the interactive design process by giving him the freedom to choose the colors of his personal space. It was decided to adopt the Interactive Thermochromic Design (TID) software mechanism (Figure 1) as follows:

- ❖ Choosing type of the space that he desired color interaction.
- ❖ Choosing the psychological effect that he wishes feeling in space.
- ❖ The resulting interactive color is a product of the two previous choices.

At this stage, the colors, psychological effects, and spaces were converted into data formats using (Access). The values given in the intersection area between psychological influence, space and color, was represented by three values (0, 1, 2), as follows:

- 0 means no correlation.
- 1 medium correlation.
- 2 strong direct correlation.

A decision-making algorithm was adopted based on the C_# programming language within the .net frame work library. In order the software to decide the appropriate color for the required physiological effect within the specified space, three algorithmic equations were adopted:

First: The Space-Factor equation=the value of space*the sum of the effects' values;

Second: Psycho-Factor equation=effect value*weight of the first physiological effect+=effect value*weight of the second physiological effect+=effect value*weight of the third physiological effect;

Third: Final Score=the first equation (Space-Factor)+the second equation (Psycho-Factor).

The program equations ensure the possibility of deducing colors even if the chosen space has limited associated colors. The equations work to derive a color related to the space and the first psychological effect. In the case that a color is not deduced, it moves to the second psychological effect, and so on, until a color is deduced. The color that has the highest score is the color that has the highest color association with space and with the psychological effect. The colors arrange from the highest score to the lowest. The first three colors shown on the display screen.

Figure 2 shows the software working mechanism (TID) which starts from the space selection (box 1), followed by selecting three desirable psychological effects in space, according to priority from box 2, then pressing button 3, the resulting colors begin to appear as shown in Figure 3.

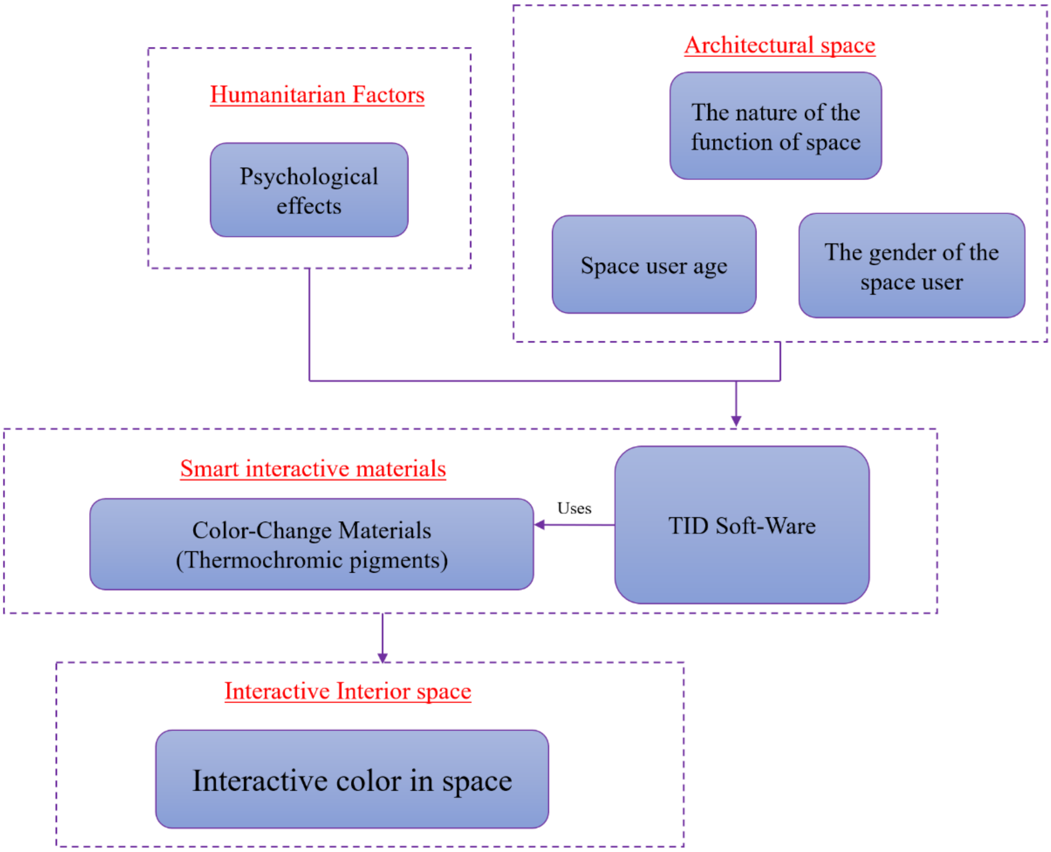


Figure 1. Functional implementation diagram for (TID)

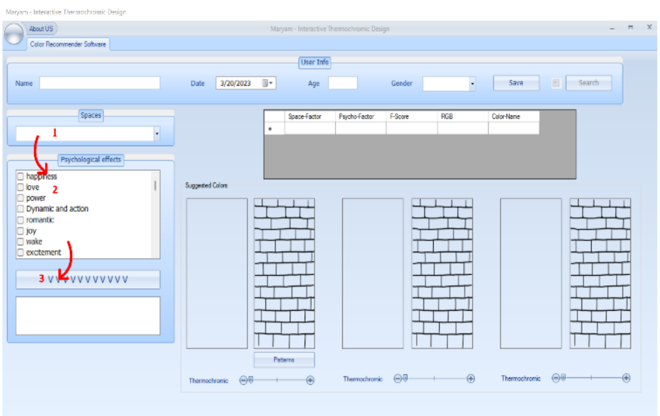


Figure 2. Software working mechanism (TID)

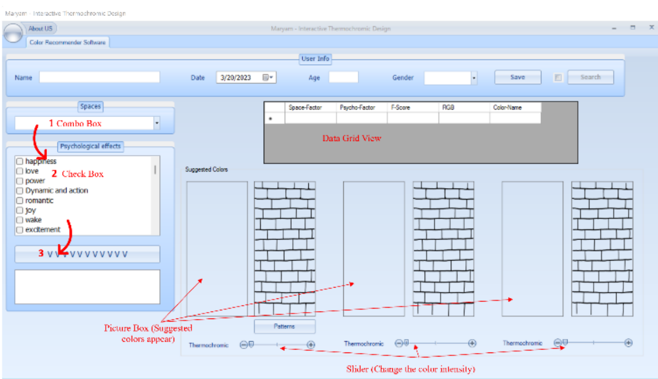


Figure 3. The resulting colors begin to appear

7.1 Software result

1. When choosing different spaces with fixed physiological effects, as shown in Figures 4-7.
2. Choose one space with different physiological effects, as shown in Figures 8 and 9.
3. An experience of similar space and similar physiological stimuli example (girls' bedroom and boys' bedroom) as shown in Figures 10 and 11.
4. One space what change is a physiological effect of one of the three effects, as shown in Figures 12 and 13.

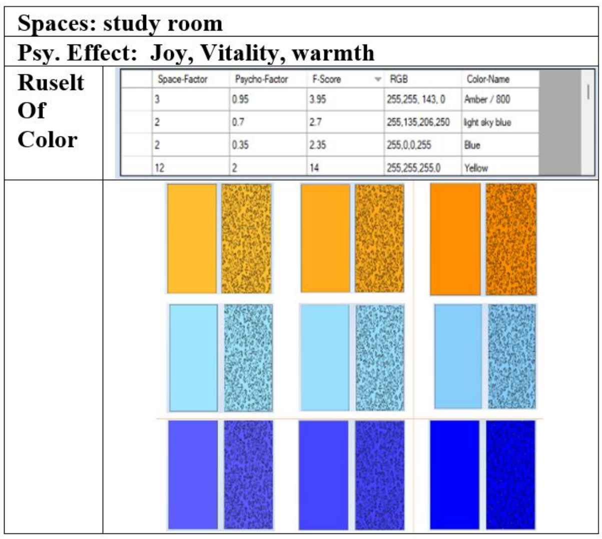


Figure 4. Study room

Spaces: Living room

Psy. Effect: Joy, Vitality, warmth

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
8	1.2	9.2	255,255,0,0	Red
6	2	8	255,255,255,0	Yellow
4	1.35	5.35	255,255,0,255	magenta /fuchsia
4	1.2	5.2	255,255,165,0	orange

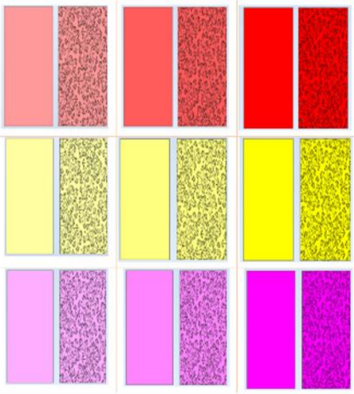


Figure 5. Living room

Spaces: Dining room

Psy. Effect: calm, refreshing, strength

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
4	1.2	5.2	255,0,128,0	Green
4	0.7	4.7	255,255, 143, 0	Amber / 800
4	0.5	4.5	255,127,255,0	chartreuse
2	0.7	2.7	255,255,165,0	orange

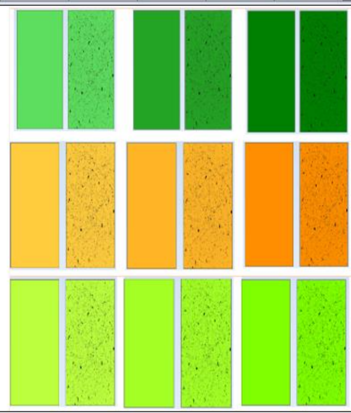


Figure 6. Dining room

Spaces: Girl's bedroom

Psy. Effect: calm , refreshing , strength

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
2	0.8	2.8	255,255,0,0	Red
2	0.6	2.6	255,128,0,128	purple
2	0.6	2.6	255,128,128,0	olive
2	0.5	2.5	255,135,206,250	light sky blue

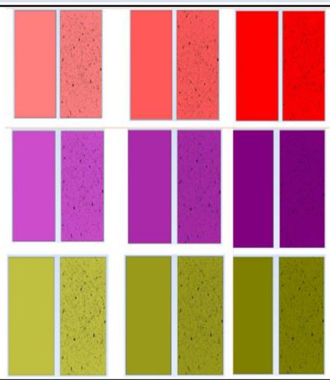


Figure 7. Girl's bedroom

Spaces: Living room

Psy. Effect: romantic, optimism , relaxation

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
6	0.9	6.9	255,135,206,250	light sky blue
4	0.8	4.8	255,240,128,128	light coral
4	0.5	4.5	255,0,128,0	Green
3	0.9	3.9	255,0,0,255	Blue

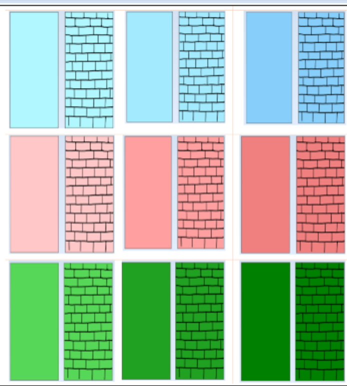


Figure 8. Living room 1

Spaces: Living room

Psy. Effect: happiness , comfort , sunny

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
8	1.3	9.3	255,0,128,0	Green
4	0.5	4.5	255,135,206,250	light sky blue
2	0.7	2.7	255,255,255,0	Yellow
2	0.7	2.7	255,255, 143, 0	Amber / 800

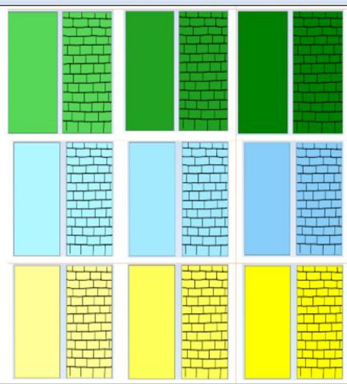


Figure 9. Living room 2

Spaces: Boy's bedroom

Psy. Effect: joy, energy, comfort

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
4	0.5	4.5	255,135,206,250	light sky blue
2	0.5	2.5	255,0,0,255	Blue
1	0.25	1.25	255,75,0,130	indigo
0	1.15	1.15	255,255,255,0	Yellow

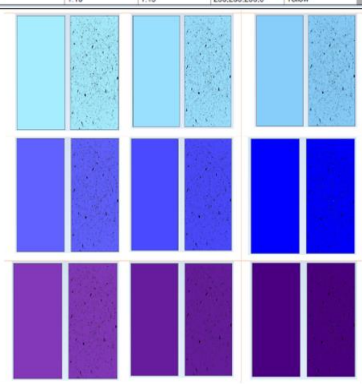
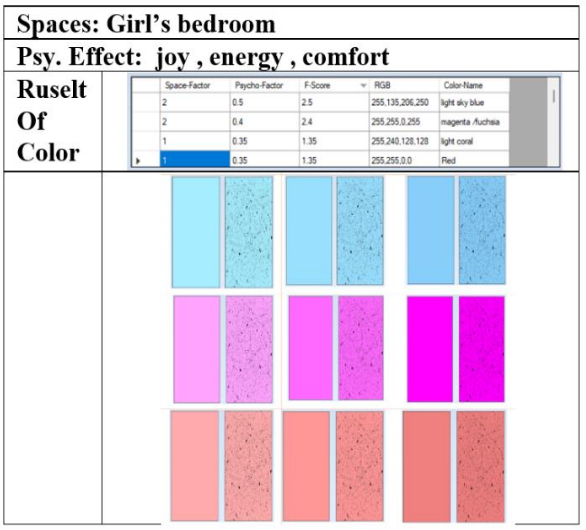


Figure 10. Boy's bedroom (when the physiological effect was: Joy, energy, comfort)



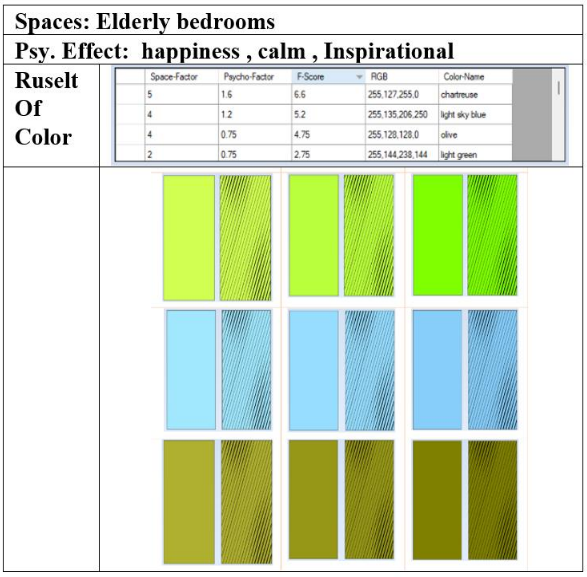
Spaces: Girl's bedroom

Psy. Effect: joy , energy , comfort

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
2	0.5	2.5	255,135,206,250	light sky blue
2	0.4	2.4	255,255,0,255	magenta /fuchsia
1	0.35	1.35	255,240,128,128	light coral
1	0.35	1.35	255,255,0,0	Red

Figure 11. Girl's bedroom (when the physiological effect was: Joy, energy, comfort)



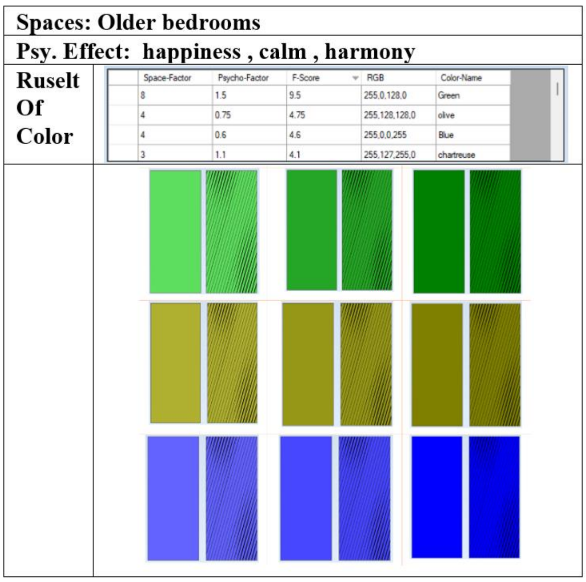
Spaces: Elderly bedrooms

Psy. Effect: happiness , calm , Inspirational

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
5	1.6	6.6	255,127,255,0	chartreuse
4	1.2	5.2	255,135,206,250	light sky blue
4	0.75	4.75	255,128,128,0	olive
2	0.75	2.75	255,144,238,144	light green

Figure 12. Elderly bedrooms 1



Spaces: Older bedrooms

Psy. Effect: happiness , calm , harmony

Ruselt Of Color

Space-Factor	Psycho-Factor	F-Score	RGB	Color-Name
8	1.5	9.5	255,0,128,0	Green
4	0.75	4.75	255,128,128,0	olive
4	0.6	4.6	255,0,0,255	Blue
3	1.1	4.1	255,127,255,0	chartreuse

Figure 13. Elderly bedrooms 2

7.2 Discussion software results

- ❖ The results of the (TID) program showed in a unified physiological effect in different spaces, the colors of the spaces will be different for each space, although they give the same physiological effect. Where each color is associated with a specific space.
- ❖ The results can be attributed to the fact that the colors are the point of intersection between the two factors, space and the physiological effects. Therefore, according to any of the two factors, the resulting colors differ.
- ❖ The selected physiological effects and their order from the most to the least important influence in deducing the resulting colors. As well as, the change of a psychological effect of one of the three psychological effects for the same space leads to a difference in one or more of the resulting colors.

7.3 Limitation of the software

In this study, the number of colors used in the software is 24 colors, 62 physiological effects and 13 spaces. However, colors, spaces, and psychological effects can be added to cover all color gradations and effects, as well as residential and non-residential spaces (open data program).

8. CONCLUSION

The findings of this research are consistent with previous study by Tigwell and Crabb [25] and Wilson et al. [26], where found that peoples preferred smart technologies, such as colour-changing lighting and interactive artwork of their homes and that residents preferred smart home technologies that customized to their individual preferences of their living spaces.

The software, through its algorithms and its use of smart interactive materials, offers a practical way to transform people's desires into their preferred indoor environment.

Software using smart interactive materials and computer technologies can contribute to changing our view of the design process and the designer's interaction with the client. The application of the software on a specific number of architect and people showed interaction especially in designing their spaces in an organized manner in the early designing stages. Applying of interactive smart materials through the software, provides the possibility of taking more than one design factor in certain proportions according to priority or importance (such as the nature of space, its function, and physiological effects) in producing an internal space that achieves both effects together, such as in the case of the same physiological effects in children's rooms, the resulting colors are different for males than for females, and this contributes to creating personal environments for each individual. However, there is a possibility of increasing the influencing factors (such as the effect of lighting, whether natural or industrial, and other design factors) since the software data is unlimited. This is the significance of interactive architecture and one of the most important characteristics of smart interactive architecture.

REFERENCES

[1] Mohamed Ahmed AL-DALAL, F. (2019). The interactive design experience of responsive interior

architecture and its impact on the culture of the recipient. International Journal of Architectural Engineering and Urban Research, 2(2): 23-33. https://doi.org/10.21608/ijaeur.2019.179835
[2] Obeidat, A.M., Al-Nabawi, H.K., Hashem, O.A., El-Said, H.M. (2020). The impact of using interactive interior design on enhancing the performance of clothing shop. Journal of Design Sciences and Applied Arts, 1(1): 146-153. https://doi.org/10.21608/jdsaa.2020.70460
[3] Parisi, S., Spallazzo, D., Ferraro, V., Ferrara, M., Ceconello, M.A., Garcia, C.A., Rognoli, V. (2018). Mapping ICS materials: Interactive, connected, and smart materials. In Proceedings of the 1st International Conference on Intelligent Human Systems Integration (IHSI 2018): Integrating People and Intelligent Systems, Springer International Publishing, pp. 739-744. https://doi.org/10.1007/978-3-319-73888-8_114
[4] Elnaggar, H. (2022). Illumination and color in interior design of living room. Journal of Design Sciences and Applied Arts, 3(1): 50-63. https://doi.org/10.21608/jdsaa.2021.76256.1112
[5] Shorewala, A., Ardito, A. (2021). The psychological impact of color and light in interior design on teenagers. Journal of Student Research, 10(4). https://doi.org/10.47611/jsrhs.v10i4.2188
[6] Ćurĉić, A.A., Kekovic, A., Ranđelović, D., Momcilovic-Petronijevic, A. (2019). Effects of color in interior design. Zbornik Radova Građevinskog Fakulteta, 35: 867-877. https://doi.org/10.14415/konferencijaGFS2019.080
[7] Yan, H., Yang, B., Li, X.M., Wu, H.Y, Fu, Q. (2020). Interactive color theme editing system for interior design. In Journal of Physics: Conference Series, IOP Publishing, 1627(1): 012019. https://doi.org/10.1088/1742-6596/1627/1/012019
[8] Zhu, J., Guo, Y.W., Ma, H. (2017). A data-driven approach for furniture and indoor scene colorization. IEEE Transactions on Visualization and Computer Graphics, 24(9): 2473-2486. https://doi.org/10.1109/TVCG.2017.2753255
[9] Jaskiewicz, T.J. (2013). Towards a methodology for complex adaptive interactive architecture. Technische Universiteit Delft. https://doi.org/10.4233/uuid:a81827c5-7d65-4cc7-9fab-20fab3a14c30
[10] Crippa, D. (2020). Interactive spaces: What if walls could talk? In Cultural, Theoretical, and Innovative Approaches to Contemporary Interior Design, IGI Global, 237-258. https://doi.org/10.4018/978-1-7998-2823-5.ch011
[11] Nabil, S., Kirk, D. (2019). Interactive interior design and personal data. People, Personal Data and the Built Environment, 103-122. https://doi.org/10.1007/978-3-319-70875-1_5
[12] Viktorovna, B.K. (2017). Senses and behavior of interactive environment. Вестник науки и образования, 2(26): 106-108. https://doi.org/10.20861/2312-8089-2017-26-001
[13] Boychenko, K.V., Boychenko, I.V. (2019). Interactive built space as the new means of telecommunications. In 2019 Systems of Signals Generating and Processing in the Field of on Board Communications, IEEE, pp. 1-4. https://doi.org/10.1109/SOSG.2019.8706772
[14] Rowan, P. (2020). Agility in interior architecture: An investigation through prototypical design for interactive spatial dynamics. Master's dissertation. Te Herenga Waka—Victoria University of Wellington, New Zealand. http://researcharchive.vuw.ac.nz/handle/10063/9314
[15] Péninou, A., Grislin-Le Strugeon, E., Kolski, C. (1999). Multi-agent systems for adaptive multi-user interactive system design: Some issues of research. In Proceedings of HCI International (the 8th International Conference on Human-Computer Interaction) on Human-Computer Interaction: Ergonomics and User Interfaces, 1(1): 326-330. https://dblp.org/rec/conf/hci/PeninouSK99.bib
[16] Boychenko, K. (2019). Agency of interactive architecture in socio-technological relationship through actor-network theory. In "Hello, Culture" 18th International Conference, CAAD Futures, pp. 192-202.
[17] Croné, M., Jansson, C.G., Jonsson, M., Kilande, F., Lönnqvist, P., Mattsson, J., Li, W., Werle, P. (2002). Ubiquitous interactive spaces. In Proceedings of the Ubicomp Conference, pp. 1-20.
[18] Parsaee, M., Motealleh, P., Parva, M. (2016). Interactive architectural approach (interactive architecture): An effective and adaptive process for architectural design. HBRC Journal, 12(3): 327-336. https://doi.org/10.1016/j.hbrcj.2015.01.001
[19] Amini, M., Mahdavinejad, M., Bemanian, M. (2019). Future of interactive architecture in developing countries: Challenges and opportunities in case of Tehran. Journal of Construction in Developing Countries, 24(1): 163-184. https://doi.org/10.21315/jcdc2019.24.1.9
[20] ICS materials: Interactive, connected, and smart materials. (2022). http://www.icsmaterials.polimi.it/.
[21] Ferrara, M., Rognoli, V., Arquilla, V., Parisi, S. (2018). Interactive, connected, smart materials: ICS materiality. In Intelligent Human Systems Integration: Proceedings of the 1st International Conference on Intelligent Human Systems Integration (IHSI 2018): Integrating People and Intelligent Systems, Springer International Publishing, pp. 763-769. https://doi.org/10.1007/978-3-319-73888-8_118
[22] Nabil, S. (2020). Organic user interfaces for interactiveinterior design. Ph.D. dissertation. Newcastle University, UK. http://theses.ncl.ac.uk/jspui/handle/10443/5130.
[23] Ferrara, M., Bengisu, M. (2014). Materials that change color. Springer International Publishing, pp. 9-60. https://doi.org/10.1007/978-3-319-00290-3_2
[24] Persson, A. (2013). Exploring Textiles as Materials for Interaction Design. University of Borås, Sweden.
[25] Tigwell, G.W., Crabb, M. (2020). Household surface interactions: Understanding user input preferences and perceived home experiences. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, pp. 1-14. https://doi.org/10.1145/3313831.3376856
[26] Wilson, C., Hargreaves, T., Hauxwell-Baldwin, R. (2015). Smart homes and their users: A systematic analysis and key challenges. Personal and Ubiquitous Computing, 19: 463-476. https://doi.org/10.1007/s00779-014-0813-0