Factors influencing environmental perception: A Systematic Review

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Abstract. This paper is a systematic meta-analysis based on selected empirical studies to evaluate human-environmental perception. The research concentrates on Eye-tracking technology, electroencephalograph (EEG), electrocardiograph (ECG), and electrodermal activity (EDA). This study investigates the realm of human cognition and its engagement towards the environment. Nevertheless, the studies focus on the factors that enhance human perception towards the surrounding environment by exploring virtual reality. Methods of the review follow systematic meta-analysis guidelines. Meta-analysis is conducted from selected empirical articles, aligned with research questions, published in journals between 2005 and 2020 in the English language. ProQuest, MDPI, PubMed, and Google scholar are the Electronic databases used to extract research works till September 2020 for data analysis. The study analyses the scope for further research using multivariable investigation in the domain of human visual perception. Future explorations could focus on factors such as Semi Immersive technology, the Elderly category, and Color-based influence. Result also suggest the necessity of exploring EEG and Eye-tracking technology in the domain of environmental perception. This work would be a reference for the psycho-physiological researchers on human-environment studies.

1. Introduction
Human beings can perceive both the tangible and intangible aspects of the environment. Researchers have explored different human environments, including the influence of nature on human attention, memory, impulse inhibition, concentration, mood, and mental health (Bratman et al., 2012; Bratman et al., 2019). The role of the natural environment and designed environment in human perception has been exploring by many researchers. They have tried to understand the efficiency of communication through different designed environments. Studies were conducted to understand the design space and management aspects of visitor perception and experience, based on the recreational environment so that targeted experience in human could be archived by different environmental settings (Dorwart et al., 2009). The study conducted by Franco et al. (2017) states the representation of nature on visuals or experiencing the view of nature through windows, uplifts the mood and health of the user. The result demonstrates the relevance of integrating nature with designed environments. Goodey and Gold in 1987 addressed the perception of built environments. Exposure to nature using controlled laboratory settings demonstrated a relaxing experience as compared to investigation with images of urban scenerios (Grassini et al., 2019). This empirical data indicates that the presence of natural environments leads to lower attentional engagement and cognitive load. Such a result is significant for a designer to achieve such psychological quality through a designed environment.
Environmental influence is significant since nature plays restorative effects on the human environment (Kaplan, 1995). The nature of perception will differ for different age groups. While considering the perception of the children's age group, educators play a crucial role in communication. It will be necessary for an educator to understand children's perception to provide a meaningful learning environment at the early stages. Nature, literature, and media had a tremendous influence on children (Keliher, 1997). It is valuable to understand the experience of children in these environments. As discussed above, nature has a strong connection with human perception; similarly, the empirical study suggests that preserving the environment for both actual and virtual conditions improves well-being and environmental transactions (Reddon and Durante, 2018). The result indicates the possibility of enhancing the performance over the technology-based environment through the real environment and states the significance of nature's benefits over human perception. It is also important to explore different environments due to emerging technological interventions. A balanced mental state is essential to understand the accurate perception of the environmental conditions. People from urban contexts, exposed to natural seek similar environments in his/her surroundings (Richardson et al., 2017). This demand is because of the restorative effect of nature that archives depleted attention capacity and improvises stress response in human autonomic nervous systems. Advanced physiological reading devices like EEG and Eye-tracking used to evaluate human beings' perception and cognition. The studies explored that Alpha activity is related to relaxation, and Beta activity with attention. Older people's EEG activities monitored while walking in different urban environments for the same. The results are fascinating. No elevated physiology reading stated for the case of urban green and quiet conditions in neuron experiments (Neale et al., 2020). This result might be due to the designed environment and influencing factors, and it has to be analyzed based on controlled environmental settings to develop efficient environment perception.

2. Methods
This systematic literature review follows the PRISMA guidelines and flow chart. The study guideline includes a 27-item checklist and a four-phase flow diagram to explain transparency in conducting this literature review (Moher et al., 2009). A large number of measurements have been identified in several tasks using Eye tracking and EEG. Most important data related to the research topic mentioned here. However, the purpose of the study is to examine existing research on human perceptions over virtual environments. This study attempts to understand the role of various factors in a real and virtual environment that can enhance attentional engagement. For the literature review, the data formulation was performed based on the inclusion and exclusion criteria. A systematic analysis performed for selected 44 articles. Table 1 represents the meta-analyzing of the data processing technique followed in each empirical study. The symbol * represents 1 point in Table 1 for the point score generation.
**Table 1.** Point score developed based on reviewed article.

| Score            | Mild / Not sure | * | Moderate / Normal | * | * | * | * | * | * | * | * | * | * |
|------------------|-----------------|---|-------------------|---|---|---|---|---|---|---|---|---|---|---|
| Influencing / input factors | Motivation | * | * | * | | | | | | | | | |
|                  | Colour         | * | * | | | | | | | | | | |
|                  | Visual Emotion | * | * | | | | | | | | | | |
|                  | Sound / Audio  | * | * | * | | | | | | | | | |
|                  | Real Built / Design | * | * | * | * | * | | | | | | | |
|                  | Virtual Design | * | * | * | * | | | | | | | | |
|                  | Point of vision | * | * | | | | | | | | | | |
|                  | Nature / human | * | * | | | | | | | | | | |
| Too 1            | EYE TRACKING   | * | * | * | * | | | | | | | | |
| Age              | ECG / EDA      | * | * | * | * | * | | | | | | | |
|                  | EEG            | * | * | * | * | * | * | | | | | | |
| Sex              | Female         | * | * | * | * | * | * | * | * | * | * | * | * |
|                  | Male           | * | * | * | * | * | * | * | * | * | * | * | * |
| Parameter        | Elderly(60+)   | * | * | * | * | * | * | * | * | * | * | * | * |
|                  | Adult (18+)    | * | * | * | * | * | * | * | * | * | * | * | * |
|                  | Children (1-18)| * | * | | | | | | | | | | |
|                  | Real time Render | * | * | * | * | | | | | | | | |
|                  | Images / Static | * | * | * | | | | | | | | | |
|                  | V-Simulation   | * | * | * | | | | | | | | | |
|                  | Virtual Immersive | * | * | | | | | | | | | | |
|                  | Semi Immersive | * | * | | | | | | | | | | |
|                  | Virtual Screen | * | * | | | | | | | | | | |
|                  | Real Environment | * | * | | | | | | | | | | |
| Author and Year  | G. Li et al., 2020 | 1 |
|                  | Ahtola et al., 2014 | 2 |
|                  | Wiens et al., 2016 | 3 |
|                  | Aspinall et al., 2015 | 4 |
|                  | Y. Wang et al., 2018 | 5 |
|                  | Peterson et al., 2018 | 6 |
|                  | Chuang et al., 2013 | 7 |
|                  | Y. Li et al., 2019 | 8 |
|                  | Desvergez et al., 2019 | 9 |
|                  | Goto et al., 2019 | 10 |
|                  | Tremmel et al., 2019 | 11 |
| Score          | Mild / Not sure | Moderate / Normal | Severe / Positive |
|---------------|-----------------|-------------------|-------------------|
| Influencing / Input factors | | | |
| Motivation    | *               | *                 | *                 |
| Colour        |                 |                   |                   |
| Visual Emotion|                 |                   |                   |
| Sound / Audio | *               | *                 | *                 |
| Real Built / Design | *   | *                 | *                 |
| Virtual Design| *               | *                 | *                 |
| Point of vision|                 |                   | *                 |
| Nature / human| *               | *                 | *                 |
| Too Influencing / Input Factors | | | |
| EYE TRACKING  | *               | *                 | *                 |
| ECG / EDA     | *               | *                 | *                 |
| EEG           | *               | *                 | *                 |
| Sex           | | | |
| Female        | *               | *                 | *                 |
| Male          | *               | *                 | *                 |
| Age           | | | |
| Elderly(60+)  | *               | *                 | *                 |
| Adult (18+)   | *               | *                 | *                 |
| Children (1-18) | *        |                   | *                 |
| Parameter     | | | |
| Real time Render | *   | *                 | *                 |
| Images / Static | *     | *                 | *                 |
| V-Simulation  | *               | *                 | *                 |
| Virtual Immersive | *       |                   |                   |
| Semi Immersive | *       |                   |                   |
| Virtual Screen | *     | *                 | *                 |
| Real Environment | *   |                   |                   |

**Table 1.** (Continued)

| Author and Year | Serial Number |
|-----------------|---------------|
| Lanata et al., 2020 | 12            |
| Maggio et al., 2020 | 13            |
| Yang et al., 2011  | 14            |
| Dimigen et al., 2011 | 15            |
| Güntekin & Tülay, 2014 | 16    |
| Wei-Long Zheng et al., 2014 | 17   |
| Romei et al., 2008  | 18            |
| Dahal et al., 2014  | 19            |
| Y.-K. Wang et al., 2015 | 20   |
| Nikolaev et al., 2016 | 21            |
| Al-barrak et al., 2017 | 22            |
Table 1. (Continued)

| Score               | Mild / Not sure | Moderate / Normal | Severe / Positive |
|---------------------|-----------------|-------------------|-------------------|
|                     |                 |                   |                   |

| Influencing/ input factors | Motivation | Colour | Visual Emotion | Sound / Audio | Real Built / Design | Virtual Design | Point of vision | Nature / human | EYE TRACKING | ECG / EDA | EEG |
|-----------------------------|------------|--------|----------------|---------------|---------------------|----------------|----------------|---------------|-------------|----------|-----|
|                             | *          | *      | *              | *             | *                   | *              | *              | *             | *           | *        |     |

| Too | | | | | | | | | | | | |
|-----|---|---|---|---|---|---|---|---|---|---|---|---|
|     | * | * | * | * | * | * | * | * | * | * | * |     |

| Sex | | | | | | | | | | | | |
|-----|---|---|---|---|---|---|---|---|---|---|---|---|
|     | Female | * | * | * | * | * | * | * | * | * |     |
|     | Male    | * | * | * | * | * | * | * | * | * |     |

| Age | | | | | | | | | | | | |
|-----|---|---|---|---|---|---|---|---|---|---|---|---|
|     | Elderly(60+) | * | * | * | * | * | * | * | * | * |     |
|     | Adult (18+)    | * | * | * | * | * | * | * | * | * |     |
|     | Children (1-18) | * |     |     |     |     |     |     |     |     |     |
|     | Real time Render | * | * | * | * | * | * | * | * | * |     |
|     | Images/ Static  | * |     |     |     |     |     |     |     |     |     |
|     | V-Simulation    | * | * | * | * | * | * | * | * | * |     |
|     | Virtual Immersive | * |     |     |     |     |     |     |     |     |     |
|     | Semi Immersive  | * |     |     |     |     |     |     |     |     |     |
|     | Virtual Screen  | * | * | * | * | * | * | * | * | * |     |
|     | Real Environment | * |     |     |     |     |     |     |     |     |     |

| Author and Year                | Weaver et al., 2017 | Maksimenko et al., 2017 | Olszewska-Guizzo et al., 2018 | Olszewska-Guizzo et al., 2020 | Valenti et al., 2014 | Campbell & Moran, 2014 | Valtchanov & Ellard, 2015 | Venkatraman et al., 2015 | Matukin et al., 2016 | Zheng et al., 2019 | van Almkerk & Huisman, 2018 |
|--------------------------------|----------------------|--------------------------|---------------------------|--------------------------|----------------------|--------------------------|---------------------------|----------------------|----------------------|--------------------------|
| Serial Number                  | 23                   | 24                       | 25                        | 26                       | 27                   | 28                       | 29                        | 30                   | 31                   | 32                       | 33                       |
Table 1. (Continued)

| Score                  | Mild / Not sure | Moderate / Normal | Severe / Positive |
|------------------------|-----------------|-------------------|-------------------|
|                        |                 | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆          |
| Input factors          |                 |                   |                   |
| Motivation             | ⋆               | ⋆ ⋆ ⋆ ⋆           |                   |
| Colour (Black & White) |                 |                   |                   |
| Visual Emotion / Value |                 |                   | ⋆                 |
| Sound / Audio          | ⋆ ⋆ ⋆ ⋆         |                   |                   |
| Real Built / Design    | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
| Virtual Design         | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
| Point of vision        |                 |                   |                   |
| Age                    |                 |                   |                   |
| Elderly (60+)          |                 | ⋆ ⋆ ⋆ ⋆           | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆       |
| Adult (18+)            |                 | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
| Children (1-18)        |                 |                   |                   |
| Parameter              |                 |                   |                   |
| Real time Render       | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
| Images / Static        | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
| V-Simulation           | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
| Virtual Immersive      |                 |                   | ⋆                 |
| Semi Immersive         |                 |                   | ⋆                 |
| Virtual Screen         | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
| Real Environment       | ⋆               |                   |                   |
| Author and Year        |                 |                   |                   |
| Michael et al., 2019   | 34              | 35                | 36                |
| Giannakos et al., 2019 |                 |                   |                   |
| Haber-Huber et al., 2019 |             |                   |                   |
| Rogers et al., 2020    |                 |                   |                   |
| Frazin et al., 2011    |                 |                   |                   |
| Berto et al., 2008     |                 |                   |                   |
| Valchitnov et al., 2010 |             |                   |                   |
| Codispoti et al., 2012 |                 |                   |                   |
| Chumerin et al., 2013  |                 |                   |                   |
| C.-M. Chen & Wu. 2015  |                 |                   |                   |
| Antle et al., 2018     |                 |                   |                   |
| Serial Number          | 34              | 35                | 36                |

| Age                    | Female | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
|                        | Male    | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ | ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ |
3. Result and Discussion
We outline the main works collected through literature survey using the method described in the previous section. The future investigations could focus on factors such as Semi Immersive technology, the Elderly category, and Color-based influences.

3.1. Influence of Real environment
The result of the study shows that the experimental investigation using the real-environment is comparatively less. Seven empirical studies with a mean value of 15.91, open a way to further research in this parameter. Outcomes of seminal studies by Richardson and collaborators found that the attentional capacity and Restorative effect can influence autonomic nervous systems, while exposed to surrounding environments. The results show that people seek out nature’s similar space in the urban context for high well-being (Richardson et al., 2017).

3.2. Impact of Virtual screen
The review indicates researchers are interested in exploring virtual environment simulations such as LCD monitors, screen, and touch screen. About 72.73% of the 44 empirical studies in this review used virtual environments as simulation media. 38.64% of the researchers that is 17 studies in 44 studies used static images in their experiments. The researchers used the display as an environment. Display such as LCD screens, touch screens, and monitors for measuring perception from different sample categories. Controlled laboratory settings will provide an accurate output for any empirical studies can obtain by using these devices (Couperus and Lydic, 2019; Folstein et al., 2017; Pillai et al., 2013; Bowman and McMahan, 2007). The virtual stimulation might be either an LCD screen or more immersive technology using an HMD or implementation of a cave automatic virtual environment (CAVE) (Cruz-Neira et al., 1993). The development of modern simulation tools and technology provide a path for new dimensions in environmental perception investigations.

3.3. The efficiency of Semi immersive environment
The result also showed that researchers using semi-immersive tools is relatively low. Among the 44 empirical studies of this survey, only five researchers (mean value of 11.36) use semi-immersive simulation tools. The studies by (Gao et al., 2000, Kyriakou et al., 2017) showed that participants from an empirical investigation using semi-immersive simulation seem more interactive because of its close similarity with the real environment. Results show the robustness of the cognitive state analysis methods and attention engagement. This experience points out that in the future of augmented reality and mixed reality, human attentional behaviors can be well-blended within the semi-immersive space.

3.4. Virtual immersive based performance
The result shows that virtual immersive not considered in the majority of empirical studies. In selected 44 research articles, only seven studies showings (mean value of 15.91) used virtual immersive based tools. Virtual immersive represented to the context where HMD and similar devices consider research experiments. Immersive Virtual Environment Technology (IVET) has the potential to enable the paradigm shift within social psychology investigations. The study expected that IVET would reduce or eliminate the trade-off between experimental control and mundane realism (Blascovich et al., 2002). IVET-based studies provide a controlled environment, which could provide a cohesive understanding of the human behavioral pattern in their environment (Loomis et al., 1999). This technological development will be an advantage to have more of a real environment without compromising natural space. The accuracy and stability of the physical settings and calibration measurements are also a prominent part of better Visual registration (Deering, 1992). So not only the environment but also the technicality have a vital role in achieving immersive virtual conditions. Virtual immersive is employed for both interactions and reading purposes. The study indicates that attention engagement can also archive increased reading performance in the HMD than in the real environment.
3.5. Consideration of age category
The study identified nine (20.45%) experiments that explore a group of age category 1 to 17, and thirty-nine researchers also use a group of participants with an age bar between 18 and 59. Moreover, the result identified that only a few research works were conducted using the elderly population. Thus two out of 44 studies use the age group of 60, and above individuals, hence the results show that more consideration is required on the environmental perception of adult categories.

3.6. Tools used for physiological readings
Point of gaze and physiological measurements are influencing tools for the researchers of environmental perception. About 70.55% of researchers adopted EEG to evaluate the human brain while the samples attend and perceive various environmental stimuli. Researchers on perception and attention studies showed their interest in multi assessments using various physiological tools and eye-tracking devices. For example, the survey noticed seven out of 44 experiments used ECG and EDA (Pozharliev et al., 2015; Mulholland and Runnals, 1962; Betti et al., 2018) to record levels of stress, dermal conductivity, cardiac rhythm while exposed to different environmental conditions (Affanni, 2020; Alexandre et al., 2016; Haouij et al., 2018). The attention, perception, and engagement level can document and evaluated using post-modern tools for eye-tracking. 43.18% of selected studies selected Eye-tracking devices for analysis of gaze movement. Gaze analysis tools are commonly found in research works to investigate eye movement and attention. The research-based on visual merchandising and retail product arrangements could widely explore attention, perception, and purchase behavior of consumers using Eye-tracking tools (Bucher and Schumacher, 2006; Clement et al., 2013; Guo et al., 2016; J. Lee and Ahn, 2012). The features of the environment also impact the human mind and body at a different level. (Treisman and Gelade, 1980). The environmental features like tactile, visual and auditory quality would result in high variations while experimenting in reading. For example, the seminal study conducted by Yoto and collaborators (2007) found the effect of color based stimulation on brain activity on EEG. Similar to color visual luminance of a setting is another contributing factor that can impact human fear and emotional perception (M. Kim et al., 2019). M. Kim and collaborators (2019) identified nightscape condition increase the fear of subjects. The visual perception application on brand management and visual merchandising is a fruitful area for further studies exploring the scope of lab-based and experiments based on live case studies. The physiological markers will be an addon for more accurate measurements over perception, attention, and behavioral dynamisms.

3.7. Influence of view point on environmental perception
The human viewpoint and angle of vision are influencing factors of environmental perception. The result shows that only a few authors (4 empirical studies, 9.09%) studied human viewpoints and environmental-based perception. The researchers used 2-dimensional simulation focus on the placement of targets with central and peripheral compositions. Also researchers used 3-dimensional stimuli that were important for the physical viewpoint or angle of vision. Perspective or angle of eye vision has a significant role in information processing. The information processing related to the environment is also a factor of level, visual angle, and distance of object on target of vision (Huynh-Thu et al., 2011; Wolfe et al., 2017; Vater et al., 2016). The study indicates that the researchers on human perception have to consider the observer's viewpoint and their perspective on human perception studies.

3.8. Impact of sound on an environment
Audio or sound properties have a prominent role in perception and cognition, which is equally sensed by human organs. Humans perceive audio signals with equal importance as visuals. Results from the survey show audio signal is an influencing factor. About 27.27% of 44 studies have used audio simulation to analyses human-environmental attention. Audio signals have a high level of effect to reduce human stress and attention restoration. Researchers have used natural sounds (such as the sound of birds, animals, waterfall, and soothing music) to verify arousal and fatigue levels (Ratcliffe et al., 2013; Rodero, 2012; Stiefelhagen et al., 2001). Testing the effect with various sound stimuli could
enhance visual attention (Vilaró et al., 2012). Researchers were thrown light on the gender performance effect based on different stimulus conditions (Pressnitzer et al., 2018). The result by Pressnitzer and partners (2018) indicates a significant tendency for girls to perform with greater accuracy than boys in different music conditions. Further research could explore multiple modalities considering visual, auditory, tactile, olfactory, and gustatory perception of different age categories and gender in multi environments.

4. Conclusion
This research area on the human perception of the environment is focused on human wellbeing and sustained development. The users perceive the same environment differently according to multiple factors such as gender, age, social, and other cognitive factors. Real environments or natural settings have a direct impact on living beings, especially humans. Artificial environments using modern stimulation technology is a viable solution for psycho-perception studies. Further research could explore the environmental influence in perception on different age categories and genders under multiple environments. Physiological evaluations of multi modalities (visual, auditory, tactile, olfactory, and gustatory) of the environmental perception on elderly population is an area for further research. Further research can conduct to design environmental settings which would aid both healthy and differently-abled individuals.

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