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THE RESEARCH - DESIGN INTERFACE

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Analyzing Effective Variables to Explain the Ratio Preferences among Autistic and Non-Autistic Children

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ABSTRACT: *Purpose:* Despite the prevalent use of the golden ratio in the environment design for autistic users, there is no experimental research that explains their desired space ratio. This study aims to find the desired ratio in the learning environment, like an occupational therapy room for autistic users, while considering effective variables on their choices.
Methodology: Based on McAllister's (2012) study, a scale model inspired by a dollhouse has been chosen to work and play with autistic children directly and find their desired space ratio. Meanwhile, the furniture configuration and the access type in the environment could also define the ratio for interviewees. Accordingly, the scale model was designed with six different scale rooms containing three ratios and two spatial access types represented by the furniture arrangement. 50 autistic children of different ages, genders, and disorders in the moderate and medium spectrum have been randomly sampled. Then, they were asked to choose their desired ratio by playing with the scale model and putting the doll in their preferred room. This study also included 50 non-autistic children as a control group with different genders and defined ages.
Result: After interviewing both groups, the chi-square test with Cramer's V calculation analyzed the result to find the statistically significant correlation between control variables, among which two independent variables had a statistically significant correlation with the chosen ratio for all the interviewees. First, being autistic significantly impacted their desired ratio choice as autistic children went for a ratio of 2:5, and no autistic ones had a high tendency toward the golden ratio (1:1.6). The chi-square test also showed that the access type in the scale model was the effective variable for both groups when choosing their desired ratio. *Conclusion:* The access type of the room with its furniture configuration impacted how users perceived the room's ratio, as well as being autistic or non-autistic users.

KEYWORDS: Autism Design; Autistic Children; Non-autistic Children; Ratio.

INTRODUCTION

Regarding the drastic increase in the number of diagnosed autistic children in this century, much attention has been directed toward providing appropriate design for autistic users, not only in early childhood to get an education but also in adulthood to be independent. The question raised how a designed environment can be effective. Autistic users are usually characterized by sensory disorders and sensory sensitivity, i.e., hypersensitivity and hyposensitivity in their sensory systems, problems in communication skills, ignoring eye contact, and lack of interest in participating in conversations (Mcallister & Maguire 2012; Mostafa 2008). It has been observed that they respond to sensory information in an unusual way that sometimes may lead to torturing themselves. Environment design can play a vital role in controlling sensory information for autistic users and help their cognitive system to perceive the environment much better (Sheykhmaleki *et al*. 2021).

Although direct impacts of environmental features, e.g. thermal comfort, on human satisfaction (Mansourimajoumerd et al. 2023, 2020; Hoes et al., 2009) has always been an issue for designers, other indirect design strategies can play a vital role in user comfort, specifically vulnerable ones like autistic users. In the last two decades, many designers and researchers have been trying to manifest environmental design guidelines for autistic users to alleviate their tensions in space. Magda Mostafa (2008), the pioneer of architecture for autism, concluded her research in the Autism ASPECTS Design Index for varied functional environments, e.g., home or school. In 2016, she addressed spatial organization and discussed the importance of sequences and order in environment design. Gaines *et al.* (2016) highlighted the importance of order in space design in their book. This strategy is regarded as helpful for autistic children to perceive their environment appropriately (Paron-Wildes 2013). Meanwhile, Humphreys (2005) claimed directly that the proportion and ratio in the environment design is one of the crucial variables affecting autistic people's cognitions. Among all the given strategies related to the importance of the proportion and ratio affecting autistic children, there was no experimental study to support which ratio is desirable, how it can be effective, and which variables impact their orientation toward that ratio.

1.0 RATIO, AUTISM, AND EFFECTIVE STRATEGIES

Ever since the environmental design for autistic users has become significantly correlated to their sensory stimulations and their response toward surroundings, many appropriate design strategies have been studied and categorized for autistic users to alleviate their environmental sensitivity. One of these effective strategies for autistic children's needs in the environmental space is the structure of the physical space (Owen & McCann 2013). This general strategy is defined by many sub-strategies like the space ratio (Humphreys 2005), defining the proportion of a room in length to width. The space ratio is one of the effective sub-strategies in environmental design for autistic users. Meanwhile, Kaye and Murray (1982) addressed that the furniture arrangement in the space design can significantly impact the ratio perception of a space. Considering the space ratio for autistic users, the furniture arrangement should also be considered.

Despite the importance of this strategy, designers still do not know the best ratio for autistic users, while the golden ratio, the desired ratio for human beings ever since ancient Greece (Humphreys 2005) has been addressed for autism design. On the other hand, generalizing this ratio to all humankind, like autistic users, may be arguable in research fields and design applications. Although Beaver (2011), like Humphreys (2005), as a professional designer in the industry, believed that spaces with a 3 to 5 ratio (golden ratio) are suitable even for autistic users and tried to apply this ratio in their design, no experimental study has supported this ratio in the space for autistic individuals**.** But the ratio alone cannot be significant in its perception. The furniture configuration and access type in the space can also influence the perception of the ratio (Kaye & Murray 1982). Thus, this study aimed to determine the desired ratio for autistic users in a learning environment, e.g., an occupational therapy room, under the shadow of other effective variables like demographic variables or the furniture arrangement in a room. Since it is only possible to consider some ratios and space furniture arrangements with access types, we should first focus on which ratios and space arrangements should be studied.

The repetitive ratios in nature have always resonated with delight in human perception (Khandelwal & Sahni 2005). Although the golden ratio has been well-reputed since ancient Greece in varied fileds, e.g., nature, the other natural ratios have been less considered; they are still repetitive and can be studied through nature, e.g., solar planets and the ratio between the orbital distances or ratio between the flower petal rhythm (Rawat 2015). Some frequently repeated ratios were considered as follows: the golden ratio (1:1.6), the ratios of (1:2), (1:3), (2:5), (3:8), (5:13), and finally (1:13) (Howell *et al*. 2010). The ratio of (1:2) was too close to (1:1.6), and (2:5) could also be perceived as (3:8) or (5:13). Considering similar ratios in a study might mislead this experiment because the difference could not be felt. Besides, the (1:3) ratio was lengthy and can cause an acoustic issue in a designed environment. Therefore, the ratio options had to be narrowed down to (1:1), the golden ratio (1:1.6), and (2:5).

The furniture arrangement layout in a room was studied through all the designed spaces for autistic users. Five pioneer autism designers, McAllister and Maguire (2012), Mostafa (2014), Yates (2016), Altenmüller-Lewis (2017), and Gaines *et al.* (2016), were chosen to consider their designed layout in our study. The access type between the functional zones in the room and the arrangement of the furniture, as well as the sequence of space zones with different stimulation levels, were studied in each of these samples. Based on their design layout for the sequences between varied zones and the furniture arrangement, the room layout of this study was designed. Finally, two primary access types with furniture configuration were obtained: Radial and linear access types. These two-access types can arrange the furniture in a room, either central-wise or linear-wise.
In this study, the research question sought the desired ratio for autistic users; however, measuring design strategy for autistic children is challenging. Although designers are always considered great illustrators in place-making and graphic representation, some obstacles exist in designing for autistic users. Not only do we have limited research in designing an environment for autism (McAllister & MaGuire 2012), but it is also challenging to know how autistic people perceive their environment to choose an appropriate study method (Nagib & Williams 2017). Concerning autism cognition disorder, for this study, the 3D scale model with a qualitative approach was used in which autistic children could understand the context of the architectural space with varied ratios and access types, and it became possible to work with them directly.

2.0 RESEARCH METHOD

This study modeled McAllister's (2012) research method. He first studied design strategies for autistic users in a classroom to design a scale model of a classroom and then asked teachers to participate in the designed scale model and modify it to create an appropriate educational environment for autistic children. In this study, we used the same method to determine the desired ratios of autistic users and whether other variables significantly affect their choices. The scale model rooms had this feature to be observed all in one glance to be compared by children. On the other hand, this project aimed to find other variables associated with autistic children's approach toward their desired ratio. Therefore, the scale model was the best approach for this study to find the significance. Accordingly, the designed scale models inspired by a dollhouse shaped the experimental approach as a descriptive-analytical method. The considered scale model examined three ratios (1:1, 1:1.6, 2:5) and two additional access types (Radial and Linear) by providing six scale room options to find the desired ratios for autistic users and measure the significance of each

variable on their decision. Although McAllister interviewed first-hand caregivers to modify the classroom design, autistic users had to participate in the current study to measure their desired ratio. At the same time, their first-hand caregivers also cooperated in the process. The non-autistic users were also considered a control group to measure the effectiveness of variables in this group.

To design the scale model, three main phases were established to make sure that this scale model is understandable to an autistic child and has validity:

Phase I. Conducting a comprehensive literature review to categorize effective
strategies in the room design for autistic individuals and applying them to the scale model design;
Phase II. Completion of the scale model with occupational therapists in four steps: (the manner of objectification of different zones in each room, the scale model size, the color of the scale model, the material of the scale model, and doll type);
Phase III. Defining the scale model.

2.1. Phase I. The Literature Review

After reviewing 42 studies concluding on environmental design strategies for autistic users, 15 different methods were obtained, listed in the following: controlling visual and tactile stimulations (related to sensory sensitivity), providing predictable space function, perceptible space, and organized space along with the spatial sequence was effective and selective strategies. Other strategies were not effective or could not be considered in the scale model.
Regarding all the gained design strategies, the scale model had to be designed with: minimal visual information to control visual stimulation, the appropriate material that does not stimulate autistic children when getting the scale model, defining the space zones clearly, and considering sequences for the space zones in each room (sequences from high stimulation to low stimulation). This fundamental data guided this research to upgrade the scale model design with some experienced occupational therapists.

2.2. Phase II. Consulting with Occupational Therapists

As occupational therapists with many years of expertise in working with autistic children know the autistic children's cognition process and how they perceive the environment, an occupational therapist should cooperate in designing the scale model. Besides, designing a comprehensible and imaginable scale model was far beyond designing an actual room to consider all autism design strategies. Accordingly, four main factors had to be considered for the scale model design: illustrating varied space zones being comprehensible as an actual room, the scale model size, color, and doll and scale model material.

2.2.1. The legibility and comprehensibility

The functions of the occupational therapy room inspired the room design in the scale model. Three main zones were defined in the interior design, being arranged from low stimulation to high stimulation, locating the high stimulus zone in front of the main entrance while deferring the calm space far from the entrance and crowded place. To avoid additional visual information in the scale model that may lead to visual stimulation, additional furniture or partitions should be disregarded by considering minimized design elements for each zone. The first space was considered a play area with high tension in front of the room's main entrance. The colored powder was used for this zone to visually stimulate and objectify stress in space (Figure 1, area in the red box). The second space was the therapy or educational zone, where the occupational therapist and child worked together. The table with some chairs around could symbolize this zone (Figure 1, site in the yellow box). To evoke calm or escape space as the last zone in this room sequence, a bed was considered to resemble calmness (Figure 1, area in the green box). The furniture with the least details and colors had to be chosen to be understandable with the least visual stimulations. Finally, colored patches were suggested to visualize the access type (linear and radial forms) between the furniture in the room. Pieces of colored paper with carpet hatches were used (Figure 1 – zone in the blue box), so the child could understand the access much better.

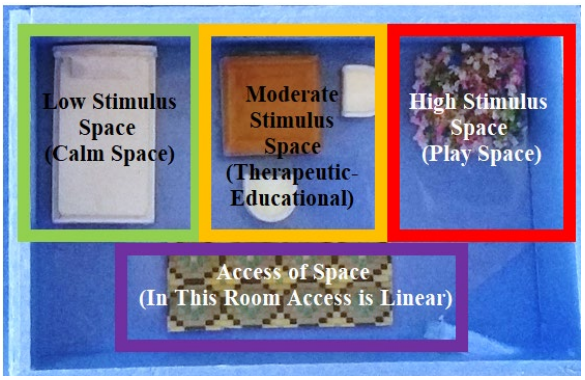

Figure 1. Space design of scaled rooms. (Author, 2020)

The Scale Parameter

Since McAllister's (2012) methodology considered scaled rooms to study autistic children, This study imitated this methodology and used a scale model. A suitable scale had to be considered so that all young interviewees could understand and use it appropriately. After preparing a few scale models and consulting with the occupational therapist, a 1:50 scale was selected as a suitable scale to design the rooms. This scale led autistic children to put the scale rooms on their legs, observe all the rooms together, and experience the room sample with their hands.

2.2.2 The Color Study

Since most autistic children suffer from visual stimulation (Sheykhmaleki *et al*. 2021), the color of the scale model could be not only effective in the autistic children's selection but also challenging to cooperate during the interview. Based on Feisner & Reed (2013), blue, red, and yellow are primary colors, and orange, green, and purple are complementary colors. The spicy colors might increase tension and distraction in hyper-visual-sensitive autistic children (Gaines *et al*. 2016). Therefore, the occupational therapist suggested that three shades of purple, orange, and red had to be eliminated from the offered options. On the other hand, three blue, green, and yellow colors had to be readily available for children's varied desires. Before the interview, Children or first-hand caregivers were asked to identify their favorite color among the colors prepared. Then, the chosen color was put in front of the interviewee to play.

2.2.3 Materials

Lastly, the scale model and doll-type material were also crucial for autistic users. Some autistic children have tactile sensitivity that the scale model material could stimulate them. The foam was chosen among all the possible materials for the scale model. The foam caused no danger for the child (in the event of aggressive reactions to the scale model) since it was lightweight and flexible. Furthermore, foam is durable and can be reconstructed easily in case of damage. The idea of an edible doll was one of the preferred options, so it would have been safe if a child swallowed the doll. However, as many autistic children had specific dietary restrictions, the soft plastic doll was used.

2.3 Phase III. Defining the scale model

This study aimed to find the effective variables on autistic children's behavior toward ratio. Except for demographic variables related to the interviewees, e.g., gender, age, and the type of sensitivity, we needed to measure two other variables (the ratio and the access type) while other variables were controlled. Concerning three scores for the ratio variable and two scores for the access type, six different rooms created the whole scale model. All these six rooms were designed with the same features except for the ratio and access type varying across all rooms. As for balance, all the rooms had the same width, and the room length changed to create varied ratios. Dimensions of the rooms in the 1:50 scale were: 3.5cmx3.5cm (1:1), 3.5cmx5.6cm (1.6:1), and 3.5cmx8.75cm (5:2). Doors with the exact dimensions and fixed locations were used while the windows were not in the same size. Windows cover the same walls with the same proportional area in each room (1:9). Furniture was also the same and put in the sequences from high-stress to low-stress space. Figure 5 shows the overall view of the scale model.

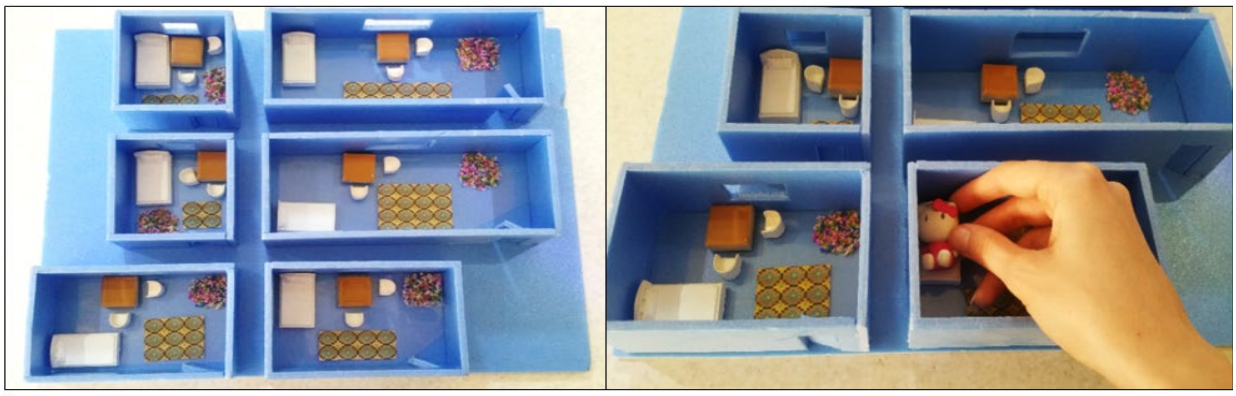

Figure 2. The overview of the scale model. (Author, 2020)

The procedure of interviewing had to be designed carefully to make sure the child perceived the scale model completely, and their response showed their desired ratio. Accordingly, the scale model and the doll were introduced to the child before the interview. The child had enough time to play with the rooms and touch the doll to get familiarized. Different rooms and functions were explained to the child through a game with the doll. This process was critical for autistic children to ensure they perceived the scale model as rooms. After this step, the child was asked to choose the best room for the doll (Figure 2). Then, the child's performance and reactions were observed precisely, and the child was interviewed twice to ensure that the child's decision was their preference.

Regarding the severity of each autistic child and their sensory sensitivities, the interviewing at each time for each child could take 30 minutes to 1 hour, depending on the therapist's approval regarding their perception of the scale model. The six scale model options were labeled and defined for the data analysis. Figure 3 shows each labeled room with a different ratio and access type:

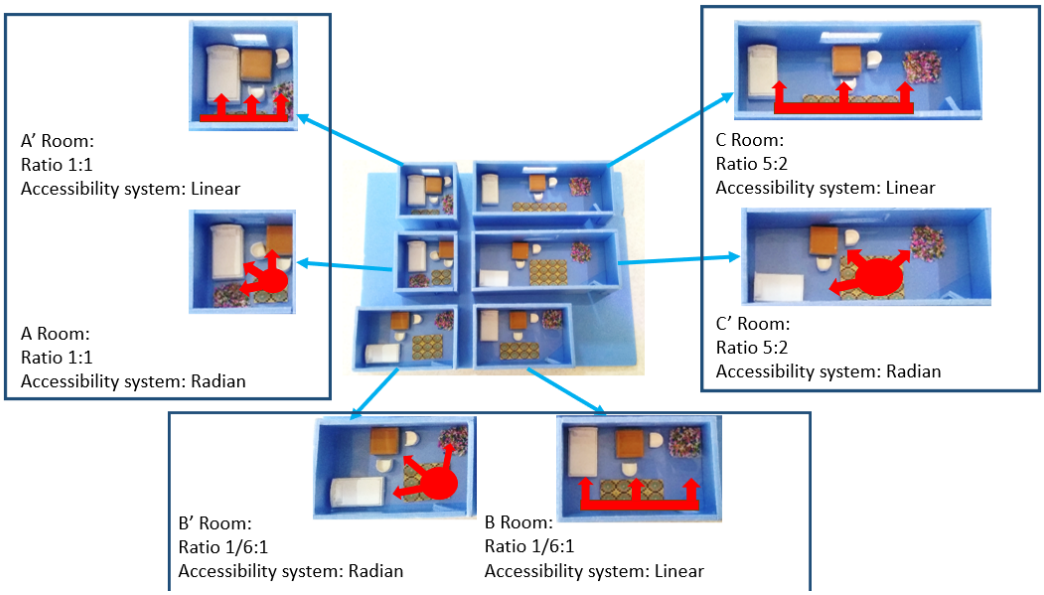

Figure 3. Explanation of each option's structure. (Author, 2020)

To increase the validity of the research, non-autistic children were also used as a control group. Based on Healey (2014), 100 cases had to be selected to meet the required assumptions for hypothesis testing and generalizability. Hair et al. (2018) also noticed that the least number of 20 cases for each independent variable is sufficient to meet the required assumption for statistical analysis. Regarding two independent variables, 50 autistic and 50 non-autistic children were observed to meet both views. The demographic information two groups were as follows:
Since this study was conducted in Iran, the research ethics certification was approved by Payame Noor University in Iran with the code of IR.PNU.REC.1399.084. As The random sampling method was almost impossible to choose autistic children and even non-autistic children, this study chose the snowball non-probable sampling method, in which the first case opted for a charitable organization in Tehran, Iran. The non-autistic children also opted in the same procedures. The age distribution of 50 autistic children was as follows: 4 to 10 years (54%), 10 to 15 years (20%), and 15 to 20 years (26%), of which 66% were male and 34% female and no intersex case was observed. These children fell into two categories of mild (46%) and moderate autism (54%), and according to the scale model conditions, it was impossible to perform the test with children with acute autism. Gaines *et al.* (2016) also classified autistic children into six sensory categories: visual, auditory, tactile, olfaction, vestibular sensitivity, and proprioception. Each category is divided into two categories hyper-sensitive and hypo-sensitive. Due to the measurement limitations, it was not possible to examine the factor of "proprioception," thus the dispersion of interviewees in the other five categories is as follows in figure 4:

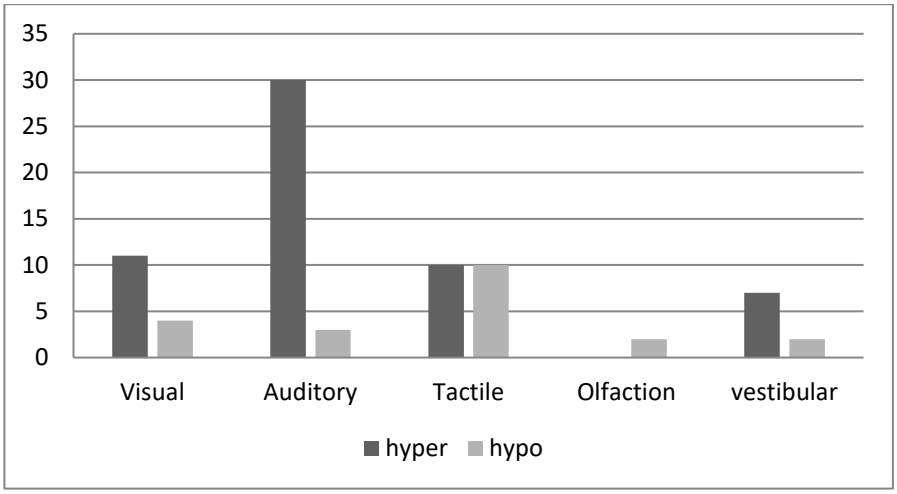

Figure 4. Dispersion of autistic children in sensory sensitivity categories.

The control group included non-autistic individuals with good cognition skills but not too developed in logical perception to mislead the study result by their analytical abilities. Piaget (2003) considered children 2 to 7 years old as being in a “preoperational stage” where they begin to learn symbolically and use imagination in games while their analytical skills have not sharpened yet. This led the article to choose non-autistic children (n=50) aged 4 to 7 years, of which 28% and 72% were 4-5 and 6-7 years old, respectively. 56% of non-autistic participants were female, 44% were male, and no intersex case was reported.

3.0 RESULT

After interviewing 50 autistic and 50 non-autistic children with the designated scale model, the frequency of their responses was measured by the time that interviewees chose each room (option). Their overall response of both groups to the scale model showed that most autistic children (64%) were inclined to a 2:5 ratio, while most non-autistic children (50%) were into a golden ratio (1:1.6); however, the effect of each variable on each group should be considered separately to see which variables were effective in their attitude toward the ratios. Accordingly, their responses were categorized based on five dependent variables (gender, age, being autistic, access type, and the sensory sensitivity for autistic children) to see each correlation with the ratio as an independent variable. Considering the nominal level of measurement, the chi-square test was chosen as a measure of association between categorical variables in a non-parametric study. This statistical test measured the statistically significant effect of each independent variable (gender, age, access type, autistic children's sensory sensitivity type, and being autistic) on the variation of the independent variable, the ratio. Accordingly, five tests were conducted (Table 1) to measure autistic children's attitudes toward the ratio; these tests were also conducted for non-autistic children. Since the strength of this association was also important in this study, Cramer's V was chosen to see how strong the relationship between the two variables was.

Table1. the chi-square and Cramer's v association test result of independent variables on autistic and non-autistic ratio preference.

Independent Variable	The chi-square test	The Cramer's V
Age (for autistic participants)	0	0
Age (for non-autistic participants)	3.51	0.26
Gender (for autistic participants)	2.56	0.23
Gender (for non-autistic participants)	1	0.14
The access type (for autistic participants)	**5.33**	**0.32**
The access type (for non-autistic participants)	**10.82**	**0.46**
Sensory sensitivity of autistic children	3.95	0.28
Being autistic	**17.3**	**0.42**

The significant relation of each dependent variable with the independent variable, ratio, was measured by the chi-square test with alpha 0.1 (marginal error) followed by the Cramer's V calculation to measure the strength of the correlation (Table.1). If the Chi-square test fell in the margin error, then the null hypothesis, i.e., the considered independent variable is not statistically effective in the considered group to choose the ratio, would be rejected. That independent variable would play a statistically important role in the ratios to be selected. Meanwhile, the Cramer's V test ranges from 0 to 1, and the closer it is to 1, the stronger the correlation and the effect size of that variable.

The result suggested that the effect size of age and gender for both autistic and non-autistic populations, and also the sensory sensitivity in autistic children on the ratio preferences, were not significant, and it failed to reject the null hypothesis. Whereas the access type and being autistic had a statistically significant association with the opted ratio, and the effect size shows a strong association between them. In other words, the access type with the furniture arrangement in the designed room and autism disorder were the two main effective variables impacting the final chosen desired ratio in all the sample of population. Although the overall result suggested that autistic children were most interested in the ratio 2:5 and most non-autistic children opted golden ratio, the access type defined in each room significantly impacted the interviewee's approach to opt for their desired ratio.

DISCUSSION AND CONCLUSION

The result suggested that autistic and non-autistic children have different tendencies for ratio. Among all the examined variables being influential in their decision toward the desired ratio, autism was significantly effective in their final approach to the ratio, as well as the access type of the space affecting the ratio preference of both groups. Meanwhile, the rest of the considered variables, such as age, gender, and the type of autistic children's sensory sensitivity, were ineffective. In other words, autistic children, regardless of their sensory sensitivity, behaved differently in choosing their

desired ratio compared to non-autistic ones. Meanwhile, the access type and the furniture arrangement of the interior design of the room have a significant association with the ratio tendency among autistic and non-autistic children. Although autistic and non-autistic people had different approaches in their ratio decision, it seems that the access type in the space had the same effect on their decision. Since both groups appealed to the radial access type in their different ratio selections, this variable affected their decision in the same direction; however, the reason for choosing this type of access in the space might be different between these two groups.

RESEARCH LIMITATION

When it comes to considering the limitation of this research, first and for most, it should be regarded that the aim of this study is not generalizing data to an actual 1:1 scale; instead, conducting a research study to alter the general perspective about the ratio for autistic users; it showed the different approaches of autistic and non-autistic sample group and effective variables on their tendency toward it. Furthermore, this research was not defined for causal study or generalizability. Instead, it aimed to find whether other variables had a statistically significant relation with ratio preferences among autistic and non-autistic children. Therefore, this research was not designated to support internal or external validity to provide generalizability.

In this study, the scale model was designed on the 1:50 scale to provide all the possible options together in front of the child and let them compare all options together and find the difference in rooms just by the proportion with two different access types; however, it might not be the best research design to make sure whether the autistic children with all sensory difficulties perceived the scale model as an actual room and find whether it is their desired proportion. Accordingly, it is highly suggested that not rely on this result to be interpreted as design code, but an actual scale of this study is required to support this result.

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