Perception and Cognition in People with Autism Spectrum Disorder: An Analysis of Workplace Infrastructure

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Over the last few decades, the prevalence of Autism Spectrum Disorder (ASD) has increased from about 0.03% to closer to 1%, which is largely attributed to expansion of diagnostic criteria and increased awareness of ASD (Thapar 2020). In 2016, the prevalence of ASD in the United States was estimated at closer to 1.5% but still, there are many gaps in scientific and common understanding of the disorder (Chiarotti & Venerosi 2020). Generally speaking, ASD is a neurodevelopmental disorder characterized by a variety of different social and cognitive symptoms including sensitivity to stimuli, social impairments, communication impairments, and repetitive behaviors and interests. Autism is recognized as a spectrum, with a variety of presentations in different people with ASD (Frith and Happé 2005).

Given the increasing prevalence of ASD but continued lack of understanding, to better support people with ASD in society, the question arises: how do people with ASD's perception and information processing differences impact their ability to operate in a traditional workplace? Specifically, current accommodations are often built on top of the workplace, asking the employee with autism to adapt to the built environment. However, using an infrastructure framework as detailed in Susan Leigh Star's article, "The Ethnography of Infrastructure" the specific cognitive and perceptual capabilities of people with autism can inform the fundamental design of workplace infrastructure (2009).

Autism and Underemployment

Both from a genetic and neurological standpoint, the exact cause of Autism Spectrum Disorder has not been identified (Frith and Happé 2005). Although ASD is one of the most

heritable developmental disorders, it is not entirely so. Even identical twins exhibit high variability in the presentation of ASD, indicating other environmental or entirely stochastic influences on ASD symptoms. However, it is known that ASD is comorbid with ADHD, learning and motor coordination disorders, and tic disorders (Thapar 2020). Much of what is currently known about ASD is surrounding the various social deficits people with ASD exhibit, including difficulty reading emotions, making eye contact, remembering faces, and communication to varying degrees. Additionally, many people with ASD are highly resistant to changes in routine, a difficulty planning ahead and adapting to new situations (Frith and Happé 2005).

Oftentimes, these differences subject people with ASD to discrimination in accessing and retaining employment, barring people with ASD from the emotional, social, and monetary benefits that neurotypical employees are afforded (Cooper & Mujtaba 2022). And although social disparities are most commonly the subject of study regarding ASD, sensory abnormalities are observed in 95% of children with ASD (Chung and Son 2020). Thus, specifically when looking at workplace infrastructure design, it is essential to understand the cognition and perception abilities of people with ASD, not just social dynamics.

Underemployment of people with ASD is a pervasive problem; one study of 68 individuals with ASD found that only two were working with full salaries by the time they reached adulthood. Moreover, of people with disabilities, people with ASD have the lowest employment rates (Chen, Leader, & Sung 2015). Moreover, another study conducted on current workplace accommodation strategies found that accommodations are more effective for people with physical disabilities compared to intellectual disabilities, indicating a need for a different strategy to aid in integrating the workplace for people with ASD (Nevala, Pehkonen, Koskela, Ruusuvuori, & Anttila, 2014). In one study conducted on methods of facilitating employment

specifically for people with ASD in Australia and Sweden, a primary finding was that design of the "built environment" was integral to employee job retention, supporting the idea that more focus needs to be put into the design of more inclusive workplace infrastructure (Dreaver et. al., 2019). However, in order to effectively design this infrastructure, it's essential to understand the perception and cognitive abilities of people with ASD, and understand how they interact with their environment.

Infrastructure as an Element of Society

Susan Leigh Star's 1999 article "The Ethnography of Infrastructure" focuses on the relational nature of infrastructure and how it's built into the background of society. Infrastructure should not be taken for granted, even though it is not noticeable to the general public, because the ways in which it's designed can reveal norms and values of the social groups that operate within it. From the ethnographic study conducted, Star created a definition of infrastructure characterized by nine key properties: embeddedness, transparency, scope, learned as part of membership, links with convention of practice, embodiment of standards, built on an installed base, becomes visible upon breakdown, and fixed in modular increments (Star, 1999). In researching the relationship between workplace infrastructure and people with ASD, the properties of infrastructure were analyzed as to whether or not they were upheld in traditional workplaces for an employee with ASD.

Star's article is a foundational work for infrastructure framework in a general capacity. However, Star herself was a sociologist, and much of her work is not specific to engineering. She does have earlier works on infrastructure, namely a 1996 article on participatory design in large information system infrastructure (Neumann & Star). Works by other authors that build on Star's

work fall into three broad categories, works about information systems, ethnography, or infrastructure. A 2020 book, Ethnography for the Internet, discusses the difficulties in conducting ethnographic research to study the internet, building on Star's research methods (Hine). Another book, Splintering Urbanism, builds more on her theories of infrastructure in its analysis of infrastructure in urban spaces (Graham & Marvin, 2001). There is continual room to build on Star's theory of infrastructure in different applications, such as workplace infrastructure, as this research paper does.

Research Question and Methods

The research question being investigated is, *how do people with ASD's perception and information processing differences impact their ability to operate in a traditional workplace?* The primary method employed in this research is a thematic literature review focused on the comparison and contrast of key themes in separate lines of literature. Namely, the Engineering Village database is used to obtain literature on workplace design and infrastructure, whereas Google Scholar is used to find more general scientific studies on ASD. Keywords for both searches include Autism, Autism Spectrum Disorder, neurodivergent, autism perception, autism cognition, workplace design, office design, workplace infrastructure, and inclusive workplace. The research is primarily categorized by whether the sources were engineering-based, focusing on workplace design, or psychology and neuroscience-based focusing on cognition and perception abilities of people with ASD. Furthermore, in both lines of research, the chronology of the sources is considered to establish the progression in workplace design and understanding of ASD separately. Ultimately, six sources are compiled relating to ASD, and from these, two overarching themes about the perceptive and cognitive phenotype of people with ASD are

identified. Likewise for workplace design, six additional sources were compiled, and two overarching themes are identified for analysis. By comparing these two types of sources, direct relationships are established between the abilities of people with ASD and the traditional workplace. Insights are drawn as to what aspects of a traditional workplace exclude people with ASD because of misalignment with their cognitive abilities, as well as design elements that include people with ASD and align well with their abilities.

Accessing Workplace Infrastructure for People with ASD

At a high level, the theory behind workplace design does align with many of the cognitive and perceptive distinctions of people with ASD; the principles of infrastructure are upheld for people with ASD in the workplace. There is an emphasis on flexibility and user-centric design that can be adapted to support the heterogeneity of the presentation of ASD. Additionally, people with ASD are commonly hypersensitive and struggle with filtering out local stimuli, and an emphasis in current workplace design is on the physical environment, factors such as light, noise, and temperature that could disproportionately affect employees with ASD. However, the theory of workplace infrastructure is nonspecific in a lot of ways, whereas there are several specific perceptive distinctions of people with ASD, such as a lack of cognitive flexibility and a bias for local perception over global, that if not explicitly addressed in the design of the workplace, would disadvantage people with ASD.

Autism Thematic Analysis: Local vs. Global Processing Bias

The first theme identified is a bias towards using bottom-up perception instead of top-down, referred to as “looking at the trees, but not the forest.” Many people with ASD show a

bias toward attending to local details rather than global ones, which leads to several perceptual superiorities such as in visual detection and search tasks (Chung & Son, 2020, pp. 106). One 2004 study on Gestalt perception in people with ASD that supports this bias analyzed the different usage of top-down processing driven Gestalt principles in grouping and categorization tasks. The two main findings that support this enhanced local processing are that people with ASD more often grouped items by proximity, not similarity. Their bias towards local processing leads to enhanced discrimination abilities which inhibits their ability to categorize by similarity. They are more primed to perceive the differences in items at a local level, rather than ignore those differences to categorize at the global level (Plaisted Grant & Davis, 2009). Thus, fundamentally, people with ASD will experience their environment differently than neurotypical people, so any existing infrastructure that leverages global processing to be understood would therefore violate the principle of infrastructure *learned as membership* for people with ASD (Star, 1999).

The first developed theory to explain this bias is Uta Frith's Weak Central Coherence Theory (WCC) (Charman et al., 2011). This theory states that the local bias is caused by a difficulty integrating locally perceived information with global information, and emphasizes a deficit in the global processing ability of people with ASD (Mottron et al., 2006). Support for the WCC comes in part from brain imaging studies that have found that the frontal lobe, which is more responsible for global processing, is less active in people with ASD when they are completing visual detection tasks (Chung & Son, 2020). Laurent Mottron later proposed a different theory as an alternative to WCC, called the Enhanced Perceptual Functioning Hypothesis (EPF). Contrary to WCC, EPF emphasizes that the differences in local versus global processing in people with ASD compared to neurotypical people are caused not by a deficit in

global processing abilities, but rather a superiority or bias towards local processing (Mottron et al., 2006). The lack of global processing means that in situations where global processing interferes with accurate perception, commonly found in optical illusions, people with ASD excel with the perception of reality (Chung & Son, 2020). Mottron conducted long-exposure hierarchical tasks, another task where global perception interferes with performance, and found that people with ASD presented with "greater autonomy of discrimination processes from the top-down influence of categorization," which is "notably different from a deficit" (Mottron et al., 2006, pp. 35).

Because of this bias for local processing, people with ASD often exhibit enhanced sensory perception. Atypical sensory behavior is observed in about 95% of people with ASD, including adverse responses to sounds, lights, or textures, indicating that there is commonality in a different sensory perception compared to neurotypical people (Chung & Son, 2020). This enhanced perception provides several different strengths to people with ASD, including visual-spatial processing, perceptual trace, feature detection, and as previously mentioned, discrimination abilities (Lage et al., 2024) (Mottron et al., 2006) (Plaisted Grant & Davis, 2009). Additionally, people with ASD are often good at detecting changes due to their placing a greater probabilistic weight on new sensory input compared to neurotypical people (Lage et al., 2024). It is this enhanced sensory perception that can lead to hypersensitivity that many people with ASD struggle with (Mottron et al., 2006).

Autism Thematic Analysis: Lack of Cognitive Flexibility

The second theme identified is a lack of cognitive flexibility, defined as difficulty intentionally shifting between mental functions. This inflexibility can manifest itself as

difficulties adjusting responses to changing environmental stimuli. Oftentimes people with ASD exhibit highly focused attention, because they are less prone to switching mental functions (Lage et al., 2024). One theory as to why cognitive inflexibility occurs is the Cortical Underconnectivity Hypothesis, which states that the cortical network between brain regions is insufficient in people with ASD. The underdeveloped connections between regions make integrating information difficult, as is switching which parts of the brain are being used for a task and thus mental focus (Chung & Son, 2020). The underconnectivity then increases the brain's localized independence for different mental processes, causing local overconnectivity. Although there's no proof that structural underconnectivity would definitively create a deficit in functional synchronicity, it is a possible explanation for the lack of cognitive flexibility and highly focused attention (Mottron et al., 2006). Oftentimes, the lack of cognitive flexibility manifests itself differently in naturalistic settings for people with ASD. In fast-paced environments, people with ASD may fail to notice cues in real time because of the excessive amount of cues presented and the difficulty people with ASD have switching their focus. People with ASD likely struggle to determine salient cues and rapidly switch their focus from not salient cues (Klin et al., 2003). This specific cognitive distinction must be considered in workplace infrastructure design, once again to satisfy the characteristic of infrastructure, *learned as membership*. If the infrastructure relies on a person's ability to rapidly determine salient cues and filter out extraneous stimuli, people with ASD will be unfairly disadvantaged, when instead the infrastructure could be designed to support the acquisition of important information and limit distractors.

Workplace Design Thematic Analysis: Environmental Ergonomics

In the analysis of workplace design theory, one common theme is environmental ergonomics, which is the background atmosphere or environmental factors that influence human comfort in a space: light, noise, air quality, temperature, etc. (Herwanto & Suzianti, 2020). Environmental ergonomics is directly tied to the *transparency* characteristic of workplace infrastructure, the idea that infrastructure should be invisible or not readily noticed by users (Star, 1999). The point of environmental ergonomics is that there are elements of the workplace that should not be noticed by employees. Moreover, a study of small to medium-sized industries in Indonesia names environmental ergonomics as the most important factor in workplace design (Herwanto & Suzianti, 2020). Another user experience based study conducted in China on biophilic workplace design, meaning including greenery and plants to improve employee happiness, also cites factors such as light, noise, and air pollution as the biggest concerns to their user group (Gao et al., 2023). A study specific to success factors for employment of people with ASD in Australia and Sweden cites the work environment, specifically reducing bright lights and ambient noise, as a key success factor (Dreaver et al., 2019). Environmental ergonomics is not only important for worker happiness and mental wellbeing, but also employee productivity. A 2002 study conducted in the Netherlands specific to office design found that improving the indoor environment can improve employee performance by 5-15% (Roelofsen, 2002). Environmental ergonomics also exemplifies another characteristic of infrastructure, *embeddedness,* which describes how infrastructure should be designed within the background of an environment, so in workplace design, focusing on the background elements included in environmental ergonomics would help elevate some of the embedded elements of workplace infrastructure.

Workplace Design Thematic Analysis: User-Centered Design

The second common dimension in workplace design is the concept of flexible, user-centered design. One source emphasizes that the "design of the workplace needs to be focused on the human factors that will occupy it," and thus depending on the type of work and the type of employees working, there will be different needs for the physical space (Herwanto & Suzianti, 2020, pp. 1). User-centered design is a newer focus of workplace design, however. The evolution of the workplace embodies another element of infrastructure, the *embodiment of standards*. The design of infrastructure should reflect the values of the organization or overarching society they operate in. The modern idea of a workplace came after the Industrial Revolution, and the design focus was solely on productivity in terms of maximizing output, completely removing the worker from consideration, and thus the design of the workplace reflected the standards of society at that time. The focus has only recently shifted toward recognizing the importance of having a work environment that increases employee happiness and well-being, as the value of mental health has increased in society (Gao et al., 2023), (Beno, 2021). Additionally, as technology has developed, and specifically post-COVID-19 pandemic, the telework and work-from-home options have drastically increased in feasibility, adding another layer of flexibility to the workplace; a 2021 paper reports that 98% of people would always like to have the option to work from home (Beno, 2021). In the post-pandemic world, workplace infrastructure will evolve even more to embody the new standards of flexibility and user-centered design.

However, user-centered design has the potential to focus design more on accommodations-additions to infrastructure that aid employees on a case-by-case basis. And while accommodations are necessary and beneficial, because they are not embedded in the workplace,

they do not increase the inclusivity of the infrastructure itself. Thus, another concept that holds the same tenant of user-centered design, universal design, is essential to maintaining the *embeddedness* property of infrastructure, while also maintaining *learned as membership* for all users. Although these two sound contradictory, universal design is about creating a design that works for all people using it, regardless of their abilities. It brings inclusion into the forefront as one of the standards being embodied in the workplace, which has positive ramifications for people with ASD. The seven principles of universal workplace design are equitable, flexible, simple and intuitive use, perceptible information, tolerance for error, low physical effort, size, and space for approach and use. The main principle guiding all of these is that the design of the workplace must be fit to the abilities of the people using it, not that people should have to adjust to the workplace. This theory also lists three elements to consider- cognitive work design, physical work design, and social factors. Specifically, this idea of cognitive work design aligns with the principle of infrastructure *learned as membership*, in that the design of the workplace must ensure that all employees can understand their environment regardless of cognitive differences (Mattsson et al., 2022).

Discussion of Comparison and Contrast of Themes

In comparing the key themes between workplace design theory and the perceptual and cognitive abilities of people with ASD, there are several key alignments. Focusing on environmental ergonomics in workplace design would be of greater importance for someone with ASD than a neurotypical person because of their enhanced sensory perception, specifically with things like lights and sound, which most sources cited as the most important considerations of environmental ergonomics. In the study conducted on success factors for workers with ASD,

loud environments were “highly distractive” and “overwhelming” for employees with ASD, whereas neurotypical members could still work in these conditions, the environmental ergonomics would be unsuitable for someone with ASD (Dreaver et al., 2019). Thus, as previously mentioned, environmental ergonomics is an element of workplace infrastructure and thus should be completely transparent, so if an employee with ASD is being distracted by the lights and sounds, the workplace infrastructure is failing to uphold one of the tenets of infrastructure (Star, 1999).

Additionally, the concept of user-centered design broadly aligns with both the themes of a lack of cognitive flexibility and the bias for local processing. If user-centered design is part of the infrastructure, then the embodied standards upheld in the workplace would be supportive of any processing differences of people with ASD. More specifically, the principle of cognitive work design that is highlighted by universal workplace design would alleviate any inequities people with ASD face due to their lack of cognitive flexibility or bias for local processing (Mattsson et al., 2022). Designing with the cognitive workload in mind in combination with the increased consideration of the users of a workspace would elucidate the cognitive needs of people with ASD in the workplace, such as advanced notice to switching tasks (Lage et al., 2024). Cognitive work design would ensure that the infrastructure principle of *learned as membership* is upheld for people with ASD in the workplace.

However, with the cognitive themes of excessing local processing and cognitive inflexibility, there is also a notable potential disconnect; nothing in the workplace design theory explicitly mentions simplifying the workplace environment or the awareness that the complexity of cues in the environment could pose an issue in workplace design. Although, broadly, user-centered design could encompass these concerns, specific “strategies to adjust environments

to accommodate the needs of autistic people in terms of cognitive flexibility" are necessary to avoid violating the infrastructure of *learned as membership* if people with ASD are unable to effectively process their surroundings as seamlessly as neurotypical people (Lage et al., 2024, pp. 17)

Another potential disconnect between the capabilities of people with ASD and the design of the workplace is the discrepancy between the theory behind workplace design and the realized implementation of these theories. The study on success factors for the employment of people with ASD mentions that manager efforts and general organizational understanding of ASD are what provide much of the support for employees- they have to be aware of their employees' needs and alter the environmental ergonomics to create transparent infrastructure for employees with ASD (Dreaver et al.). While necessary manager support is not negative, it also means that there is a difference in the theory of workplace design and the practice of it. Given that many of the characteristics of theoretical workplace design are vague, it is unclear exactly how the infrastructure should be, for example, flexible or equitable (Mattsson et al., 2022).

Limitations and Future Research

The main limitation of research regarding Autism Spectrum Disorder is that ASD includes people with a wide variety of presentations and many different comorbidities that can influence the specific characteristics of any individual with ASD. The cognitive and perceptual phenotype of ASD as a condition is difficult to narrow down and is heterogeneous. One of the sources that specifically attempted to define the cognitive phenotype of people with ASD found that in almost every experiment conducted, there was an overlap in the performance of subjects with ASD and the performance of neurotypical subjects (Charman et al., 2011). Additionally, with research into

workplace design, the biggest difficulty was in defining the "workplace." The definition was intentionally left broad to gain a more holistic view, but in practice, there's a difference between an office as a workplace and a factory as a workplace in terms of functional design requirements. It's likely that the more specific the type of workplace being researched, the more specific alignments and misalignments could be discovered.

The biggest potential for future research based on the findings presented in this paper would be investigating the differences between the theory of workplace design and the practice of workplace design. Specifically, determining which elements of the theoretical design get sacrificed when cost and time pressures appear. Also, much of the theory of workplace design is broad, so more research is needed to determine how exactly these theories are implemented, and then how that implementation aligns with the cognitive and perceptive abilities of employees with ASD. Already from one of the sources mentioned above, managerial practices influence the extent to which environmental ergonomics and infrastructure flexibility are implemented in practice (Dreaver et al., 2019). This research could follow the original practice of Susan Star's research as an ethnographic study of the workplace and would have benefits to several different fields, including human factors engineering, sociology, or industrial organizational psychology.

Conclusion

Overall, there are several notable alignments between the perceptual and cognitive abilities of people with ASD and the design of the workplace. There is an emphasis on user-centric design that would support any unique needs of employees with ASD as well as an understanding of cognitive work design that could help identify the needs of people with ASD surrounding their cognitive inflexibility and local processing bias. Additionally, the focus on environmental ergonomics aligns exceedingly well with the hypersensitivity of people with ASD. However,

despite these apparent alignments between the theory of workplace design and the capabilities of those with ASD, people with ASD still struggle to retain employment and oftentimes struggle to operate within the workplace infrastructure as it is built, and thus more research is needed to determine more specifically where in the design of the workplace in practice people with ASD are held back. Employment has essential benefits to quality of life, giving people financial stability, a social network, and cognitive stimulation; it is important to improve employment outcomes for people with ASD to give them equal access to these benefits.

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