GUIDELINES FOR DESIGN OF LEARNING ENVIRONMENTS FOR CHILDREN ON THE AUTISTIC SPECTRUM

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ABSTRACT

There is a lack of reliable and comprehensive guidelines in the area of the design of learning environments (LE) for persons on the Autistic Spectrum (AS) (e.g., see Kanakri, 2012; McAllister & Maguire, 2012). In addition, there is no appropriate model for knowledge translation that can resolve the gap of knowledge between psychological evidence and design implications. These factors have often led to arbitrary and intuitive designs of LE that do not always accommodate the special behavioral and cognitive needs of persons on the AS. In order to address these problems, the author undertook this thesis. The focus of this research will be upon educational settings for higher functioning ASD elementary-aged students.

The primary objectives of the thesis are the following:

1. To decrease the knowledge gap between empirical studies of physical and psychological aspects of ASD experiences and design implications for more appropriate learning settings.
2. To produce the design guidelines based on scientific knowledge.

The method of inquiry is translational research implemented by systematic transfer of empirical knowledge from the domain of cognitive and clinical psychologies into the domain of design (see Woolf, 2008 for review of a concept of translational research).

The expected outcomes are:

1. A reduction in the knowledge gap between empirical research and design.
2. Guidelines for designers based on the knowledge translation activity.

Prospects for the future work:

1. Refining the process for knowledge translation.
2. Application of the same approach to design of a whole school setting.
3. Further exploration of neuroscience and psychology/sociology as potential providers of knowledge for design.
4. Addressing new research questions.
5. Continuing to address the knowledge gap between scientific evidence and design in other relevant settings (e.g., residential or healthcare environments).
1. INTRODUCTION

“He wandered about smiling, making stereotyped movements with his fingers, crossing them about in the air. He shook his head from side to side, whispering or humming the same three-note tune. He spun with great pleasure anything he could seize upon to spin...When taken into a room, he completely disregarded the people and instantly went for objects, preferably those that could be spun...He angrily shoved away the hand that was in his way or the foot that stepped on one of his blocks...”

Leo Kanner, (1943)

1.1. The Autism Spectrum

“Autism Spectrum Disorders” (ASD) is the clinical term for a range of neurodevelopmental disorders that persist throughout life of an individual (Frith, 2001). The autistic population is increasing rapidly. According to Ahrentzen and Steele (2009), “current estimates of the U.S. population under 20 years of age with ASDs range between 486,000 and 567,000” (see also Fombonne, 2009). Moreover, according to studies provided by the Center for Disease Control and Prevention in 2000, “about one in 150 American children born today will fall somewhere on the autistic spectrum” (Ahrentzen & Steele, 2009; Rice, 2007).

The autism spectrum includes (1) classic autism, (2) Asperger syndrome, (3) Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) (Volker et al., 2010). The severity of autistic symptoms could vary but the overall symptomology remains common for all the variations of the spectrum.

Classic autism is the first discovered disorder of the spectrum. In 1943, child psychiatrist Leo Kanner used the term “early infantile autism” for description of the psychiatric impairments of the children (Volker et al., 2010). He differentiated autistic syndrome from schizophrenia and introduced the first set of autistic characteristics that he observed in 11 children for a several years (Volker et al., 2010). Kanner’s observations became the breakthrough since they formulated the first framework for diagnosis of autism.

Following the Kanner breakthrough, Hans Asperger (1944), Austrian physician, published an article describing children with characteristics similar to Kanner’s observations (Volker et al., 2010). Asperger’s characteristics, however, were apparently milder than those proposed by Kanner. He also observed similar traits in parents of the studied children and, therefore, argued that there was a hereditary factor in the revealed syndrome (Volker et al., 2010). Interestingly, the English audience had not been aware about Asperger’s work until Lorna Wing, an English psychiatrist, introduced the term “Asperger’s syndrome” in her article (Wing, 1981; Volker et al., 2010). Wing’s work gained a lot of attention from the English-speaking audience and term “Asperger’s Syndrome” became widely referenced (Volker et al, 2010). Nowadays, Asperger’s syndrome is considered as a mild form of ASD with less impact on intellectual and linguistic functions.

In this report, I will use the terms used in the research and clinical literature like “Autism Spectrum Disorder”, “disorder” and “disability” with the understanding that they often have negative connotations because it is important for the reader to understand the perspectives of the authors cited. Elsewhere, I will refer to the Spectrum or Autism Spectrum and use terms like “variations”, “impairments” and “limited abilities” to avoid negative connotations as much as possible. People on the Spectrum truly have limitations in certain abilities and atypical behavior but that is not a reason to label them in a negative way. Moreover, many people on the Spectrum have abilities that surpass those of people who are not on AS and have learned to compensate for their atypical behaviors.
Another disorder, which lays in the high-functioning end of AS continuum, is PDD-NOS. Diagnosis with PDD-NOS can be applied when the criteria are not met for schizophrenia, shizotypical personality disorder, avoidant personality disorder or four other PDDs (e.g., Rett’s Disorder, Childhood Disintegrative Disorder) (Volker et al., 2010; see also APA, 2000). Delay in manifestation of impairments can also lead to a PDD-NOS diagnosis (Karabekiroglu & Akbas, 2011).

According to DSM-IV-TR (Diagnostic and Statistical Manual), the disorders of the Autistic spectrum share three major symptoms that are usually called a triad of impairments (Volker et al., 2010). These impairments are concerned with (1) social interaction, (2) communication, and (3) restricted repetitive and stereotyped patterns of behavior (Volker et al., 2010; APA, 2000). It is interesting to note that impaired social interaction is considered as a core element of the triad, which “unifies” the Autistic spectrum (Volker et al., 2010). Due to the importance of social cognition in ASD diagnosis, the non-social cognitive aspect had long been a second concern for researchers. The situation changed when new theoretical notions were introduced in order to explain atypical perception of people on the spectrum (e.g., Mottron & Burack, 2001; Baron-Cohen, 2006; Frith, 2003). Some of them even suggested that atypical perception of people on the AS could cause impairments in the social domain (see Happe & Frith, 2006).

1.2. Children on the Spectrum

Every child is unique. The same is true for those on the AS. The population on the AS, however, have some similar characteristics that underlie, or lie within, their triad of impairments. Hence, this section provides the description of children on the spectrum within a context of their cognitive and behavioral limitations. This should help to convey the main idea of how the individuals on the AS are different from a typically functioning population and what issues people on the spectrum usually face while interacting with the surrounding world.

1. Atypical Social Functioning:

- Usually, people on the AS are not able to live a typical social life. They can be immersed in solitary activities while completely ignoring a social surrounding. Nonetheless, according to anecdotal findings provided elsewhere (Ashburner et al., 2013), some individuals on the AS may have a desire to socialize but they are not able to do so due to their cognitive deficits.
- People on the AS have difficulties in creating and sustaining relationships with others due to their cognitive limitations (Volker et al., 2010). From a typical viewer’s perspective, they may appear as aloof, odd and individualistic. In order to sustain socialization, a person on the AS needs therapy for a period of time, the length depending on the individual. In general, people on any point of the spectrum may have limitations in socialization abilities (e.g., see Frith, 2000).

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2 Further in the text, the terms “people”, “individuals” and “persons” are used as equivalent to “children.” When research concerned older age group is discussed and if findings are attributed merely to that age group, the appropriate reference will be made.
2. Communicative Impairments:

- People on the AS usually have a significant delay in language development. Some low-functioning individuals do not develop an ability to speak at all (Volker et al., 2010). Thus, the normal communication and participation even in a basic social interaction can become a huge challenge for people on the spectrum. There are studies suggesting that the use of advanced technologies (e.g., shared touchscreens) can make the communication and collaborative work easier for children on the AS (Ben-Sasson et al., 2012).
- The speech of some individuals on the spectrum can be unnaturally formal, loud and pedantic (Volker et al., 2010). Sometimes they repeat words that someone recently said (i.e. echolalia syndrome). Such behavior can annoy and even scare people. People on the AS, therefore, may become victims of bullying and teasing.

3. Repetitive Behaviors and Restricted Interests:

- Restricted interests, repetitive behaviors and strong attachment to routine are among the most enigmatic characteristics of the AS. A good example of such unusual characteristics would be play style of children. While his/her peers are involved in pretend play (e.g., playing in “doctor and patient”), a child on the AS could be busy aligning toys in precise straight rows (Frith, 2003).
- Individuals on the AS are usually highly reliant on routines in their daily lives. The interruption of a routine usually leads to stress (Happe & Frith, 2006). In addition, a failure to follow the routine as it is usually followed could lead to an obsessive desire to repeat the process from the beginning until it is “appropriately” accomplished. For instance, if a person on the AS would unintentionally step out of a bath with the right foot (instead of left, as usual) he/she could have an obsessive desire to step back to bath and, then, step with the left foot again.
- People on the AS usually have an object of restricted interest, which they tend to explore with unusual rigor (Volker et al., 2010). For instance, a child on the AS could accurately describe how the pipes in the kitchen work (if it is of his/her interest) but not be able to describe other common things.

1.3. Enigmatic Nature of the AS

Despite having unusual cognitive behaviors, people on the AS may have some extraordinary abilities and special talents (Mottron, 2011; Mottron et al., 2013). The child on the AS, for example, can be unable to socialize but can memorize all the bus routes by a number or destination or croon Vivaldi’s “Four Seasons” with outstanding precision (Frith, 2003). Moreover, there is an evidence that savant abilities in the AS are more frequent than they are in a typical population (see Mottron et al., 2013). Individuals on the AS, therefore, are disabled in certain domains but can have intact or superior abilities in another. This raises an interesting question: “What does the term disability mean in the context of autism?”

According to the International Classification of Functioning, Disability and Health (2001), disability is a dynamic interaction between health conditions of individual and contextual factors, both personal (i.e., motivation and self-esteem) and environmental (i.e., physical environment) (see WHO, 2011). If the environment does not accommodate the needs of individual with special health conditions, it will limit
his/her capabilities and affect personal factors (e.g., self-esteem). In contrast, the environment that accommodates special needs of a person with impairments can increase the quality of his/her life and support his/her development. Consequently, reduction of conflicts with the environment, and the organization of support for interaction with it will help persons on the AS to be independent and effective in their actions. An appropriately designed environment, therefore, can reduce the impact of limitations caused by autism.

The severity of limitations, however, can vary depending on a person’s functioning level (i.e., lower of higher-functioning). High-functioning children on the AS (those with higher IQ and milder symptoms) may be more able to cope with particular issues and overcome their impairments when the appropriate environment is provided (for review on functioning levels of the AS see Volker et al., 2010). In contrast, lower-functioning people may need extensive care and medical treatment throughout their whole life. This significantly limits their ability to function independently and makes it extremely difficult to design settings that would support them in many respects. Although it is still possible to design “supportive” environments for low-functioning people, these environments would be care type environments very different from learning environments where people on the spectrum could function independently with the general population. In order to delimit the scope of research and increase the quality of the end-product, this project is focused on the high-functioning children on the AS and the learning environment (LE) of typical elementary schools.

1.4. Elementary Learning Environment and the AS

The learning environment (LE) has a profound effect on learning and performance of students, especially those on the AS (Kanakri, 2012; Mostafa, 2008). The experience and knowledge provided in the LE can serve as a foundation for a future independence of people on the Spectrum (Kanakri, 2012). The elementary learning setting is particularly important in that respect. Elementary school is a first stage that provides children with a foundation of knowledge for development of personal interests and social relationships. It sets the basis for a child’s intellectual growth and success. Properly designed LE can help people on the spectrum to maintain the interest to education and encourage their special interests. These interests, even if limited, can be valuable for finding employment and being as self-reliant as possible. From a social perspective, investing in LE that supports development of abilities of people on the Spectrum will reduce future dependence (and associated costs) and increase the contributions that this group makes to society.

The accommodation of perceptual and cognitive needs and the provision of support for learning are the two most important goals for design of the LE. However, reaching these goals can be extremely challenging for designers and architects due to the complexity of the AS and the unique needs of each individual. Indeed, there are many factors that can affect the well-being of the individual and may undermine the process of education. It is critical for designers to understand that the environment is a complex network of factors that interact with people through either purely perceptual (i.e., not goal-oriented) or “attentive” (i.e., goal-oriented) behaviors. These factors are embedded in different features

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3 The term “learning environment” is broad and may indicate any setting where the learning process occurs. For children, in particular, any setting could become a learning environment. Thus, in order to control the scope of inquiry, project was focused on a classroom and other spaces necessary for students’ activities (e.g., room for physical exercises). The major focus, however, was on classrooms design.
of environment and affect comfort and well-being of people. The access to information and its characteristics, products, social context, and visual, acoustical and thermal conditions are among those important factors, which lie in a basis of Person-Environment (PE) interactions. The neglect of these factors in design of the elementary LE can make the PE interactions unsuccessful and can decrease the quality of a learning process. In the context of designing for the AS, consideration of PE interactions is particularly important. While typical children can adjust to an inappropriately designed setting, those on the spectrum may not, due to their cognitive and behavioral impairments.

In the context of a growing population on the AS, the major objective for designers should be a provision of accessible learning settings where people on the AS would not be constrained by their limitations while still being a part of a society. According to decision of US Supreme Court dated to June 22, 1999 (i.e., “Olmstead decision”), people with mental impairments have the right to be a part of a community rather than an institution (ADA, 2014). In order to make an “inclusion” possible, environment should be structured so to accommodate the needs of impaired people (see Steinfeld & Maisel, 2012). This raises two major questions: What issues should be addressed in the design of inclusive elementary LE for the AS? And how can those issues best be addressed? To address these questions profound knowledge regarding the AS is needed. Unfortunately, a reliable and consistent knowledge base in a form useful for design is lacking.
2. OBJECTIVES

2.1. Existing Practices

The British architect Simon Humphreys (2008) proposed recommendations for design of school environments for persons with autism. Humphreys based his recommendations on physical and social aspects of a school setting. He developed a set of design categories to organize these recommendations within each aspect. For the physical aspect, the categories are the quality of natural and artificial light, acoustics, quality of materials, and simplicity of spatial arrangements. The social aspect includes proxemics (i.e. amount of personal space), containment (i.e. feeling of safety) and observation (i.e. possibilities for supervision of children by teachers/trainers). The author concludes that his recommendations can provide a strong conceptual framework for design. Furthermore, Humphreys emphasizes that an introduction of these simple characteristics within a school setting can benefit all students, not just those with autism.

The main value of this work is the wide range of issues considered ranging from social processes to the physical experience of a space. Potentially, such an approach could be the basis for development of comprehensive design implications. The main limitation, however, is that the recommendations are not derived from a comprehensive and systematic review of the scientific knowledge about autism. Therefore, their validity is suspect. Humphreys mentioned that he continues to do research in this field but no theoretical models or references were presented to justify the relevance of the guidelines.

Figure 1 – The photograph of a school interior provided by Humphreys (2008) as the illustration of a spatial clarity. It may be argued, however, that drastic reduction in visual cues and monotonous appearance of space increase its clarity.⁴

In contrast to Humphreys, McAllister and Maguire (2012), researchers from the UK, based their design recommendations on systematically obtained research evidence. McAllister and Maguire proposed design recommendations for elementary school classrooms (for pupils with age of 5-7). The authors produced their guidelines using three stages of activities. The first stage was a review of literature for getting “an understanding of what challenges are represented by the built environment for those with ASD”

⁴ Here and further in the text adapted pictures are referenced to their original sources. The absence of a reference means that picture or diagram was produced by the author.
In addition, nine “ASD-friendly” classrooms were visited and surveyed in order to determine what components constitute the appropriate classroom for people on the AS. The second stage was the development of kit for construction of physical models of classrooms. In addition, authors organized workshops for creation of physical models with teachers experienced in educating students on the AS. Finally, authors developed CAD models based on the layouts of physical models produced in the workshops. The major strengths of this work are (1) the literature review that underlies the recommendations, and (2) the involvement of teaching staff in the process of design of “AS-friendly” classrooms. The main limitation is the unclear focus of the literature review. The authors did not clarify whether cognitive issues of the AS were evaluated and whether Person-Environment reciprocity was systematically assessed. The authors emphasized the benefits of cooperation with teachers. However, teachers’ opinions might not be as effective as they appear. Teachers may perceive the learning environment differently from persons on the AS. Thus, the provided design recommendations could be good in accommodating needs of teaching interventions but could be less effective in accommodating the cognitive and physical needs of students on the AS. Ironically, the latter could negatively affect the former.

![Figure 2](image-url)  
**Figure 2** – Kit for design of physical models (on the top) and CAD 3D drawing of “ASD-friendly” classroom (on the bottom). (Adapted from McAllister & Maguire, 2012)

An excellent example of evidence-based guidelines is a set of recommendations for housing design provided by Ahrentzen and Steele (2009). This work is focused on a residential environment for adults on the spectrum and therefore does not directly relate to the thesis topic. Nonetheless, this work is a good example of comprehensive, research-based approach to producing design guidelines and therefore it deserves close attention.
The authors conducted extensive case studies of "exemplary" housing projects accommodating needs of people on the AS. The knowledge derived from the case studies helped them understand what issues are addressed and what are not in the current design models. The wide scope of the case studies helped to set the list of "design goals", i.e. general "guideposts" that can be used for developing and renovating a housing for population on the AS (Ahrentzen & Steele, 2009). More specific guidance for designing particular spaces and their attributes was provided in guidelines. Authors argue that guidelines and goals are not prescriptive and should be taken as a "platform" for identification and selection of "desired" design strategies (Ahrentzen & Steele, 2009). Wide scope of the addressed issues as well as comprehensiveness of the approach provides an in-depth understanding of what objectives should be pursued, what issues should be addressed, and how they should be addressed.

It is unclear, however, whether any theoretical framework was used to better define and interpret issues encountered by people on the AS while interacting with an environment. A theoretical framework is essential for reducing bias when designing for such specific population. Extensive case studies, however, may eliminate the need for explicitly stated theories since a lot can be learned from the large number of design examples.

In general, the sources of recommendations available for design with respect to the AS demonstrate the need for a more systematic and comprehensive approach that clearly delineates the sources of recommendations and addresses the different aspects of the AS. It is not possible, however, to identify and address the complete range of issues of the AS. Therefore, this project is narrowed down to only key issues. Nonetheless, in a long-range agenda, this project may serve as a good foundation for expanding the knowledge base regarding a design of elementary LEs for the AS and design for the AS in general.

2.2. Goals, Strategy and Scope

Cognition must be a key focus in the formulation of considerations for a design for people on the AS. According to Morton and Frith (1994), the cognitive characteristics of "developmental disorders" mediate between their biological and behavioral characteristics. The disorders of the AS, in particular, may have different biological and behavioral characteristics mediated by a single "cognitive deficit" (see Morton & Frith, 1994; Happe, 1994). Therefore, knowledge about cognition of people on the AS provides designers with a profound understanding of needs of potential users that cannot be understood merely through behavioral manifestations.

Thus, the major objectives of this project are to: 1) develop a comprehensive understanding of the cognitive issues of people on the AS, and 2) develop corresponding design recommendations for mainstream elementary LE.

In order to fulfill these objectives, a "Research-Based Design (RBD)" (Orfield, 2013) strategy was applied. This strategy was based on the extensive literature review of research on the cognitive styles of people on the AS in the domains of cognitive psychology and neuropsychology. The findings were then translated into Design Guidelines and Strategies according to the six-staged process described further.

In this work, the terms "cognition" and "cognitive" are used in their broadest interpretation meaning the general processing of external stimuli and information on attentive (i.e., goal-oriented) and pre-attentive levels (for review on a concept of "cognition" see Robbins & Aydede, 2009).
The use of other types of information in the development of recommendations for design is also valuable (see the previous section) but the scientific literature must be used as a starting point. This will benefit the advancement of knowledge by linking the recommendations to a scientific theory and facilitate validation of recommendations through input from stakeholders like teachers, people on the Spectrum and experienced designers by creating a strong conceptual framework. This framework can then be used to evaluate and integrate knowledge gained from case studies on what works and what does not in practice.

The project’s strategy was based on six stages (Fig. 3): (1) an extensive literature review for research on the cognitive styles of children on the AS; (2) a formulation of key knowledge about cognitive limitations of children on the AS; (3) a formulation of problems for design according to the key knowledge; (4) Guidelines and strategies for addressing the problems; (5) formulation of design principles (i.e., general design ideas embedded in the Guidelines); (6) producing prototypes to test Guidelines in practice and provide the design examples.

Design language is different from scientific language. Thus, the translation of scientific knowledge to design requires steps of synthesis and transformation of language. In the process, the link between recommendations and knowledge is often impossible to follow. This six-stage process provides transparency to the Knowledge Translation process. Stakeholders like researchers, designers, parents, teachers and others can trace the logic behind the translation process and evaluate the validity of the recommendations. The process also allows the application of other sources of knowledge, such as educators’ or designers’ opinions to develop recommendations in the future without confusing the source of the recommendations. In turn, the transparency of the process allows designers to ask the right questions of researchers and helps researchers to see how their work can address knowledge gaps in practice.

![Figure 3 – The strategy](image)

The scope of the project was delimited by the cognitive issues identified in the search for key knowledge and by a focus on particular aspects of an elementary learning setting. The project was mainly focused on a physical environment including spatial organization and visual, aural and thermal qualities of the LE. Socio-spatial aspects were also considered in terms of the well-known concepts of personal space and crowding (see Altman, 1975; Sommer, 1966). Product design (e.g., design of furniture) and organization of information in the LE (i.e., “informational” environment) were considered to a lesser extent. Although important, the virtual environment was not considered in this work since the author is an architect with no formal training in that area. The virtual environment, however, is an important area for future research.
2.3. Theoretical Framework for the Literature Review

The theoretical framework was established in order to systemize and organize the process of research on the AS cognition. Cognition in the AS is a complex and broad topic. The research domain concerning this topic includes 719 research articles found in the *PsycTESTS, PsycINFO, PsychARTICLES* and *Psychology and Behavioral Sciences Collection* databases.

The theoretical framework was constructed according to information obtained from a general overview of the main sources and topics related to AS cognition. Three theoretical categories were identified and, then, integrated within one system to provide a theoretical foundation for design recommendations.

- **“Non-social” cognition** (Eack et al., 2013). This is the processing of information that does not have a social meaning and does not directly relate to a particular social situation. The most prominent attributes of non-social cognition in the AS are enhanced visuospatial abilities and detail-driven vision (i.e., local processing bias). These cognitive attributes are well explained by the theories of Weak Central Coherence (WCC), Enhanced Perceptual Functioning (EPF) and Hyper-Systemizing (HS) (Happe & Frith, 2006; Mottron et al., 2006; Baron-Cohen, 2006).

- **Social cognition**. This category is represented by a Theory of Mind (ToM), the fundamental theory explaining a phenomenon of social dysfunction in the AS (Happe, 1994).

- **Executive Functioning (EF)**. EF is an “umbrella term” related to both social and non-social aspects of a cognition in the AS (Kenworthy at al., 2008). It includes a number of vital cognitive processes and mechanisms required for culturally normative every-day function within space and time.

In addition to research on the theoretical framework, the state of the art regarding sensory responsiveness in the AS was investigated. The reviewed studies provide the deep insight into the nature of perception of the AS and expand the knowledge provided in the general cognitive theories (e.g., WCC or EPF). The next chapter provides the details of the trends in research on cognition and the AS. These theories and concepts represent a well-established and reliable foundation for translation of scientific knowledge into a design.
3. OVERVIEW OF COGNITIVE THEORIES

3.1. Non-Social Cognition

3.1.1. Three Cognitive Theories and Atypical Sensory Responsiveness

The research on “non-social” cognition in the Autistic Spectrum (AS) was focused on two perceptual phenomena: (1) local processing bias, that is, the unusually strong attention to details and (2) atypical sensory responsiveness, which is an abnormal reaction to external stimuli (e.g., light). Local processing bias and theories relevant to it will be discussed first. Then, an overview of knowledge regarding the atypical sensory processing in the AS will be provided. Finally, the interrelations between these two phenomena will be emphasized.

3.1.2. Local Processing Bias

“Local bias in autism is now consensual and represents one of the strongest arguments for an atypical perception in autism as well as a key path to the understanding of overall autistic cognition.”

Mottron & Soulières, (2012)

Local Processing Bias (LPB) is the important attribute of perception in the AS. It implies that people on the AS perceive their surroundings in a detailed, locally focused manner.

The empirical data suggest that typical individuals put precedence on global processing in perception of their surrounding environment (see Iarocci et al., 2006). The term precedence is equivalent to bias. It means the prevalence of global information over local, during a process of perception. In other words, typical individuals perceive “forest first, not trees” (Iarocci et al., 2006) and use the global mode of perception as default. In contrast to the typical group, a significant body of studies suggests that people on the AS have local processing mode as default, i.e., they focus on “trees” first instead of “forest” (see Happe & Frith, 2006).

Different theories describe LPB differently. Some of them attribute LPB to a deficit in global processing (Frith, 1989) while other argue that global processing is intact but local is enhanced (Mottron et al., 2006). Three different theoretical explanations of LPB are provided below.

**Weak Central Coherence**

Weak Central Coherence (WCC) theory was originally introduced by Uta Frith in 1989. Frith (1989; 2003) explained the term “weak coherence” as “the lack of an effect of context” and “the lack of a drive for meaning.” The first evidence of weak coherence in autism was found in an experiment conducted by Frith and her colleague Beate Hermelin (1969). This experiment involved two types of puzzles. First type included “rectangular puzzle pieces with straight edges with a picture.” The second included “typically juggled pieces but without picture” (i.e., without “meaning”) (Frith & Hermelin, 1969). The study found that children with autism outperformed typical individuals on the second type of a puzzle. According to

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6 Although, focused population of the experiment was children with autism, LPB may be generalized to the entire Spectrum (for review see Happe & Frith, 2006).
Frith (2003), children with autism succeeded due to their detail-driven vision and lack of meaning-driving vision, which is the typical approach to solving puzzles used by people who are not on the AS. In other words, those with autism enjoyed connecting piece to piece, with no expectation of the final (i.e., global) picture in the end (Frith, 2003). The lack of a drive for meaning in the AS was explained as a “global processing deficit”, the key concept of the original WCC model (Happe & Frith, 2006).

Francesca Happe and Uta Frith revised the WCC in 2006. The concept of global processing deficit was substituted by the concept of local processing bias (Happe & Frith, 2006). In other words, persons on the AS can be locally biased (i.e., have a local processing as default) but still have an ability to construct the global picture. Finally, authors emphasized that LPB could be associated with the enhanced perception of details and a unique “cognitive style.”

In general, WCC is an important theoretical model that explains atypical characteristics of perception in the AS. Furthermore, it is a first theoretical model that explained the LPB phenomenon in the AS. Enhanced Perceptual Functioning discussed below was proposed as an account alternative to the WCC (Mottron et al., 2006).

Enhanced Perceptual Functioning

Enhanced Perceptual Functioning (EPF) was originally proposed by Laurent Mottron and Jake Burack in 2001. EPF accounts for superior performance of some people on the Spectrum on the tasks that involve visual and auditory stimuli (see Mottron et al., 2006). Such phenomenon can be attributed to an enhanced “first-order” perception, i.e., perception not involving complex (i.e., higher-order) cognitive operations (see Mottron et al., 2006). EPF argues for high involvement of perception in execution of difficult cognitive tasks and “the centrality of perception-related behavior in typical every-day situations” of some people on the AS (Mottron et al., 2006). In some cases, enhanced perception can become a ground for development of savant abilities in particular domains (e.g., drawing or music) (see Mottron et al., 2013; Mottron et al., 2006).

The important argument of EPF is that the local bias is a result of enhanced perceptual abilities rather than consequence of a deficient in global processing (as suggested in the earlier version of WCC). Indeed, the EPF model is supported by strong empirical data suggesting that people on the AS can process global information under certain circumstances (see Caron et al., 2006). Furthermore, proponents of EPF criticize the “optional” character of the term “cognitive style” used in the WCC concept (see Mottron et al. 2006, Happe & Frith, 2006). EPF proponents argue that differences in perception between autistics and non-autistics are not a matter of choice or preference; people on the AS have profound and distributed difference in brain organization. (Mottron et al. 2006).7

Hyper-systemizing Account

The Hyper-systemizing (HS) Account was originally proposed by Simon Baron-Cohen in 2006 (Baron-Cohen, 2006). Baron-Cohen (2006) suggests that people on the AS are “hyper-systemizers who can only process highly systematic (i.e., law-governed) information.” Systemizing was described as a tendency to

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7 Of note that EPF model is a profound and elegant way to explain an atypical perception in the AS. Major part of key knowledge concepts (see Chapter “Knowledge Translation and Formulation of Problems”) was formulated according to ideas suggested by EPF.
“construct and analyze systems, i.e., sets of rigid “if p, then q” rules which are able to predict changes in the “lawful” nonsocial (or “non-agentive”) world” (Baron-Cohen et al., 2009; Mottron et al., 2013). The HS has much in common with a concept of local bias and enhanced perception in the AS. For example, the strong ability to construct and understand systems can be based on an increased attention to details (of a certain system) caused by enhanced visual perception (e.g., see Baron-Cohen et al., 2009). Furthermore, the HS model fits well in the context of preferences for routine and restricted interests by people on the AS (see Baron-Cohen et al., 2009).

Generally, enhanced ability to construct and analyze systems is a unique attribute of the AS based on atypical processing of information from the surrounding environment. Perhaps, the HS can be explained as a coping strategy, which allows people on the AS to control the impact of changes in the surrounding environment (see Baron-Cohen et al., 2009).

The next section introduces the topic of atypical sensory responsiveness in the AS. The relationship of this cognitive phenomenon with the theoretical models above will be discussed.

### 3.1.3. Atypical Sensory Responsiveness

According to Hilton et al. (2010), sensory systems acquire surrounding information, which helps a complex life form successfully respond and adapt in an environment. Sensory systems provide the pathways for delivering the external information to the brain through which it interprets this information and implements a response (Hilton et al. 2010).

Numerous studies suggest that individuals on the AS have difficulty processing stimuli from their surroundings (e.g., Baranek et al., 2007; Leekam et al., 2007; Hilton et al., 2010). Moreover, some authors propose two categories for Atypical Sensory Responsiveness (ASR) in the AS: (1) sensory over- (hyper-) responsiveness and (2) sensory under- (hypo-) responsiveness (Hilton et al., 2010). Over-responsiveness implies unusually strong reaction to stimuli (e.g., bright light) that usually leads to a stress and avoidance reaction (Hilton et al. 2010; Dunn 1999). In contrast, under-responsiveness may involve sensory-seeking behavior and unusual aloofness (Hilton et al. 2010; Dunn 1999). For example, an under-responsive person may gaze intensely at an object that others would not (e.g., gazing at the running fan).

Under-responsiveness, however, contradicts the idea that people on the AS have enhanced perception as proposed in the EPF and in the later version of WCC (see Mottron et al., 2006; Happe & Frith, 2006). Indeed, an important question is how the superior perceptual abilities found among people on the AS can be reconciled with the under-responsive behavior? The answer to this question can be found in the phenomenon of local processing bias (LPB). According to Belmonte and Yurgelin-Todd (2003), atypical local processing is a compensatory mechanism that helps the individual withstand an intense flow of external information caused by enhanced perception. Thus, under-responsiveness in the AS can be a manifestation of LPB, which functions to filter the flow of external stimulation to a level of information that the person can manage effectively.

According to Hilton et al. (2010), Atypical Sensory Responsiveness in the AS spreads over a wide range of sensory modalities. Research suggest that persons on the AS have an atypical reaction to:

- Visual Stimuli (Belmonte & Yurgelin-Todd, 2003; Frey et al., 2013).
- Auditory Stimuli (Kanakri, 2012)
- Vestibular Stimuli (Kern et al., 2007)
- Tactile Stimuli (Baranek et al., 2007)
- Olfactory Stimuli (Lockner et al., 2008)

Enhanced responsiveness to visual and auditory stimuli in the AS is a well-established fact (Bonnel et al., 2003; Mottron & Burack, 2001; Shah & Frith, 1993). Enhanced visual and auditory perception can be a basis for development of special and savant abilities (e.g., savant draftsman) (see Mottron et al., 2013) as well as be the reason for overload and overstimulation (e.g., see Kanakri 2012). In addition, enhanced visual and auditory perception likely underlies the local processing bias in visual (e.g., enhanced discrimination of embedded stimuli) and in the auditory (e.g., enhanced pitch discrimination) modalities (Mottron et al., 2006).

Atypical reaction to vestibular stimulation in the AS is also reported in the literature. According to Hilton et al. (2010), over-responsiveness to this modality might include becoming anxious when feet leave the ground or avoiding the playground equipment. People on the AS can also exhibit “sensory-seeking behavior” to provide themselves with vestibular sensations in an under-stimulating environment (Hilton et al., 2010; Dunn, 1999). For example, they can rock sitting on the chair or jump intensely. In addition, Malloy et al. (2003) argue that people on the AS are highly reliant on visual stimuli in maintenance of postural balance due to impaired vestibular and somatosensory mechanisms.

Enhanced reaction to tactile stimuli includes aggressive reaction to touch, peculiar proxemics and strong reaction to pain (Hilton et al., 2010; Tordjman et al., 2009). In addition, some people on the AS may have an obsessive desire to touch particular surfaces and objects (i.e., sensory-seeking behavior) (Hilton et al., 2010). Notably, some authors suggest a decreased responsiveness to pain in the AS (e.g., see Frescka & Davis, 1991). Although this could be another example of a compensatory filtering process, according to study by Tordjman et al (2009), children on the AS have problems with expressing the painful emotions while still experiencing the painful feelings.

Finally, people on the AS can be overly sensitive to specific odors and tastes (i.e., abnormal olfactory perception) (Grandin & Scariano, 1986). Some empirical studies do not support this hypothesis, however, suggesting that individuals on the AS have a typical olfactory perception (e.g., Galle et al., 2013; Tavassoli & Baron-Cohen, 2012). In general, the claim of an enhanced olfactory perception in the AS is quite controversial.

It is important to note that children on the AS may have problems with multi-sensory processing, i.e., integration of different sensory modalities together (Hilton et al., 2010). Again, this idea interacts with concepts of the enhanced perception and local processing bias since people on the AS can be overly sensitive to a particular stimulus and fail to construct a complete sensory experience.

3.1.4. Conclusion

It is not surprising that concepts of LPB and ASR are interrelated. Sensory responsiveness can be a result of an enhanced perception. At the same time, LPB is likely a coping mechanism that helps individuals on the AS to withstand unusually intense load of external stimulation. It is possible, therefore, that so-called under-responsive behavior can be a reaction to a sensory-rich and complex environment and underlying it is over-responsiveness. Therefore, making the environmental stimuli more manageable would reduce both under-responsiveness and over-responsiveness.

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8 This does not contradict the fact, however, that there can be different responses to stimulation levels within the population on the Spectrum.
The theories discussed above provide an overview of knowledge regarding LPB and studies that explain unusual sensory responsiveness and non-social cognition in the AS. This knowledge can provide a profound foundation for the formulation of design implications for LE for children on the AS.

3.2. Social Cognition

“Experimental evidence shows that the inability to attribute mental states, such as desires and beliefs, to self and others explains the social and communication impairments of individuals with autism.”

Uta Frith (2001)

3.2.1. Theory of Mind and Autistic Spectrum

The social world is a complex system and in order to successfully operate in it, humans have evolved to possess cognitive abilities to interpret verbal and non-verbal behavior of others. According to Cosmides and Tobby (1995), what we usually take for granted, i.e. the achievement of coordinated models of mutual social interaction, is a “triumph of automated modules and evolutionary cognitive engineering.” The Theory of Mind (ToM) concept, which was originally proposed in the studies of chimpanzee’s consciousness (Premack & Woodruff’s, 1978), became the vital tool for explaining the complex architecture of a social cognition of humans.

The ToM suggests that people have the capacity of “mind reading” (Frith, 2001), that is, understanding of beliefs and intentions of others. Cosmides and Tobby (1995) argue that humans evolved the ToM abilities because cooperative and competitive social world requires the ability to interpret what is on one another’s mind. Thus, the ability to understand and interpret the mental states of others could be the fundamental factor contributing to a social integrity and collaborative relationships.

Individuals on the AS have strong limitations in understanding and maintaining social relations (Frith, 2001). People on the AS are usually aloof on the earlier developmental stages and remain “egocentric” despite learning the basic skills of social interactions (Frith, 2001). Furthermore, studies of abilities to understand the mental states (i.e., intentions and beliefs) of others revealed that children on the AS fail to develop these vital social skills in their early life (Baron-Cohen et al. 1996). This earlier failure could be the basis for their overall social dysfunction in the future. Therefore, the ToM became a leading model in description of social impairments in the AS. In addition, the ToM has proved extremely successful in describing of both universal and specific features of individuals on the AS (Happe, 1994).  

3.2.2. Background

This section provides a brief overview of the development of ToM concepts as an explanation of social impairments of people on the AS. The term “autism” is often used in this section instead of “AS” in order to be consistent in the interpretation of statements and concepts proposed by authors referenced. In some cases, the authors defined ‘autism” differently than we do today using the concept of AS. However,

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9 Due to the social character of learning environments, the ToM is of particular interest for this project.
there is a strong body of evidence suggesting that there are impairments in social cognition across the entire AS (e.g., Lombardo et al., 2011; Adams, 2013).

As mentioned above, the ToM provides the key concepts for explaining social dysfunction in the AS. One of the first researchers who worked on the ToM in autism was Alan Leslie (Happe, 1994). Leslie explained the inability to understand the mental states of others as a failure to construct “meta-representations” (Leslie, 1987; 1988). Leslie suggested that in order to understand the mental states of others, one needs to have the ability to construct abstract (imaginative) meta-representations instead of “primary presentations” of present-at-hand reality. Thus, the inability to think imaginatively about the thoughts of others became the foundation for the development of ToM concepts. This idea is known as the phenomenon of “mind blindness” (see Happe, 1994; Baron-Cohen, 1995).

The first suggestion of impairment in making meta-representations was the observation of a reduced engagement of children with autism in “pretend play” (see Happe, 1994). Leslie (1987; 1988) explained the inability to initiate and sustain the pretend play as the failure to look beyond present-at-hand reality. In particular, this inability hinders the understanding of the “pretense” and therefore prevents children on the AS from imitating and understanding the roles of pretend play (e.g., doctor and patient) (see Happe, 1994).

In addition to the work of Leslie (1987; 1988), Simon Baron-Cohen and colleagues provided empirical evidence for mind-blindness (Baron-Cohen et al., 1985). They tested 20 children with autism on the classic Sally-Ann task, a false-belief task invented by Wimmer and Perner (1983) (see Happe, 1994). The findings revealed that 80 percent of children with autism failed to understand a false belief while 86 percent of children with Down syndrome succeeded on this task as well as all normal children participated in the experiment (see Baron-Cohen et al., 1985; Happe, 1994).

During the eighties and nineties, the idea of the impaired ToM capacities in the AS became widely recognized. Moreover, the failure to comprehend mental states was considered as a core deficit underlying the triad of impairments in the AS (Happe, 1994). In recent time, however, the universality of the ToM was significantly challenged due to the origin of perceptual theories that provide different viewpoints about cognition of people on the AS (see “Non-social Cognition” section). Indeed, ToM should be considered within the broad theoretical framework that involves additional concepts and explains AS cognition in a broader manner.

3.2.3. Conclusion

The elementary LE is a setting that usually involves increased levels of a social interaction and collaboration. Because of limitations that children on the AS might have in the social domain, it is critical to provide an environment where levels of privacy and socialization can be regulated as needed. There is no doubt that increasing the quality of the social interaction in LE would have a positive effect on the comfort of all students and on the learning process in general. Human beings are social animals and anything that can improve social interaction is beneficial to all human activities.
3.3. Executive Functioning

“Executive control is an umbrella term that captures a set of cognitive processes that direct behavior regulation and orchestration of attaining a future goal.”
Kenworthy et al. (2008)

3.3.1. Overview

Executive Functioning is the governing process of goal-oriented behavior (Kenworthy et al., 2008). It manages many other cognitive processes that are necessary for everyday well-being. According to Rogers and Bennetto (2000), these processes include working memory (i.e., remembering actions needed to be done during the goal accomplishing), flexibility (i.e., shift from one goal to another), inhibition (i.e., inhibiting behavior hindering the goal execution), monitoring (i.e., checking actions for errors), planning (i.e., planning sequence of actions for a goal execution) and generativity (i.e., generation of ideas, goals, and actions). Liss et al. (2001) proposed a more extensive list of EF cognitive processes including formation of abstract concepts, focusing and sustaining the attention and rapid retrieving relevant information from the environment. It is often reported that people on the AS are impaired in a majority of EF processes. However, limitations in flexibility and planning are the most frequent (e.g., see Kenworthy et al., 2008). This may explain some anecdotal findings suggesting that people on the AS encounter difficulties in executing their daily tasks (see Kenworthy et al., 2008). It is often argued that atypical EF could have a strong causal effect on both social and non-social impairments in the AS (Kenworthy et al., 2008; Ozonoff et al., 1991; Russel 1997).

3.3.2. Background

Damasio and Maurer (1978) were the first who proposed the idea of impaired EF in autism. They compared behavioral impairments of people with autism to people with frontal brain lesions (see Kenworthy et al, 2008). From this research, which demonstrated similar cognitive impairments, they suggested that autism could be a frontal brain disorder. The authors argued that atypical functioning of the frontal part of a brain leads to deficits in social motivation, poor communication and “perseverative behaviors” that are core characteristics of autism (Damasio & Maurer, 1978; Kenworthy et al. 2008). Following these findings, EF has become a focus of interest for many researchers. According to Kenworthy et al. (2008), there were 150 articles and 3 major reviews conducted after Damasio and Maurer’s breakthrough. The recent evidence challenges the “causal” role of EF in autism but argues that EF plays an important role in dysfunction in both social and non-social impairments of the AS (Kenworthy et al., 2008; Hughes 1996). Modern neurological studies support the idea of abnormal function of frontal brain regions in the AS but avoid statements that would link these abnormalities to a primary cause of AS deficits (e.g., see Russo et al., 2007). Rather, there are new hypotheses suggesting that abnormalities of the AS may be caused (at least partially) by a decreased connection between different brain regions and atypical development of some of these regions (e.g., parietal parts of a brain) (Belmonte et al., 2004).

The methods used for assessing EF of people on the Spectrum have also been challenged. Interestingly, some recent studies failed to find impairments in mental planning and flexibility when computerized methods for testing were utilized (instead of human-administered tests) (see Kenworthy et al., 2008). This
raises a question regarding the efficacy of human-administrated tests since poor performance on such tests may be caused by problems in social cognition rather than impaired EF (Kenworthy et al., 2008).

### 3.3.3. Conclusion

Due to its importance for so many behaviors, EF has a direct impact on everyday well-being of persons on the AS. EF is a main factor of successful goal-oriented behavior, which is important component of the educational process. Thus, accommodating atypical EF is critical to address the special needs of people on the AS. Design to support EF clearly can also benefit all children in an educational setting.
4. **KNOWLEDGE TRANSLATION**

4.1. **Literature Review and Key Knowledge**

An extensive literature review was conducted within the theoretical framework described previously. The literature review was focused on studies that address the following research questions: (1) What difficulties do high-functioning children on the AS experience while interacting with an environment? (2) What are the cognitive deficits underlying these difficulties in interaction? Moreover, the following inclusion criteria were used to narrow the selection of articles for review further: (1) the relationship of the study to established cognitive theories (WCC, EPF, HS, ToM, EF, ASR), (2) the presence of supportive empirical findings from other studies, (3) the relationship of findings to high-functioning children on the AS, and (4) publication in peer-reviewed journal(s). Some studies concerning low-functioning population were also reviewed considering that generalization of findings to a high-functioning population is possible. In addition, if the study was theoretical and had a number of revisions, the most recent revision was reviewed.

The search was conducted using databases that provide knowledge from cognitive psychology, clinical psychology and neuroscience: PsycINFO, Psychology and Behavioral Sciences Collection, PsycARTICLES and PsycTESTES. The search was conducted according to five categories related to cognitive theories. For each category, specific keywords were applied:

1. WCC: “Autism Spectrum Disorders”, “Weak Central Coherence” or “weak coherence” (Found studies: 359; Reviewed: 20).
2. EPF: “Autism Spectrum Disorders”, “Enhanced Perceptual Functioning” or “enhanced perception” (Found studies: 500; Reviewed: 31).
3. HS: “Autism Spectrum Disorders” or “autism”, “hyper-systemizing” (Found studies: 8; Reviewed: 6)
5. EF: “Autism Spectrum Disorders”, “Executive Function” or “Executive Functioning” (Found studies: 82; Reviewed: 25).

In addition, a search for the relevant references provided in the initially reviewed studies was conducted.

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10 The literature review was based on some of the principles of what is called a “systematic review” in the field of knowledge translation (i.e., inclusion criteria, research questions). The goal of the literature review was not to provide an exhaustive review of the psychological evidence concerning the AS. Rather, it was used to identify a limited number of key issues (i.e., key knowledge) for translation into guidelines for design. It is still possible, therefore, that key issues are not complete and may be further extended by input from experts and the growing knowledge base on the AS.

11 The majority of literature that explains the cognitive theory (e.g., WCC), has a one or several updated versions.

12 The number of “reviewed studies” was obtained after application of research questions and inclusion criteria to the total number of found studies.
From the results of the literature review, Key Knowledge (KK) was identified. The criteria for determination of KK was similar to the inclusion criteria provided for the literature review (see above). Key knowledge was then summarized in 21 statements that represent the most critical concepts regarding social and non-social cognition of the AS.

4.2. Design Problems

The Key Knowledge (KK) is the primary driving force in the process of knowledge translation used in this work. It provides the research basis for the design implications. The KK statements summarize the results of research into a concise set of issues. However, since the KK is presented in the form of knowledge about cognitive processes, it is difficult to directly translate it into the design. Therefore, 26 Design Problems were derived from the KK that cast the KK into a framework for design. Problems have a reference to a particular condition of environment, which makes it easier to translate them into design implications. For example, Problem 2 (see table below) refers to “an abrupt change between different activities” that may cause a particular undesirable outcomes. To apply this knowledge to a design, physical features/conditions that cause “an abrupt change” need to be identified and addressed.

Problems provide a coherent transformation of knowledge from the field of psychology to an action oriented focus for design. They refer the empirical evidence regarding AS to potential issues that may occur within person-environment interactions. In other words, Problems provide a focus for appropriate design responses that lead to desirable design outcomes. They are cast as conditions to avoid, based on Alexander’s concept of fitness (1971). Alexander argues that identifying problems is more efficient that identifying solutions. It avoids endless enumeration of goals that are obvious. The mapping of Key Knowledge statements to Design Problems moderates the potential subjectivity of translation from scientific knowledge directly to design directives and provides transparency to the process of knowledge translation.13

Although Design Problems were derived from research on cognitive styles on the AS, they generally represent sets of issues that are also relevant to a general population as well. The inappropriately designed LE would have a negative effect on all students, however, if the Design Problems are not addressed adequately, the effect might be much greater for those on the AS due to their cognitive impairments. There are particular “problems”, however, that, at first glance, may be uniquely attributed to the AS (e.g., atypical distraction of some individuals with complex and unusual shapes; see Problem 7, Appendix I). But even these problems may be generalized to some groups of “normally” functioning people (e.g., those who have a weaker ability in managing attention). And given that emotional states influence behavior at any time, there are times when all people may have these very same problems (e.g. difficulty concentrating due to test taking anxiety or distraction by some family or personal circumstance).

13 The Design Problems are linked to the Key Knowledge based on the reliable empirical data. This makes the design directives, aimed on addressing the problems, less subjective.
4.2.1. Examples of Key Knowledge Concepts and Related Problems:

<table>
<thead>
<tr>
<th>Key Knowledge</th>
<th>Design Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KK1:</strong> Behavioral flexibility is the neuropsychological ability to shift from one sequence of actions to another in response to changes in the goal execution context (e.g., the route that one usually uses is closed and one should search for alternative) (D’Cruz et al., 2013). Due to a reduced cognitive and behavioral flexibility, people on the AS have troubles with transition from one occupation/task to another (see D’Cruz et al., 2013; Reed et al., 2013; Sterling-Turner &amp; Jordan, 2007). Transitions between occupations usually highly stressful for individuals on the AS (Sterling-Turner &amp; Jordan, 2007).</td>
<td>P1: An environment that has an <em>abrupt</em> change between different activities (e.g., moving from one task to another) may be confusing and distressing.</td>
</tr>
<tr>
<td><strong>KK15:</strong> People on the AS can have problems in perception of complex (i.e., second order) stimuli (Bertone et al., 2005). Such stimuli might include the movement of animate (e.g., man is walking) (Blake et al., 2003) and inanimate objects (e.g., motions of the leaves on the trees) in the real-world settings (for review see Bertone et. al., 2005, 2003). This may lead to a reduced awareness about some activities occurring nearby (e.g., walking people; book falling from a shelf).</td>
<td>P19: Intrusions into personal space and undesirable encounters with other people are more likely since people on the AS are less aware about movements of others.</td>
</tr>
<tr>
<td></td>
<td>P20: The unstable objects that may injure can be dangerous for all students. They may represent a <em>particular</em> threat for those on the AS.</td>
</tr>
</tbody>
</table>

4.3. Organization of Design Guidelines

To aid designers in translating Key Knowledge to actual design interventions, a set of design recommendations in the form of Guidelines and Strategies was provided that address the Design Problems. The recommendations include information from the scientific literature concerning the quality of a built environment (e.g., IESNA [2000] standards for lighting design, 2000; WHO’s [1991] study on the quality of indoor settings) and information obtained from the analysis of existing design recommendations (e.g., Ahrentzen & Steele, 2009), including those provided by teachers (e.g., Kabot & Reeve, 2010).

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14 Refer to Appendix I for the complete list of Key Knowledge and related Design Problems.

15 The behavioral flexibility implies the flexibility in a goal shifting as well.
Relevant concepts and theories from the field of environmental psychology were also considered, including the concepts of privacy (e.g. see Sommer, 1966), wayfinding (e.g., Garling & Evans, 1991) and the theory of situated concepts (Barsalou, 2009). The latter provides an overview of how people process and categorize the information necessary for their actions in a context of different situations (for review see Barsalou, 2009).

The recommendations were organized with varying levels of specificity and abstraction. This avoids an overly prescriptive tone that implies only one solution, but still provides the designer with detailed information on what is known to work in practice. The Guidelines represent the most abstract level, setting the general framework within which the particular problem should be addressed. The Guidelines are followed by Design Strategies providing more concrete ideas for design solutions. The Design Strategies usually have a reference to a particular physical feature or attribute of the environment. After the Strategies were developed, it became obvious that there were a smaller set of general principles, that could be derived, that are useful for generating Strategies and help to identify which Strategies are more important because they address a number of Problems at once. Thus, each design strategy has a reference to one (or more) Design Principle(s), which are the general ideas regarding the design for the AS. Icons representing each Principle addressed were developed and positioned next to each Strategy to provide an index to the Principles it addresses. Finally, many design strategies include the set of important “tips,” using bullet points, with more specific information regarding the proposed design solution. Many of these tips were taken from the practice literature, e.g. sources in special education or design for people on the AS (e.g., Kabot & Reeve, 2010).

4.3.1. Example of a Guideline Organization:

Problem 1:
An environment that has an abrupt change between different activities (e.g., moving from one task to another) may be confusing and distressing.

Guidelines:
G 1.1: Provide smooth transition between different spaces.

S 1: Provide a buffer zone before entering the classroom to allow people on the AS preparation for the new setting and activity.

- The buffer zone should have at least one visual attribute, that is identical to one in the classroom, preferably more. For instance, the walls can be the same color as those in the classroom or the floor can have the same color or texture.
- ...

G 1.2: ...

The proposed organization is open-ended and encourages growth in knowledge in design of high-quality elementary LEs for the AS and LEs in general. The set of Guidelines, Strategies, hints, and even Problems and Principles, may grow based on inputs from professionals, experts in the field, or systematic

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16 For more information on the Design Principles, refer to the next chapter.
evaluations of LE. Teachers, researchers, designers and autism activists are encouraged to build upon the provided foundation of knowledge and facilitate the application of evidence-based design.

4.4. Prototypes

In order to test how the Guidelines would work in a practice two prototypes (A and B) were designed. The author imagined himself a user of the proposed Guidelines by applying them into a design of two elementary classrooms and school blocks (i.e., a group of classrooms). The design of prototypes therefore, not only addressed the issues of design for the AS but also the context of other real world design issues (e.g., adjacent spaces; orientation) of the real world of practice. To insure that contexts were realistic, the examples were taken from existing school buildings (see below). This approach also helped to narrow the focus of design to only the issues addressed by this research.

There was no attempt to re-design each school. Therefore, certain parameters (e.g., dimensions) of projects were changed so to apply as many Guidelines as possible in the chosen design context. The context for Prototype A is Jefferson/Best Early Childhood Center in Buffalo, NY (Architect: Foit-Albert Associates). This pre-kindergarten through third grade school is designed to accommodate 1377 children ranging from pre-kindergarten to third grade ages. The building is divided into three small “houses” vertically organized so to include the full range of student grades. Each “house” represents a “block”, i.e., the cluster of classrooms and some additional spaces. The block and the classroom chosen for design of Prototype A are located at the ground floor in the North-Western part of a building (see Figure 4).

The context for Prototype B is Rosa Parks Elementary School in Redmond, WA (Architect: Mahlum Architects). This school serves about 650 students and is designed according to principles of environmental sustainability. The school is divided into three “learning community centers”, i.e., groups of classrooms with shared activity areas (see Architectural Record (1), 2008). Two of the blocks are the two-story structures and one is one-story, located on the ground floor and includes space for preschoolers. The first level of a southern block and one of its classrooms was used for design of Prototype B (see Figure 5).

The drawings of prototypes include the spatial organization of school blocks and classroom layouts, including thermal, acoustical and lighting design. It should be noted that the ideas represented in the drawings are limited to the proposed Guidelines and therefore should not be considered as a complete approach for designing any type of environment (e.g., thermal environment). However, these drawings would encourage the designers to consider the LE holistically, which is necessary for addressing large scope of issues associated with the AS.

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17 The project information is retrieved from the Schematic Design Album for “Best Early Childhood Center”, provided through a courtesy of office of “Foit-Albert Associates.”
Figure 4 – Jefferson/Best Early Childhood Center. Design layouts for Level 1 and 2
Figure 5 – Rosa Parks Elementary School. The design layout of Level 1.
5. DESIGN PRINCIPLES

The following list of Design Principles represents the general ideas that designers must keep in mind while initiating/refining the design of Learning Environments (LEs) for people on the Spectrum. These principles were identified as patterns emerging from the proposed Design Strategies. Interestingly, other recommendations related to design for the AS also support these principles but in different ways (e.g., Paron-Wildes, 2013; Ahrentzen & Steele, 2009). Although these principles were based on empirical research on Autistic Spectrum (AS), their application in the learning environment will enhance the learning process for all students.

These seven principles are fundamental in the design of LE for people on the AS. The Design Guidelines and Strategies should be considered within the context of all these principles to understand their complementary effects and also to avoid conflicts. In the presentation below, the interactions between principles are identified.

Principle 1, Visual Cues

A visual cue is a salient visual stimulus represented by an object or a spatial attribute. Visual cues may communicate information in direct (e.g., name on a chair) or in indirect ways (e.g., colored floor identifies a particular zone). Due to the enhanced visuospatial perception of people on the AS (Caron et al., 2004), visual cues are important for navigation, communication and interaction of those on the AS with the physical and social environment. Therefore, the provision of visual cues in the LE is a widely recognized method for alleviating the communication limitations of students on the Spectrum (Kabot & Reeve, 2010; Deris Di Carlo, 2013; Scheuermann & Webber, 2002; Ganz, 2007; Heflin & Alberto, 2001).

Key interactions with other principles:

- When visual cues are provided, it is critical to control their quality, character and amount (see Principle 4, “Control of Stimuli”) in order to prevent sensory overload.
- People on the AS have strengths (i.e., peak abilities) in the visuospatial domain. Thus, visually cued tasks can significantly improve the learning process (see Principle 7, “Specific Learning Material”).

Principle 2, Regularity and Order

Regularity of the environment means providing an arrangement of spatial components that clearly defines function, configuration and meaning of a setting. Regularity of processes means providing consistency of activities that occur in the environment. In general, the organization of spatial information and processes provides consistency, order and visual clarity which helps to support effective mental processes.

Regularity and order of the surrounding environment is a critical component for normal learning process, especially of those on the AS. Authors suggest that a consistent
and clear physical organization “enhances the ability of students with autism to understand and function effectively in their environments” (Schopler et al., 1995). The principle of regularity and clarity is widely used in recommendations for a design of LE for students on the Spectrum (see Kabot & Reeve, 2010; Schopler et al., 1995; Deris & Di Carlo, 2013; Ganz, 2007).

**Key interactions with other principles:**

- In arranging space for regularity and order, it is important to consider a hierarchy among the components (see Principle 3, “Hierarchy”). This will further enhance the cognition of space and support use and navigation.
- A regular arrangement of objects and spatial attributes helps to distribute the resources within space clearly, systemize the paths of access to them and reduce crowding (see Principle 5, “Social Control”).

**Principle 3, Hierarchy**

A hierarchy of spaces, objects and spatial attributes means that there are systematic and easily perceived subordinate relationships between spaces and between spatial components. The hierarchical organization of an environment emphasizes differences between its global/local components and foreground/background (i.e., relevant/less relevant) components and provides each space and component of the environment with its distinct character. Moreover, it organizes zones and spaces according to their function (e.g., space for group work) and quality (e.g., quiet zone). A clear hierarchy in spatial organization is critical for clarity of the environment and for normal navigation within it. It is especially critical for navigation and operation of individuals with limited executive function (i.e., those who have difficulties to navigate and coordinate their actions).

It is important to note that there are no direct references in literature supporting this principle. However, the strong contribution of hierarchy to the clarity of spatial organization, which is well documented, justifies its importance in the design for people on the AS.

**Key interactions with other principles:**

- A hierarchy of spaces establishes a hierarchy between territories (e.g., private place for individual work; semi-public place for group work). Clearly defining territorial boundaries will help to accommodate territorial behavior of children in the LE (see Principle 5, “Social Control”).
Principle 4, Control of Stimuli

Control of stimulation is a critical principle for design to address the atypical sensory responsiveness of children on the AS in the LE (see previous chapter). The concept of “stimulation” is broad and therefore Principle 4 can be broken down into five sub-categories related to different modalities of stimulation. They are: (1) control of visual stimuli, (2) control of auditory stimuli, (3) control of tactile stimuli, (4) control of vestibular stimuli, and (5) control of olfactory stimuli.

A number of authors strongly recommend control of auditory and/or visual stimuli in learning environments for students on the AS (Henry, 2011; Humphreys, 2008; Kanakri, 2012; Beaver, 2010). Control of vestibular and olfactory stimulation, however, is a rare attribute of design approaches despite the difficulties that persons on the AS experience in respect to these modalities (see Hilton et al., 2010).

The learning process can be significantly enhanced if both over-stimulation (i.e., too much distractions) as well as under-stimulation (i.e., lack of sensory experiences) are prevented. These levels of stimulation can be easily get out of control if particular conditions of the environment are not considered in design (e.g., glare; loud noise). Although some of these conditions could be tolerable (but still undesirable) for a typical population, they may cause an overload or/and stress of those on the Spectrum. Therefore considering the levels of stimulation in the LE is critical.

Key interactions with other principles:

- When specific learning material is provided (see Principle 7, “Provision of the Specific Learning Material”), it is important to reduce distraction as well as controlling over-/under-stimulation by the learning material itself.
- Interaction with other people is a source of auditory (i.e., noise from conversation) and visual stimuli (e.g., brightly colored clothes). Thus, avoiding crowding (see Principle 5, “Social Control”) helps to control overstimulation and insure appropriate levels of social contact (avoiding forced isolation) can help to overcome under-stimulation.
- To support private study (see Principle 5, “Social Control”), it is critical to control distractions and prevent under-stimulation caused by a learning task (i.e., insure that the task is stimulating in itself).

Principle 5, Social Control

Due to the social impairments of people on the Spectrum, controlling aspects of the social environment in the LE is critical. Principle 5 considers the fundamentals of social ecology and addresses issues as violations of personal space, territorial behavior, crowding and privacy regulation. A brief overview of how important those issues are in the context of design for the AS is provided below.

1. Violations of a personal space. Control of violations (i.e., intrusions) of personal space can enhance individual’s well-being and improve his/her social relationships. According to Robert Sommer’s
(1969) definition, personal space is an area with an “invisible boundary” surrounding the person into which others are not welcome without permission. Personal space regulates interactions and helps to achieve a desired level of privacy (Altman, 1975). Therefore, personal space is important for the well-being of individual and for the maintenance of good social relationships. However, due to impairments in social function (i.e., “mind-reading”) (Frith, 2001; Happe, 1994) and an atypical responsiveness to tactile stimuli (Hilton et al. 2010), persons on the AS can have a distorted sense of personal space. This issue is rarely addressed in design recommendations. Nonetheless, some of the authors pay attention to this important characteristic (e.g., see Humphreys, 2008; Ahrentzen & Steele, 2009).

2. **Territorial behavior.** In order to maintain a proper social stability and good relationships between peers, it is important to accommodate territorial behavior in LE. Territorial behavior is a boundary-regulation mechanism that involves personalization of or marking of a place or object and communication that it is “owned” by a person or group (Altman, 1975). Moreover, territoriality is an important mechanism for regulation of social interaction and achieving of social stability (Altman, 1975). Due to a limited capacity to understand the intentions and desires of others (Frith, 2001), people on the AS may be highly egocentric (see Frith & De Vignemont, 2005). Additionally, individuals on the AS usually have a limited set of objects (Frith, 2001) to which they are strongly attached. These factors may significantly enhance the importance of territoriality among people on the AS. Despite its importance, design recommendations usually do not take this into account.

3. **Crowding.** Crowding is a specific breakdown in privacy regulation (Altman, 1975). Feeling crowded is a resultant of situational (i.e., population density), personal (e.g., mood), interpersonal (e.g., insufficient resources) and organismic factors (e.g., stress) (Altman, 1975). Crowded surroundings will affect the learning motivation of students and may lead to fatigue and irritation. In addition, crowding depends on the effectiveness of privacy regulation mechanisms (i.e., coping responses) and their psychological or physiological costs. People on the AS have permanently impaired “personal” and “organismic” processes that increases their sensitivity to crowding (Hilton et al., 2010) and have less ability to use coping strategies to reduce discomfort. Thus, a crowded environment which also usually has more noise and visual stimulation (e.g., many colors, moving people) can cause stress and discomfort in individuals on the AS.

4. **Regulation of privacy levels.** Any person needs to be alone for some time to “digest” the experiences (both social and non-social) that he/she went through during a day. The necessity to be alone from time to time is called a need for “privacy” (see Altman, 1975). The concept of privacy is broad and may be interpreted differently in contexts of different settings and different populations. In the learning setting involving people on the AS it is especially critical to regulate the amount of social interaction and privacy by providing different study modes (i.e., collaborative and personal learning) due to problems that those on the AS might experience in a social interaction. This will allow students on the AS to take breaks between events that involve social interaction yet maintaining consistency in a learning process. In addition, it will help to decrease the avoidance of collaborative environments by students on the AS given if appropriate means for support of interaction are provided (e.g., shared touchscreen table) (see Ben-Sasson et al., 2013; Cheng et al., 2010).
**Principle 6, Safety and Well-being**

Safety and well-being are among the most important issues that should be addressed in design for people on the Spectrum. Due to their impairments in executive function and atypical attentive (i.e., “top-down”) perception (see Kenworthy et al., 2008; Happé & Frith, 2006), people on the AS may be unable to ensure the safety for themselves and become very vulnerable to particular challenges. It is not surprising, therefore, that safety finds a strong support in literature concerning the design for the AS (e.g., see Ahrentzen & Steele, 2009; Paron-Wildes, 2013; Humphreys, 2008).

Health and wellness also deserves the attention of designers and architects. Studies suggest that some people on the Spectrum may have an abnormal immune system, which undermines the ability of their bodies to protect them from particular external factors (e.g., see Jyonouchi et al., 2011). This may be the reason that so many people on the Spectrum suffer from allergies, gastrointestinal problems and various chronic diseases (Ahrentzen & Steele, 2009). A healthy environment would clearly benefit people on the AS as well as the general population.

**Key interactions with other principles:**

- An environment in which the amount and quality of stimulation is well controlled (see Principle 4, “Control of Stimuli”) is healthier since it reduces biological and psychological stress.
- Visual clarity and good organization (Principle 2, “Regularity and Order”) enhances safety by minimizing “conflicts” between occupant and environment caused by chaos and disorganization.

**Principle 7, Specific Learning Material**

Specific learning material for people on the AS should be provided in a way that exploits their unique abilities and cognitive style (e.g., TEACCH, 1996; Schopler et al. 1995). Brains of persons on the AS function in very distinct manner (Mottron, 2011). Tasks easily completed by general population can be a great challenge for those on the AS. At the same time, cognitive operations mostly impossible for normally functioning people, can be easily performed by some people on the AS (Mottron, 2011; Baron-Cohen et al. 2009). For example, some people on the AS are able to rotate a complex shape in their mind (Falter et al., 2008) or recall what he/she read ten days ago with unbelievable precision (Mottron, 2011). People on the AS usually have strengths (i.e., peak abilities or even savant abilities) in visuospatial or auditory domains (Mottron et al. 2013). Superior visuospatial abilities are the result of enhanced perceptual functioning, detail-driven vision and an ability to accurately systemize material (see chapter “Non-social Cognition”). It is important to build on the strengths of children on the AS to help them to achieve success in a learning process despite their inherent differences in thinking style.
Key interactions with other principles:

- Provision of customized learning material is important for sustaining interest and motivation during personal work (see Principle 5, “Social Control”).

The Design Principles are embedded in design strategies (see next section). They provide a designer with visual cues to explain the design solutions in a more general, conceptual manner and to identify priorities for Strategies (e.g., those that address more Principles have a higher priority). Although these Design Principles were produced through the development of strategies for design of elementary LE for children on the AS, they may be used in a design of any building for the AS.
6. DESIGN GUIDELINES

This section provides a complete list of Guidelines and strategies for the entire set of Design Problems. Guidelines follow the structure described in the Chapter 3, “Knowledge Translation” (see page 21). Visual examples and diagrams are provided where necessary to clarify the reference to a particular design attribute or a general idea of proposed recommendations. The letter “G” denotes a guideline statement and letter “S” is referred to a strategy.

Problem 1:
An environment that has an abrupt change between different activities (e.g., moving from one task to another) may be confusing and distressing.

G 1.1: Provide smooth transition between different spaces (see Fig. 6).

S 1: Provide a buffer zone before entering the classroom to allow people on the AS preparation for the new setting and activity (Fig. 9).
- The buffer zone should have at least one visual attribute, that is identical to one in the classroom, preferably more. For instance, the walls can be the same color as those in the classroom or the floor can have the same color or texture.

S 2: Provide a photograph of the classroom’s interior on the entrance door of a classroom. The photograph can include the students and teacher of that classroom.
- Alternatively, pictures of the expected activities in class should be included. For example, a picture representing students sitting at the round table would mean that the LE involves collaborative work.\(^{18}\)

S 3: Provide glazing in the doors or a lite near the doors to allow students to observe the activities in a space before entering.

G 1.2: If classroom involves different activities, provide smooth transition from one task area to another (see Fig. 6).

S 1: Provide transition spaces between different activity areas. Transition spaces should be located so that students can observe the upcoming activity without feeling that they are expected to participate in it.
- These spaces may be surrounded by temporary partitions from two or three sides.\(^{19}\)
- Transition spaces may include a visual description of the upcoming activity (i.e., what to expect next) or schedules with the daily plan of students’ tasks.

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\(^{18}\) It may be reasonable to remove the irrelevant background from the pictures.

\(^{19}\) The temporary partitions can be removed if the teacher notes that the student learned the order of the tasks and does not need any assistance.
Problem 2:
If the visual character of the learning environment changes when students are not in a class (e.g., time after classes), it may cause inappropriate reactions from students on the AS.

G 2: Allow students to control changes in the environment by themselves (see Fig. 7).

- **S 1:** Provide storage for students where they can put materials after they accomplished a task.
  - Make storage easily accessible (see Problem 22 and related guidelines).
  - Provide guidelines for maintenance that address the visual environment.

- **S 3:** Allow students to participate in changing the layout of classroom (e.g., activity areas) when it becomes necessary.
  - Avoid use of bulky and heavy furniture so students can move things independently.

*Figure 6 – Transition between different spaces and activity areas*

*Figure 7 – Through easy interaction with objects students can control change in the environment*
Problem 3:
Wayfinding will be difficult if there is a lack of visual cues (e.g., landmarks) on the path to the destination and if those cues are visually isolated from each other (i.e., one cannot access a cue B right after accessing a cue A).

G 3.1: Provide a consistent pattern of visual cues to enhance navigation (see Fig. 8).

S 1: Provide distinct but non-intrusive pictures on the walls.
  - Arrange pictures so that the next one in a series can be seen from the last one to provide continuity along a path (however, avoid the excessive use of visual cues; See Problem 4).

S 2: Color-code the main entrances and doors (or merely the doorframes) to cue the places of destinations and nodes on a one’s path.
  - Avoid placing a classroom entrance right next to another entrance or, if this is unavoidable, separate them visually (e.g., provide a partition or through design details).

G 3.2: Make circulation spaces, public spaces and learning environments visually distinct from each other (see Fig. 9, 8).

S 1: Provide different colors for floor or walls. Distinctly different illumination schemes can also be considered (but see Problem 5 and related guidelines).

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20 Consistent visual cues on a path are essential for individuals who are limited in developing and maintaining cognitive maps and who may be highly reliant on present-at-hand visual cues.
Figure 9 – The circulation path and buffer zones (before classrooms’ entrances) are defined by differences in colors of walls and floor. Different illumination schemes are also provided. (Adapted from www.occupationaltherapy.me.uk)

Problem 4:
High levels of visual stimuli can create a sensory overload.

G 4.1: Prevent clutter in the LE (see Fig. 10).

1-2 **S 1:** Provide storage containers and cabinets for each activity area.
- Storage containers and cabinets should be located close to spaces where the particular activity occurs so the material/toys may be immediately removed when they are no longer needed.

1-2 **S 2:** Provide information board(s) in specific spaces of a classroom to prevent cluttering a classroom’s walls.

1-2 **S 3:** Consider using movable boards or table letter-boards in each activity area of the LE to transfer the information from walls to areas where it is most relevant.

Figure 10 – Cluttered (on the left) and uncluttered (on the right) classrooms.
(Adapted from www.sweetschoolmoments.blogspot.com and www.magicalmaths.org)
G 4.2: Organize circulation paths in the LE (see Fig. 11).

S 1: Provide easy access to materials in the places where the task occurs. Doing this should discourage chaotic circulation across the LE and reduce the amount of visual stimulation.

S 2: Develop a one-way circulation flow within the classroom (i.e., one-way circuit linking key activities).

G 4.3: Control visual access to stimulating views (see Fig. 11).

S 1: Provide different spaces for different activities and visually separate them.

S 2: Avoid over-stimulating outdoor views such as urban view with large volumes of pedestrian and automobile traffic and public activities.

- A distant natural view can be stimulating without being intrusive or distracting.

G 4.4: The shapes of spaces should not create excessive visual stimulation.

S 1: Avoid large and long open spaces; they usually enhance visual stimulation (e.g., see Fig. 12).²¹

²¹ This strategy can be applied to an overall school layout.
Figure 12 – The long classroom (on the left) provides more visual stimulation than the smaller classroom (on the right). Note that bookshelves in the long classroom delimit a visual access from one activity area to another thus controlling distraction and stimulation (pictures are adapted from Architectural Record (1), 2014).

Problem 5:
Direct and indirect glare, flashing light and very bright light may be exhausting and may hinder the learning process.  

G 5.1: Control a direct and an indirect glare in the LE.

S 1: Use semi-indirect luminaries (i.e., fixtures with higher upward output and lesser downward output).

- Increase the non-specular reflectance of the ceiling surface and upper parts of walls to enhance the efficiency of the lighting system.
- Fixtures should be suspended 0.4-0.6 m from the ceiling to avoid the “hot spots” and to provide more diffused lighting conditions.
- Position fixtures alongside the study places and in parallel to the line of sight (where possible).

S 2: Use adjustable window shades or translucent window glass to diffuse daylight. “Light shelves” can also be considered.

- It is better to use a grey color for translucent glass to minimize the perceived brightness of material.

22 The Guidelines for the Problem 5 are based on the information provided in Grondzik et al. (2010) and IESNA (2000).
S 3: Avoid use of incandescent lamps in the LE since they may produce a strong direct and indirect glare.

S 4: Locate study places so to minimize window-facing positions.

S 5: Minimize a use of glossy materials with low brightness (e.g., black linoleum) to prevent “sharp” reflections.

S 6: Where possible, provide school desks with adjustable desk surfaces. Adjusting the angle of a desk allows prevention of veil reflections (i.e., reflected glare).

G 5.2. Control light levels in the LE.

S 1: Dark walls, floor and furnishing should be avoided because they create high luminance ratios between lighting sources and a background. Low ratios reduce the perceived brightness of a luminaire and enhance visual comfort.

S 2: Use light fixtures with adjustable output levels (i.e., dimming option).

G 5.3. Prevent bright light flashes in the LE.

S 1: Avoid fire alarm systems that produce bright light flashes when active.

Figure 13 – Indirect lighting conditions

Figure 14 – Visual “softness” of the LE achieved by indirect lighting. (Adapted from www.fagerhult.com)
Problem 6: Sharp contrasts of light and shadows, complex textures and visually expressive artwork may be distracting and disturbing.

G 6.1: Control the intensity of light-and-shadows contrasts in the LE.

S 1: Make sure that outdoor and indoor shading devices do not create sharp shadow-light patterns in a classroom interior.
  - Consider use of translucent glass and solar shades without complex textures to control the levels of daylight in the LE.

S 2: Reduce positioning of dark and bright materials/items close to each other since they have different reflective properties and may increase the light-shadow contrast.

S 3: Optimize use of photo-luminescent tapes in fire safety design since their appearance in the darkness can be overwhelming and may distract and/or disorient some people on the AS (see Fig. 11).
  - Maximize use photo-luminescent signs (instead of tapes) to provide the direction of a motion.

![Figure 15 – An over-stimulating environment (on the left) caused by the increased use of photoluminescence and glossy materials (adapted from www.img.alibaba.com); an environment with optimized use of photoluminescence and glossy materials (adapted from www.gbsafety.glow.com).]

G 6.3: Control the exposure of students on the AS to too many bright colors and complex textures (e.g., see Fig. 16).

S 1: Most artwork should have a soft color palette. Artwork with bright colors should be used sparingly for accents and wayfinding assistance.

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23 This picture was modified by the author; the photoluminescent “arrows” were provided on the walls.
• Try not to use more than three colors for walls and floor finishing. Subdue the contrast between colors.
• Avoid use of large and vivid graphics on the walls, ceiling or floor of a classroom

S 2: Minimize use of materials with complex textures.

S 3: School desktops should have a medium color value (i.e., neither bright nor dark) to subdue the salience of scratches and/or dust that can be accumulated on a desk’s surface.24

Figure 16 – Complex texture of a school rug provides extra stimulation (adapted from www.3bp.blogspot.com).

Problem 7:
Complex and unusual shapes may be highly distracting.25

G 7: Control exposure of students on the AS to complex and unusual shapes.

S 1: Eliminate elements in the environment with highly irregular or/and complex shapes if those elements are not intended to be used for education purposes (e.g., drawing task). If elimination is impossible, limit visual access to those objects.

• Avoid use of “present-at-hand” objects (e.g., pens) of very unusual shapes since they are usually very close to a student and can become a major source of distraction.
• Minimize the use of openings with a complex geometry (e.g., window with curvilinear irregular shape). The shape of openings mediates spaces that may have different levels of illumination, brightness, palette and etc.

24 The scratches and dust on a desk can create a texture that can be distracting for students on the AS due to their enhanced visuospatial perception.
25 The unusual shape of the object may distract general population as well (see Berlyne, 1971).
• Minimize the use of arbitrarily complex shapes in the LE. Furniture with complex shapes could be used, for example, if the shapes have an understandable function.

• Provide a subdued contrast between objects with complex shapes (e.g., table figure) and their background, if such objects located in the LE.

• Make sure that there are no plants having highly irregular shapes of stem and/or leaves.²⁶

Figure 17 – Unusual shape of this workstation may be distracting for children on the Spectrum. Note how complex curvilinear contour of the workstation is contrasting with environment (adapted from www.magazine.good.is).

Problem 8:
Bright and intense colors may became a reason for outbursts and stress.²⁷

G 8: Prevent exposure of students on the AS to bright and intense colors in the LE.

S 1: Use colors in a neutral, minimally saturated palette for background elements of the environment (i.e., elements of environment that usually deserve least attention; e.g., walls and floor).²⁸

• Make sure that excessively high contrasts between objects and background are avoided.

S 2: If items with saturated color(s) are provided to attract attention (e.g., posters), the number of those items should be controlled.

• Especially, minimize the use of intense reds.

S 3: Primary colors could be used for small objects. Extreme saturation, however, should be avoided anyway.

²⁶ It is also important to make sure that there is no complex and rich textures on the leaves.
²⁷ The information from Bosch et al. (2012) was used for producing this set of recommendations.
²⁸ Of note that Bosch et al. (2012) suggest the use of “de-saturated”, neutral colors for the background within the one’s view range. At the same time, objects of attention are believed to be of a brighter color (i.e., richer in white). Hypothetically, this provides visual clarity and benefits for attentive perception.
Problem 9:
Objects with many details may enhance the local bias (i.e., detail-driven vision; see page x). This may reduce attention and cause distraction.

G 10: Control exposure of students on the AS to detail-rich objects during the tasks requiring concentration and attention.

S 1: Specify potential distractors close to a study area and apply actions to resolve the issue.

- Highly reflective (e.g., chromed) objects should not be used close to study desks since they may reflect the surrounding environment thus “accumulating” many details on a relatively small surface.
- Avoid locating products with intriguing mechanical and electrical systems (e.g., table clock with a visible mechanism) close to study desks unless they are provided for educational purposes.

Figure 18 – Classroom with intense palette (on the left) and classroom with de-saturated palette (on the right) (adapted from www.4bp.blogspot.com and www.archdaily.com).

Figure 19 – The chromed tapes (outlined in red) in front of the desks can increase distraction (adapted from www.xn----itbkcijdbf2ab0f9b.xn--p1ai).
Problem 10:
Loud high-pitch sounds and noise can be highly distressing and may disturb the learning process.

G 10.1: Control high-pitch sounds and noise within the LE.

**S 1:** Minimize noise produced by mechanical systems.
- Provide the acoustical isolation for mechanical equipment in case if it can becomes a source of noise in the LE.
- Provide acoustical treatment for ductworks to minimize a noise that may be produced by fan or/and by turbulence.

**S 2:** Incorporate the fire alarm system with verbal warnings and visual signs and avoid loud high-pitched sounds.

**S 3:** Provide appropriate materials for furniture and/or floor to prevent “squeaky” sounds produced by friction (e.g., moving one’s chair).

**S 4:** Areas for independent study and individual work should be separated by full-height partitions since to minimize noise.
- If separation of activity areas by full-height partitions is impossible, maximize the sound absorption in the areas for collaborative (group) work and on the ceiling and provide barriers to deflect and baffle the noise source.

**S 5:** If the area of space is small, maximize the sound absorption of walls to prevent sharp resonances.29
- To prevent extreme “dullness” of an environment caused by the enhanced absorption, provide demountable reflective panels to control the paths of sound transition within space.30
- Resonances also can be minimized if the pair of (or all) walls are positioned nonparallel to each other.

**S 6:** Avoid the use of large concave surfaces in the LE to prevent focusing and “creeping” of a sound.31

G 9.2. Prevent penetration of noise from other spaces into the LE.

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29 This strategy relates to a classroom space and to spaces that may be adjacent/included to it (e.g., enclosed space for a private study).
30 This recommendation is not intended to be a general approach to noise prevention in the LE. It may be necessary if the “dullness” of environment becomes a problem.
31 Creeping effect may be cased when the sound travels along the curved contour of a surface. This makes an emitted sound unusually loud in some particular zones of a space (see Grondzik et al., 2010).
S 1: Evaluate the aural profile of the spaces adjacent to the LE and consider a cavity wall with embedded acoustical insulation between the LE and adjacent classrooms, public spaces and any spaces that may produce a noise.

S 2: Provide the acoustical treatment of windows and doors if they face noisy or/and public spaces.

Figure 20 – Control of a transition and reflections of a sound.

Problem 11:
An environment should be able to accommodate the requirements of music therapy. Failure to do so may limit the therapeutic potential of a learning environment.

G 11: Provide the proper acoustical and spatial conditions to enhance the positive effects of music therapy.

S 1: Music therapy can be provided in a general classroom or in space(s) adjacent to it (e.g., sensory room).

- If the adjacent space for music therapy is considered, it is better to provide access to it directly from a classroom space. If access is mediated by another space (e.g., corridor), the problems with transition can occur (see Problem 1).

S 2: Make sure that there are no resonances in space where music therapy is provided (see Problem 10). Resonances may significantly deteriorate the musical experience.

S 3: Make sure that music therapy does not create a noise and disturbance for any other activities of the LE occurring at the same time.\(^\text{32}\)

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\(^{32}\) Measures of noise reduction (see Problem 10) can be considered in that context.
• If it is difficult to prevent the disturbance of other activities (occurring in a same space or in the adjacent spaces) by the means of physical barriers, the sound projecting speakers may be a good option. The sound produced by speakers should be controlled to prevent its penetration in other spaces.

S 4: Consider the use of materials that will diffuse the sound and will provide soft auditory experience.

• If sound-diffusing panels are used, make sure that they do not significantly increase the visual complexity of environment due to a patterned structure of their surfaces (see Problem 6).
• The volume levels of music should be subdued. The music content should be chosen carefully and consist only of harmonic sounds (e.g., classic music).
• In some cases, demountable reflective panels can be considered. However, the sound paths should be well controlled and loudness of music should remain subdued (see Problem 10 and related guidelines).

Figure 21 – Provision of proper acoustics for music therapy

33 The company named “Holosonics” provides the sound projecting systems for residencial and commercial use. Such systems can be successfully adapted to learning environments as well. For more information, refer to http://www.holosonics.com/technology.html
Problem 12:

The lack of visual stimuli can cause clumsy movements and feelings of disorientation of some students on the AS.

G 12: Provide a non-intrusive pattern of visual cues in the LE to support orientation and motor function of students on the AS.

S 1: Provide pictures on the walls in the LE.  
- Pictures drawn by students can be used for this purpose.
- Control contrasts and brightness of pictures’ contents (see Problem 6 and related guidelines).

S 2: Color-code certain areas of a floor or walls (e.g., cued floor spot indicating sitting/standing areas) (see Fig. 21, 22).
- The color-cued floor rugs or sitting mates can help with orientation.

S 3: Consider darker floor in relation to walls and furniture. It may help to define the ground and support the postural balance.
- It is important, however, to avoid the sharp contrasts (see Problem 6 and Problem 8).

S 4: Avoid dark (i.e., badly lit) environments since they may provide a particular threat to postural stability of people on the AS (see Fig. 22).

Figure 22 – Visual cues indicate the standing positions
(Adapted from Kabot & Reeve, 2010).

34 Wall pictures are among the most preferable types of visual cues since they can be easily removed, relocated or substituted by other pictures in case if they would provoke inappropriate reactions.
35 This recommendation relates to the whole school layout. It is particularly important to avoid dark areas in circulation spaces.
Despite the “soft” light conditions, a monotonous color palette can make the environment disorienting (adapted from www.pinterest.com).

Problem 13:
Interior materials with high heat conductivity and surfaces with fine, “tickling” textures can cause an overload in tactile stimulation and highly irritating experiences.

G 13: Increase the “warmth” and “softness” of the LE.  

S 1: Provide soft materials for sitting places.
- Avoid use of materials with tiny stiff fibers to prevent undesirable tactile experience of children on the AS.

S 2: Provide soft pillows and rugs to wrap around the body.
- Soft blankets and pillows can be provided in the break time area or/and in a sensory room (if those spaces are provided in the LE).

S 3: Where possible, maximize use of materials with a low heat conductivity (e.g., wood).

S 4: Avoid use of materials that may injure student when he/she rubs or touches it intensely (e.g., a particular rough material).

36 It is important to note that the perceived softness of the environment is based on the soft appearance of materials but not necessarily on the amount of the soft material.
S 5: Surfaces extensively exposed to a direct sunlight (e.g., table surface near the window) should be of light hues and with low conductivity to prevent their overheating.

S 6: Provide therapeutic tactile stimulation in sensory rooms.

- Try to avoid vibrations. The corral ball pool can be a good option.

Figure 24 – Pillows, rugs and wooden floor and furniture increase perceived warmth of the environment (adapted from www.ideare-casa.com).

Figure 25 – Home interior of Scandinavian architect Alvar Aalto enhances a feeling of warmth and coziness (adapted from www.midcenturyhome.com).

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37 See Blakemore et al. (2006) for information about responses to vibro-tactile stimuli of people with Asperger’s syndrome.
Figure 26 – Corral ball pool provides children with therapeutic tactile experiences (adapted from www.specialneeds.com).

Problem 14:
The school program and learning environment should be able to accommodate an interest in music and art.

G 14: Support the development of drawing and musical skills in the LE.

- **S 1:** Provide the area for drawing.
  - Area can be located in a classroom or in a space adjacent to it.
  - Leaking of smells (i.e., the smell of dyes) from this area to other spaces should be prevented.
  - Unusual shapes and figures can be provided for development of three-dimensional reasoning.  

- **S 2:** Provide specific places for exhibition of students’ work.
  - Control a visual access to those places from study areas to minimize unnecessary distractions.

- **S 3:** Provide a space for music practice. Make sure that the sound does not disturb other students who are not involved in a music practice (see Problem 10 and related Guidelines).
  - Music practice can be conducted in the spaces adjacent to the LE. Separate spaces for private study (if provided) can be temporary transformed for that purpose.

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38 The unusual shapes used for development of drawing skills should not become a distraction for students involved in other types of activities (see Problem 7 and related recommendations).

39 The exhibition space can contain more contrasting and bright work as long as its amount and access to it from the study areas are controlled. Pictures with more calm content and subdued contrasts, however, can be used throughout the classroom (e.g., as necessary visual stimuli; see Problem 12).
• Manage the absorption-reflectance ratios and reduce resonance to achieve good acoustical conditions (see recommendations for the Problem 10).

Figure 27 – Interests in music and drawing should be encouraged but the impact of these activities on other activities in the LE need to be addressed.

Problem 15:
Failure to provide an access to a specific learning material (i.e., visually clear and well-structured) for students on the AS will prevent them from reaching full potential and can hinder the access to culture and development of abstract thinking.

G 15: Learning environments should encourage interests in mechanics, physics and math by providing visually clear examples of scientific principles.

S 1: Provide projector(s) and all the necessary equipment to allow teachers to present information visually.

S 2: LE teaching programs should accommodate “math and science games.” These games should be based on the straightforward systems (e.g., constructing a figure from two toy blocks or magnets). The complexity of those systems can be increased during a time.

• The “science games” may involve high amount of demonstrative and/or task materials. The appropriate amount of storage or/and resource rooms for that material should be provided.
• Resource rooms can be provided to storage material and provide specific areas for an individual study.

S 3: Provide the set of Individual Computer Stations (ICS) in the LE. ICSs should have Apps and virtual games for development of scientific skills of students.

40 For the list of potential ideas for games design, refer to www.igamemom.com and www.babbledabbledo.com.
S 4: Consider providing access to a garden (indoor or outdoor) from the LE (see Fig. 26). This will allow teachers to include “field trips” in their program to demonstrate some physical and biological concepts in the real world.

- The potential for overstimulation and exposure to allergens in field trips is significant but controlled experiences have less risk.\(^{41}\)
- If the garden is located outside, ensure shade from trees or canopies to protect children from the direct sunrays.
- Avoid extensive diversity of plants in a garden to prevent allergic reactions of students. Ideally, the types of allergens that students are vulnerable to should be specified prior to the “field trips.”
- Prevent students’ exposure to dust to avoid any allergic reactions and problems with breathing. In this context, lawns would be a good option.

*Figure 28 – Visual learning may enhance students’ interest in science.*\(^{42}\) *(adapted from Scott, 2009).*

*Figure 29 – Easy access to a garden will provide students with opportunities to learn scientific concepts in a real world.*

\(^{41}\) See Problems 4, Problem 10 and Problem 24 for information regarding potential perceptual problems of people on the AS.

\(^{42}\) Note, however, that highly contrasting textures in immediate proximity to students on the AS can create an undesired distraction and even scare students. Refer to Problems 6, 7 and 8 related Key Knowledge for more information.
Problem 16:
A failure to encourage motion and physical exercises may lead to musculoskeletal problems for all students. People on the AS, however, are in a greater risk for these problems.

G 16: Encourage physical activity in the LE.

S 1: Provide space for physical exercises.

- Preferably, exercise space should be adjacent to the LE to minimize problems with transition and over-stimulation that can occur if space is far from the classroom.
- Open-air place for physical activity also can be a good option if it is not over-stimulating and healthful.43
- The program for physical exercises and required equipment should be discussed with a physical therapist. Physical exercises can involve aerobic activity, stationary cycling, walking, jogging (last two may be more appropriate if the activity occurs outside).44
- Occupational Therapy (OT) (if considered) can be conducted in the exercise room.45
- Dimensions and size of the equipment in the exercise space should correspond to dimensions of a child’s body to allow easiness of use and operation.
- Floor and lower parts of walls of the exercise room may be covered with soft or resilient material to prevent injures. Sharp and solid corners should be eliminated.

![Diagram of classroom and garden](image)

*Figure 30 – Access to both outdoor and indoor spaces for physical exercise can enhance well-being of students.*

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43 See Problem 15 (G 15; S4)
44 For the review of types of physical exercise that benefit children on the Spectrum see Lang et al. 2010.
45 For more information, refer to Paron-Wildes (2013).
Problem 17:

Complex tasks consisting of a large number of required actions, especially multitasking, may be unusually challenging for students on the AS. A failure to accomplish task can be the reason for anxiety and reduction in a learning motivation.

G 17: The complexity of tasks (incl. educational and everyday activities) should be managed to allow students to succeed in the execution of their objectives while still learning new skills.

S 1. Provide visual guides, cues and schedules to assist students in the execution of their educational and everyday tasks (e.g., see Fig. 28).

- For example, a poster that explains the process of how to wash hands may be included in a bathroom. The dining area may include visual cues explaining the process of where and how to pick up food and where to remove the trash. Similarly, the “step-by-step” explanation of processes for different educational tasks may be provided.

S 3. Sudden interruptions of a process of task execution should be avoided.

S 4. Where relevant, steps to a goal execution should be reduced.

- For example, the process of accessing the milk can include (1) approaching the table, (2) opening the kitchen cabinet, (3) finding an appropriate glass, (4) opening the refrigerator, (5) taking milk bottle, (6) opening it and (7) pouring milk into a glass. By creating an open cabinet with marked personal glasses, this process can be simplified to: (1) approach the table, (2) take a glass, (3) open the refrigerator, (4) take a milk and (5) pour milk into a glass.

S 4. Easy access to necessary resources should be ensured.

46 The guides and schedules can be provided as Apps for touchscreens or smartphones. If such option is considered, it is critical to avoid any distraction that such devices may provoke. The easiness of operation is also important.

47 Any visual distractors can cause interruptions of task execution that people on the AS may not be able to resume. For possible solutions, see recommendations for Problem 4 and Problem 19 (G 19; S 2).

48 See Problem 2 and related recommendations.
Figure 31 – A schedule with visual codes can help students organize their actions and function more independently (adapted from Kabot & Reeve, 2010).

Problem 18:
Elements of the environment that are not linked by a common visual feature (e.g., color) limit the abilities of those on the AS to construct concepts (i.e., mental images of objects or environments). This leads to a diminished capacity of action planning and hinders the goal-oriented behavior.

G 18: The key attributes and objects of the LE should have a noticeable visual feature in common (e.g., color) (e.g., see Fig. 30).

S 1: Provide the monochromatic palette or common texture for objects that are linked by a particular common function or/and involved in particular type of activity (e.g., table and chairs involved in a study process).

Figure 32 – Objects linked by a common function are linked by a visual attribute.
Figure 33 – It may be easier to construct the concept of a “study place” based on table and chairs linked visually and by function (picture on the right). (Pictures adapted from www.smithsystems.com and www.ioo.i.aliimg.com).

**Problem 19:**
Intrusions into personal space and undesirable encounters with other people are more likely since people on the AS are less aware about movements of others.

**G 19: Provide more space per student in the LE.**

- **S 1.** Provide wider entrances, doors and spaces for circulation.\(^{49}\)
- **S 2.** Sitting places in areas for collaborative study should be arranged to provide an adequate amount of space per student and to avoid penetrations in a personal space.
  - Elbow-to-elbow positions should be avoided.
  - The learning material and school supplies of one student should not distract another student by intruding into his/her field of view.
- **S 3.** Active circulation through/within learning spaces of the LE should be avoided.\(^{50}\)
- **S 4.** In small spaces where students on the AS could need some assistance (e.g., in a bathroom for learning the hand washing process), the extra space for an assistant should be provided.\(^{51}\)

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\(^{49}\) This recommendation is applicable to the whole school layout.

\(^{50}\) The easy access to all necessary resources from one’s study place can decrease the chaotic circulation (see G 4.2).

\(^{51}\) For review, see Paron-Wildes (2013).
Problem 20:
Unstable objects can become a serious threat to safety in the LE.

G 20.1. Make sure that objects in the LE are stable and cannot injure students by falling down.

S 1: Tall objects (e.g., torchier, decorative vase) should be firmly fixed to surfaces on which they are standing to prevent accidental falling.

S 2: Provide small barriers on the edges of shelves that are within the reach of students (see Fig. 32). This will help to prevent objects from accidentally sliding off when touched.\(^{52}\)

- Avoid positioning bulky, heavy and glass objects on surfaces high above the floor, especially if those surfaces are within the reach of students and in an area not controlled by teacher or staff.\(^{53}\)

S 3: Make sure that jointed objects (e.g., doorknob, window curtains) are durable enough to prevent breakage and injury.

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\(^{52}\) The height of barriers could vary depending on how dangerous objects are and how big or small they are.

\(^{53}\) It is interesting to note that objects defined by brightness or luminosity (e.g., lamps that are turned on) may not be as dangerous for students on the Spectrum, don’t capitalize ‘spectrum’ as for those who are not, due to the intact or enhanced perception of luminance-defined motion of some people on the AS (see Bertone et al., 2005). Ok this whole previous sentence is confusing to me.
Figure 36 – Tall, bulky and unstable objects can be dangerous for students (adapted from www.blog.greenfloralcrafts.com).

**Problem 21:**
The visually disorganized LE may hinder comprehension and diminish clarity.

**G 21: Increase the visual and spatial clarity in the LE.**

- **S 1:** Clearly define central space(s) and spaces adjacent to it (i.e., sub-centers).
- **S 2:** Provide clear boundaries for different spaces.
- **S 3:** Make the circulation paths logical, simple and efficient.
- **S 4:** Do not use complex axial schemes for positioning of objects and spatial attributes.
  - Numerous intersecting axes and axes of complex shapes may increase the complexity of the LE organization.

Figure 37 – Organization of classroom spaces
Problem 22:
The environment that does not provide an easy physical access to functionally important items may seriously delimit functioning and performance of students.

G 22: Provide easy physical access to all items of the LE that students are going to use.

S 1: Prevent the situations when students must apply fine motor efforts in order to reach a desired item (e.g., to stand on a tiptoe to reach a book) (see Fig. 32).

- Consider the body size of children to position objects appropriately. To discourage the impulsive grabbing, consider positioning of items either closer to a student, to ensure the firm grasping, or further away to encourage a student to more deliberately approach an item and reach for it.
- Objects, that students interact with, should be designed so to allow easy reaching and firm grasping.
- Elements of the environment should not create barriers for functionally relevant movements (e.g., a high chair’s back can prevent a student from reaching the book from a shelf).

S 2: A height of all functional surfaces (e.g., height of surface for writing, height of surface for seating etc.) should be adjusted to the body size of children.

S 3: Avoid use of mechanisms that cannot be easily manipulated by students due to their physical properties (e.g., heavy door or doorknob requiring a strong physical effort for operation).

Figure 38 – Some situations requiring increased coordination may create problems and should be prevented.
Problem 23:
Choices for action that look similar may be confusing and may increase anxiety.\textsuperscript{54}

G 23: Support decision-making by reducing or eliminating alternatives for action that are not significantly different.

\textbf{S 1:} Analyze the situations where one is expected to make a decision (e.g., choose the one way from two) and visually distinguish the objects of choice.\textsuperscript{55}

- Visually define the alternatives for movement on one’s path (e.g., two doors positioned next to each other can have signs describing activities behind those doors).
- Storage places with different contents should be visually distinct.
- In areas involving collaborative activities, consider use of personal cues (e.g., sticker with a name) to help students decide where to sit, stand etc.
- The visual cueing should be of clear, associative character (e.g., sign on the door depicting the activity occurring behind the door).

\textbf{S 2:} Make sure that provided choices for action are not \textit{functionally} identical (i.e., they do not lead to a similar result in similar ways).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure39.png}
\caption{Identical alternatives for action may hinder the decision-making process.}
\end{figure}

Problem 24:
An environment where students are exposed to inappropriately low temperatures and infectious diseases will have a highly detrimental effect on students’ health.\textsuperscript{56}

G 24: Control temperature levels and air quality to maintain healthful conditions in the LE.

\textbf{S 1:} Avoid temperatures in the LE below 18 °C - 20 °C (65° F – 68° F).

\textsuperscript{54} The discomfort may be caused by the increased blood pressure, the inability to make a right choice and anxiety.
\textsuperscript{55} See recommendations for Problem 24 that describe the
\textsuperscript{56} The solutions for Problem 24 are based on the information provided by World Health Organization (WHO, 1990), Ormandy & Ezzraty (2012), Gao et al. (2014), Choi et al. (2014), and Bako-Biro et al. (2012).
• The thresholds for low temperatures may vary depending on the season. In general, however, temperatures falling below the range above should be avoided.\footnote{Some people on the AS may resist wearing particular clothes due to an irritating tactile experience that it may create (e.g., a sweater feels scratchy). Therefore, low temperatures that can be tolerated by a general population due to increase in clothing insulation can cause the problems with health of those on the Spectrum.}

• Make sure that temperature at foot level is warm enough and generally higher than temperatures at the head level of occupants.

• Prevent overheating as well.

• Consider use of radiant or constant air volume systems to provide more stable temperature conditions in the LE.

**S 2:** Provide a ventilation rate (air changes per hour) sufficient to eliminate air contaminants in the LE (e.g., CO\textsubscript{2}) and provide a fresh air input.

• Control the direction, temperature and intensity of airflows to avoid drafts.

• Control the capacity-to-volume ratio of the LE to reduce the amount of human-produced contaminants (e.g., infections or CO\textsubscript{2}).

**S 3:** Remove or reduce, as much as possible, sources of pollution and allergens in the LE.

• Reduce the reliance on materials producing irritating odors or/and toxic emissions. Pay particular attention to polymers (e.g., PVC).

• Carpeting can become a habitat for fungi (at damp conditions) or mites (at dry and warm conditions). If control of carpeting contamination is impossible (e.g., by routine cleaning), it is better to avoid its use in the LE.

• Make sure that there are no significant dust accumulations in the LE. Light colors of surfaces and objects may help teacher and stuff to notice the dust and subsequently remove it.

• Reduce ledges and horizontal surfaces like canopies, sills and window moldings where they cannot be easily reached for cleaning can reduce dust accumulation.

• Air-based mechanical systems (if provided) should be cleaned regularly to prevent occurrence of harmful microorganisms and bacteria.

**S 4:** Provide adequate levels of humidity to avoid the dryness of mucous of occupants.
Problem 25:
The interaction with objects and activities that may cause injuries (e.g., scissors) are particularly dangerous for students on the AS since they may not be able to adequately protect themselves.\(^{58}\)

G 25: Remove hazardous activities and objects in unsupervised areas and apply all necessary precautions to provide a safe environment for students.

- **S 1:** Control access to sharp items (e.g., knives, scissors, needles etc.).
  - Provide students with plastic cutlery during the mealtime. Avoid knives with sharp tips.

- **S 2:** Control access to food storage to prevent excessive intake of food by student(s).

- **S 3:** Teacher or/and staff should be able to monitor students’ activities easily to ensure safety (see Fig. 41).
  - Particular attention should be paid to solitary activities (e.g., private study).
  - The monitoring can be accessed by a particular spatial arrangement or by surveillance technology (e.g., camera in a space for a private study).

- **S 4:** Ensure safe use of hot items and substances.
  - Provide single lever faucets for ease in mixing cold and hot water.
  - Make sure that there is enough space provided in a dinning room to avoid spilling hot liquids or dropping food containers.\(^{59}\)

- **S 5:** Ensure electrical and mechanical safety.
  - Reduce visual or/and physical access to wires.
  - Provide enclosures for unused electrical outlets.
  - Provide a visual guidance for use of electrical and mechanical features (e.g., windows) in the LE.\(^{60}\)

- **S 6:** Make sure that the equipment and supplies needed for emergencies are available in the LE.
  - Those equipment and supplies should be allocated in the area controlled by teachers and staff to prevent students accessing those items by themselves.

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\(^{58}\) The recommendations for Problem 25 are based on the information provided in Ahrentzen and Steele (2009), American Chemical Society (2001) and Paron-Wildes (2012).

\(^{59}\) See Problem 19 and related recommendations for more information.

\(^{60}\) The information should provide a clear visual description of required actions. Photographs can be a best option. Avoid use of ambiguous, highly symbolic pictures and codes.
Problem 26:
Students on the AS have diminished social motivation and impairments of social cognition. This can lead to avoidance of collaborative environments and negatively affect overall motivation for learning.

G 26: Provide opportunities for private study to maintain learning motivation for students who are tired and would like to withdraw from the collaborative context.

S 1: Provide the separate space(s) for private study.

- It is important to control the amount of stimulation in spaces for private study with partitions although open spatial arrangements can be considered as long as they minimize the penetration of irrelevant information.
- Besides their primary function, space(s) for a private study can provide a place for psychological restoration.
- Make sure that opportunities for collaborative study are available. Technological support for students on the AS can help them overcome their anxiety and dislike of collaborative work. For example, virtual collaboration can be provided through computer systems and the amount of time in face-to-face group work can be gradually increased as social skills develop.
7. PROTOTYPES

This section demonstrates how the proposed guidelines can be applied to actual design. Two prototypes (A and B) are presented by the sets of annotated drawings considering different scales of prototypes design (i.e., school block and classroom). The design of the school block is limited to spatial organization whereas the design of a classroom is more detailed. The classroom drawings are divided into the set of categories representing different aspects of environment considered in the guidelines. They include circulation, lighting, acoustics, and thermal conditions. Additionally, a “miscellaneous” category is provided, which considers recommendations that do not fit any of the other categories. These categories are provided for presentation purposes and help to prevent cluttering of drawings with annotations, improving clarity and comprehension. The design strategies applied to a prototypes design correspond to those provided in the section “Design Guidelines” and are limited to addressing of the discussed Design Problems. Almost all the annotated design attributes have a reference to a particular guideline or strategy in the text. Those attributes that are referenced to a Guideline or a Design Problem only (not to a Strategy) and demonstrate the example of how the designer can improvise and develop his/her own design alternatives within the conceptual framework and requirements of the Guidelines. Those attributes that do not include any reference are provided to clarify some particular feature of a drawing.

As noted earlier, the Prototypes were developed from two real school buildings. Only the information needed to understand the application of guidelines (e.g., types of adjacent spaces, orientation of classrooms) has been included. Some of the features in the existing buildings were altered because they were in conflict with proposed design recommendations but they remain realistic examples reflecting contemporary public school design practices in the U.S. This does not mean, however, that the proposed recommendations are restricted to only particular types of projects based on a certain educational values. The open-ended system of the Guidelines allows designers and architects to expand it by adding design solutions that are specific to a particular design context. They represent a general framework of problems to be addressed. How they are addressed can vary greatly based on the context of buildings and educational values. For example, smaller student-faculty ratios than found in contemporary public schools would change the context significantly and lead to different prototypical solutions.
Prototype B:

*Design Context*: Rosa Parks Elementary School, Redmond, WA

![Plan of a Level 1](image)

**Notes:**

- **Focused School Block**
- **Focused Classroom**

1. Classroom
2. Activity Area
3. Kindergarten
4. Resource Room
5. Commons
6. Gymnasium
7. Library

*Figure 43 – Plan of a Level 1.*
School Block:

Figure 44 – Organization of a School Block. Prototype B.

Legend (Fig. 44):

A – Classroom Space; B – Room for Physical Exercises; C – Room for Music Practice; D – Room for Drawing; E – Mechanical Room; F – Lunch Room; G – Space for Private Study; H – Restroom; I – Garden.

Annotations (Fig. 44):

1. A room for music practice and room for drawing are provided to support students’ interest in music and art (G 14, S 2 and S 3).
2. A space for physical exercises is provided. Easy access to it is ensured for all classrooms (G 16, S 1).
3. Access to the garden is provided to provide possibilities for outdoor learning and physical activity (G 15, S 4; G 16, S 1).
Classroom Design. Circulation:

Annotations (Fig. 45):

1. Buffer zone is provided before the entrance to classroom (G 1.1, S 1).
2. Lockers and daily schedule for each student are provided near the entrance (see G 17).
3. Transition spaces mediate activity areas in the classroom (G 1.2, S 1). Transition spaces are defined by the L-shaped partitions allowing students to observe the upcoming activity prior to joining it. The schedule of daily tasks is provided on each partition so to help students operate in a classroom independently (G 17, S 1).
4. The circulation is organized in a one-way flow (G 4.2, S 2).
**Lighting:**

**Figure 46 – Lighting scheme of the LE**

**Annotations (Fig. 46):**

1. The entrance is turned away from the windows. This prevents stress that may be caused by transition from space with lower brightness (i.e., corridor) to a space with higher brightness (i.e., classroom) (see Problem 5).
2. Suspended semi-indirect lighting fixtures are provided to sustain “soft” and diffused lighting conditions in the LE (G 5.1, S 1).
3. Indirect lighting fixtures provided in the areas for private study (G 5.1).\(^6\)
4. Lighting fixture in the restroom is enclosed by diffuser to reduce glare and diffuse light (G 5.1).
5. Most study places do not face windows (G 5.1, S 4).

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\(^6\) Indirect lighting in spaces for private study may be the best option considering the parameters of spaces. Small rooms for private study may have more potential for efficient reflections (i.e., because surfaces are located closer to each other). In addition, lower ceiling (in comparison to that in general classroom space) reduces the potential for application of direct lighting due to the glare that it can produce.
**Annotations (for Fig. 47, 48):**

1. Intense summer daylight is reflected back from the exterior light shelf. This helps to prevent overheating of the LE (see G 25.1; S 1).
2. Winter sunrays reflect from the light shelves and deliver the diffused light into the LE (G 5.1; S 2).
3. Translucent material of the exterior light shelf reflects a portion of a light but still diffuse and transmit some of its amount into the LE (G 5.1; G 5.2). Translucent material also decreases light-shadow contrasts (G 6.1, S 1).
4. Solar shades on the windows provide more control over the daylight levels, glare and outdoor distractions (G 5.1, S 2; G 5.2; G 4.2).
5. The windows in spaces for private study are located higher so to prevent the distraction with trees and to prevent glare produced by the eastern sun (G 4.2). However, windows still provide the daylight diffused by trees (G 5.1).
6. The ceiling height in spaces for private study is decreased so to create the space scale that would be more appropriate for a child.
Acoustics:

Figure 49 – Acoustical conditions in the LE

Figure 50 – Section A-A’
Annotations (for Fig. 49, 50):

1. Cavity wall is provided between the room for physical exercises and classroom to prevent noise penetration (G 10.2).
2. Projector equipment can be used for a music therapy (G 15, S 1; G 11).
3. Sound diffusing panels on the walls will help to create appropriate aural conditions for music therapy. Open bookshelves would enhance the sound diffusion as well (G 15).
4. Bookshelves will diffract some portion of direct sound coming from the activity areas (G 10.1).
5. Sound absorbing panels provided in spaces for private study to reduce resonances (G 10.1, S 5).
6. Partitions in transition spaces are covered with sound absorbing material and therefore help to attenuate a direct and reflected sound (G 10.1) (for details, see “3D Views” below).
7. Sound absorption is increased in the areas of group work (G 10.1, S 4).
8. The information board in the center of a classroom (see G 4.1, S 2) is covered with sound absorptive material (for details, see “3D Views” below).
9. Windows covered with solar shades function as absorptive panels and attenuate the sound exchange between activity areas.
10. The spaces for private study are separated by the full-height partitions and by the buffer zone (G 10.1, S 4). 62
11. Sound absorbing panels are provided in spaces for private study to reduce resonances (G 10.1, S 5).
12. Windows of spaces for private study have a tight structure since they face the garden, which could involve noisy activities (G 10.2, S 2).
13. Sound absorbing ceiling is provided (G 10.1).

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62 The buffer area is separated from the general classroom space by the sound absorbing drape.
**Thermal Conditions:**

*Figure 51 – Thermal conditions in the LE*

**Annotations (Fig. 51):**

1. Mechanical air system is able to maintain a proper air exchange rate to eliminate air contaminants in the LE (G 24, S 2).\(^{63}\)
2. The aerodynamic shapes of a ductwork will reduce turbulence and noise (G 10.1, S 1).\(^{64}\) The noise produced by fan can be reduced by the non-fibrous sound absorption or baffles.
3. The water radiant heaters embedded in the wall under the windows will block the drafts (G 24, S 1 and S 2).

\(^{63}\) Temperature and direction of airflows can be well controlled by the mechanical system as well (see Grondzik et al., 2010).

\(^{64}\) See Grondzik et al., 2010.
Annotations (Fig. 52):

1. Physical access of children to radiant heaters is limited by the bookshelves (G 25, S 4).
2. Higher positioning of air supply diffusers allows incoming air to mix up with the interior air prior to reaching a student’s body (G 24, S 2).
3. Automatic operable windows (AOW) are provided to ensure adequate fresh air intake in case if mechanical ventilation system fails (G 24).⁶⁵

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⁶⁵ AOW can have the embedded sensors reacting to CO2 levels in the LE (see Grondzik et al., 2010).
Miscellaneous:

1. Wider circulation spaces are provided to prevent the intrusions into personal spaces (G 19, S 1).
2. Teacher has a visual access to each activity area in the general classroom space. Rooms for private study, however, will need a special monitoring system (G 25, S 3).66
3. Study material can be immediately accessed (and easily removed) from each activity area (G 4.2, S 1).
4. The lunchroom and restroom are provided adjacent to the classroom. This will prevent the problems with transition (see Problem 1).
5. Rugs, pillows and soft materials increase “warmth” and “softness” of the LE (G 13, S1 and S 2).

66 The activity area in the bottom left part of the LE implies the participation of teacher in the activity and do not need a supervision.

Figure 53 – Other strategies applied to Prototype A design

Annotations (Fig. 53):

- Sight direction
- Horizontal reach plane (0.55 m)
6. The information board “centralizes” general information (e.g., school events schedule; birthdays) in specified place and prevents the chaotic cluttering of the walls (G 4.1, S 1).

7. Cabinets and shelves with material are positioned away from the students’ reach so to encourage students to approach an item instead of impulsively trying to reach it (G 22, S 1).

8. Buffer area between the spaces for private study and general classroom can become the space for emotional restoration.

9. Spaces for private study are provided for students who are tired from the collaborative work and social environment (G 26, S 1).

10. Automatically irrigated lawn decreases the amount of dust in the air (G 15, S 4) and makes the field trip experiences healthier.

3D Views:

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67 The horizontal reach plane was calculated according to extensive anthropometric study provided by Weber et al., 1985.
Annotations (Fig. 54):

1. Movable boards and letter-boards are provided to present the information in places where it is most relevant (G 4.1, S 3).
2. Neutral and light palette is used for background elements (G 8, S 1; G 5.2, S 1).
3. Semi-indirect lighting and diffused daylight provide soft visual environment (G 5.1, S1 and S 2).
4. Monochromatic palette is used for functionally linked objects to help students construct the concept of the “activity” occurring in the space (G 18, S 1).
5. The number of saturated objects and details is minimized (G 8, S 2 and S 3).
6. Doors of the LE have an embedded glazing to enhance the space transitions (G 1.1, S 3). In addition, the doorframes have distinct colors. This will assist students in navigation and decision-making (G 23, S 1).

Figure 55 – Classroom Interior 2
Annotations (Fig. 55):

1. In addition to its primary function, the information board defines center of the LE (G 21, S 1) and visually separates different activity areas (G 4.3, S 1).
2. Devices such as touchscreens are used to provide visual information and guidance that will assist students in a task execution (G 17, S 1).
3. Medium color value is provided for desks to subdue the contrasts of scratches that may distract students (G 6.3, S 3).
4. The transition spaces are cued by floor rugs to support orientation and navigation of students (G 12, S 1).
5. The dark floor is provided to better define the ground and support postural balance (G 12, S 3). Glossiness of the floor is decreased to avoid sharp reflections (G 5.1, S 2).
6. The schedule with daily program for each student. The tasks to complete are represented as magnets with photographs of the activity areas (G 17, S 1).

Prototype B:

*Design Context: Jefferson/Best Early Childhood Center, Buffalo, NY*

*Figure 56 – Plan of a level 1*
School Block:

Figure 57 – Organization of a School Block.

Legend (Fig. 57):

A – Classroom Space; B – Room for Physical Exercises; C – Room for Music Practice; D – Room for Drawing; E – Storage Room; F – Lunch Room; G – Restroom; H – Sensory Room; I – Courtyard (garden).

Annotations (Fig. 57):

1. Space for physical exercises is easy to access from all classrooms of the block (G 16, S 1).
2. Courtyard (garden) is provided in the center of the block (G 15, S 4).
3. Spaces for drawing and music are provided in two spaces adjacent to each other. (G 14, S1 and S 3).68
4. The buffer zone provided before classrooms entrances extended to reduce the problems with transition from classrooms to sensory rooms (G 1.1).
5. Expanded area of the storage space can be transformed into resource room containing different scientific artefacts (G 15, S 1).

Classroom Design. Circulation:

Figure 58 – Circulation scheme of the LE.

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68 Note that walls of spaces for music practice are nonparallel. This will reduce resonances and benefit students involved in a music practice (e.g., see G 11, S 2 and G 10.1, S 5).
Annotations (Fig. 58):

1. Corridor and classroom space are mediated by the buffer area (G 1.1, S 1).
2. Soft seating places are provided in the buffer zone (see to G 13, S 1).
3. The daily schedule is provided on the partition in front of the classrooms entrance to provide students with expectations regarding the upcoming activity (G 17, S 1).
4. Transition space in the center of the LE allows students observation of the upcoming activity from the distance (G 1.2, S 1). It includes four daily schedules arranged so to provide an exclusive access to each of them from each activity area (see pictures of interior below).
5. One-way circulation flow is provided (G 4.2, S 2).

Lighting:

Figure 59 – Lighting scheme
Figure 60 – Section A-A’

Annotations (for Fig. 59, 60):

1. Semi-indirect lighting is provided (G 5.1, S 1). Luminaires are positioned alongside the study places and in parallel to lines of sight.
2. Indirect lighting fixtures are provided in the lunchroom (G 5.1).
3. Luminaire enclosed in a diffuser provided in the restrooms to avoid glare (G 5.1).
4. The luminaire is embedded into the light shelf so to increase the level of diffused light in the LE that may not be achieved solely by the northern daylight.
5. The luminaires suspended 0.6 m from the ceiling to prevent the “hot spots” on the ceiling surface (G 5.1, S 1).
6. Distinct lighting scheme is provided for a buffer zone to distinguish it from the corridor space (G 23, S 1; G 3.1).
Figure 61 – Acoustical conditions in the LE
Annotations (for Fig. 61, 62):

1. Sound absorption is increased in the areas for group study (G 10.1, S 4).
2. Shelves separating the activity areas diffract a direct sound (G 10.1).
3. Partitions of computer-work areas are made of a sound absorbing material (G 10.1).
4. Pillow, rugs and soft seats increase the sound absorption in the LE thus decreasing the noise levels (G 10.1).
5. Wall with high NRC (noise reduction coefficient) is provided between the classrooms (G 10.2, S 1).
6. The sound absorbing ceiling attenuates the ceiling reflections of sound (G 10.1, S 4).
7. The floor is covered with carpeting and absorbs the sound (G 10.1).\textsuperscript{69}
8. Transition space in the center serves as a barrier for direct sound (G 10.1).\textsuperscript{70}

\textsuperscript{69} The extensive sound absorbing is applied because places for individual work (top right part of the plan layout, see Fig. 57) are not separated by full-height barriers.

\textsuperscript{70} Partitions of the transition space may diffract or absorb sound depending on the material properties.
Thermal Conditions:

Figure 63 – Organization of a thermal environment.

Figure 64 – Section A-A’
Annotations (for Fig 63, 64):

1. Air diffusers are provided slightly apart from the seating places to avoid directional airflows (G 24, S 2).
2. Only exhaust diffusers are provided in the restrooms and kitchen to keep the low pressure in these spaces and keep the undesirable odors away from the classroom area (G 24).
3. In order to protect students from the exposure to hot surfaces, radiant heaters are embedded deeper into the wall cavity (G 25, S 4). The protecting mesh is provided on the top of the heat-producing opening.

Miscellaneous:

Figure 65 – Other strategies applied to a Prototype B design.
Annotations (Fig. 65):

1. Storage containers and cabinets are provided close to activity areas (G 4.1, S 1). Different spaces of the LE are visually separated (G 4.3, S 2).
2. Individual computer stations (ICS) are provided to support students’ development through virtual learning and virtual social environments (G 15, S 3).
3. Activity areas in the LE are supervised by teacher and teaching assistant (G 25, S 3).

3D Views:

Figure 66 – Classroom Interior. View 1

Annotations (Fig. 66)

1. Contrasts between dark and light materials are decreased (e.g., grey is used instead of black) (G 6.1).
2. Children’s artwork with non-intrusive content is provided on the walls (G 12, S 1; G 6.3, S 1).
3. Materials with complex textures are avoided (G 6.3, S 2).
4. Exclusive access to a daily schedule is provided from each activity area. It helps students to
   navigate and operate consistently within space and time (G 17, S 1).
5. Distant natural view from the windows is provided (G 4.3, S 2).

![Floor plan of the area](image)

![Furniture properties](image)

**Figure 67 – Furniture properties**

**Annotations (Fig. 67):**

1. Mesh used for table surface material in order to prevent a dust accumulation (G 24, S 3).
2. Chairs are made of light plastic and handles in the backs are provided to allow students easier
   manipulation of the furniture (G 2, S 2).

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71 The plastic legs of chairs and carpeting on the floor will contribute to easier sliding of chairs (G 2, S 2).
3. Carpeting on the floor will prevent “squeaky” sounds produced by the moving furniture (G 10.1, S 3).

Figure 68 – Buffer space before the classroom entrance

Annotations (Fig. 68):

1. Floor material of the buffer space is similar to that in the classroom (G 1.1, S 1).
2. Visual cues provided on the doors indicating the function of a space that one is going to enter (G 23, S 1).
3. Glazing is embedded in the entrance door to provide students with visual access to a learning environment (G 1.1., S 1).
4. The photograph of pupils with teacher is provided near the entrance (G 1.1., S 1).
5. Pictures with soft palette and non-intrusive content are provided in the circulation area for wayfinding purposes (G 3.1., S 1).
8. CONCLUSIONS

The number of people diagnosed with autism is growing. Although this trend can be attributed to better diagnostic methods, the fact is that there are many individuals with mental limitations who need additional support from society. The goal of architects, therefore, is to provide inclusive environments (i.e., environments, appropriate for everybody) that will fit the needs of those on the AS and will support their right to be an equal part of the society. However, design for this population requires a profound knowledge about how people on the AS interact with the environment. Considering the lack of knowledge in a form appropriate for design, this thesis developed recommendations for design of mainstream elementary learning environments for high-functioning children on the AS. The recommendations were based on an extensive review of a scientific literature. Theory about how people on the AS think and empirical evidence from neuroscience and cognitive psychology underlie the proposed design recommendations. A conceptual framework was developed that will also accommodate information from other domains of knowledge (e.g., precedents study, surveys, review of anecdotal reports) to expand and improve design recommendations.

The project was based on the multi-staged system for translating scientific knowledge into the design recommendations. A major part of this system is a set of Problems interpreting the scientific knowledge (i.e., Key Knowledge). Design Guidelines and Strategies provide recommended solutions to the Problems. The Strategies were analyzed and the most important ideas regarding a design for the AS were derived from them (i.e., Design Principles). Finally, two Prototypes were designed to test how the end-product could differ from conventional design if the proposed design recommendations were followed. Prototypes also provide clear visual examples for the design recommendations.

The scope of the project is bounded by the number of considered issues (i.e., the list of Key Knowledge and Problems, see Appendix I), the target population (high-functioning children on the AS) and the setting (elementary LE). This made the project manageable within the context of a thesis. Design recommendations consider different aspects of the LE (e.g., social, informational and products) but the physical aspect was given the most emphasis. Recommendations are given for organization of space, the thermal, visual acoustical and haptic environment, and the air quality of LE spaces.

It is important to mention that the proposed design recommendations are organized as an open-ended system. They can be expanded further by the inputs from scholars, designers, autism advocates, parents, and teachers. The theoretical framework underlying recommendations will help to organize different types of knowledge into a consistently structured system of knowledge. Moreover, the proposed design guidelines will encourage scholars to conduct interdisciplinary studies aimed to explore the interaction of children on the AS with different aspects of environment. Below the author provides a list of research questions to encourage the formulation of new empirical knowledge and make the guidelines even more extensive, in-depth and profound.

Research questions for continued research on AS-Environment interactions:

1. What sound levels in the LE (exact value or a range of values) correlate with increases in inappropriate behaviors (e.g., tantrums, emotional outbursts)? What sound sources will be the most disturbing (see Problem 10)?
2. What the output value of lighting fixtures would be appropriate for good illumination but will not cause inappropriate behaviors and stress (see Problem 5)? What threshold values (in luminance) for the direct and indirect glare that those on the AS cannot tolerate?

3. How many soft materials should be provided in the LE so to achieve positive behavioral outcomes (see Problem 13)?

4. What temperature levels, air quality and what type of mechanical system will help to reduce the sickness and absentees of pupils on the AS (see Problem 25)?

5. What situations encountered in a school setting are the most challenging for children on the AS, in terms of decision-making (Problem 23)?

6. What visual contrast (e.g., expressed in a ratio) would be the most distracting (Problem 6)?

7. How much saturation (value or range of values) and what hues have the strongest correlation with increases of inappropriate behaviors and stress of those on the AS (Problem 8)?

8. What methods would be the best for measuring the environmental complexity (e.g., number of objects per sq. ft.)? What levels of environmental complexity will increase stress of students in the LE (Problem 4)?

9. How much space per person should be provided in the LE to accommodate the needs of personal space of students on the AS (Problem 19)?

10. What new products should be designed to increase the comfort of students on the AS in LE? What products should be re-examined? Will the re-examination of those products will satisfy both normally functioning students and those on the AS?

Post-occupancy evaluations (POE) can provide a validation of the Guidelines after their application to a design of a particular setting. Conducting the POEs will maintain a cyclical process of production and application of Guidelines and will provide another source of knowledge for the proposed system (in addition to inputs from knowledgeable people in the field). However, the idea of facilitation of a knowledge growth by POEs is not new, it has been already employed by the Center of Health Design for practicing the evidence-base design of healthcare facilities (for review refer to “Pebble Project” on: http://www.healthdesign.org/).

This project provides a unique source of information for professionals who seek to design inclusive mainstream elementary LEs that can accommodate the needs of high-functioning children on the AS. In future, the same approach to knowledge translation can be applied to design of a whole school setting. Some design recommendations provided in this work could be easily generalized; some of them, however, will require a revision and modification.

Generally, this work provides an important step forward to address the lack of comprehensive knowledge regarding the interaction between those on the AS and environment and the knowledge gap between the

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72 If study to concern the indirect lighting fixtures the appropriate brightness levels of reflecting surfaces can be measured.

73 For addressing this research question, it may be necessary to investigate the correlation between physical and tactile (experienced) properties of different soft materials.

74 Research on this question would probably require taking into consideration the value of colored area a person or group to be exposed to (e.g., a wall or a table desk).

75 In this context, the furniture design can be of particular interest for researchers due to musculoskeletal problems that children on the AS may face (see Problem 16).
design and scientific communities. The recommendations will help to increase the quality of the LE in general thus providing benefits for all students, not just for those on the AS. Hence, the proposed project provides a valuable contribution to a neglected area, design for the AS, as well as for improving human centered design in general.
# APPENDIX I, KEY KNOWLEDGE + PROBLEMS

<table>
<thead>
<tr>
<th>Key knowledge</th>
<th>Related Problem</th>
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<tr>
<td><strong>KK1</strong>: Behavioral flexibility is the neuropsychological ability to shift from one sequence of actions to another in response to changes in the goal execution context (e.g., the route that one usually uses is closed and one should search for alternative) (D’Cruz et al., 2013). Due to a reduced cognitive and behavioral flexibility, people on the AS may have problems with transition from one occupation/task to another (see D’Cruz et al., 2013; Reed et al., 2013; Ozonoff et al., 2004; Sterling-Turner &amp; Jordan, 2007). Transitions between occupations may become highly stressful for individuals on the AS (Sterling-Turner &amp; Jordan, 2007).</td>
<td>P1: An environment that has an abrupt change between different activities (e.g., moving from one task to another) may be confusing and distressing.</td>
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<td><strong>KK2</strong>: The exceptional visuospatial abilities may be maladaptive as long as they may lead to distress at small changes in the environment (Happe &amp; Frith, 2006).</td>
<td>P2: If the visual profile of learning environment changes when students are not in a class (e.g., after classes), it may cause inappropriate reaction of students on the AS.</td>
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<td><strong>KK3</strong>: Spatial orientation and navigation of people on the AS is based on enhanced “What” (occipito-temporal) visual system and intact or inferior “Where” (dorsal) system (Caron et al., 2004). Thus, a cognitive mapping (i.e., mental representation of physical space required for navigation) of some people on the AS can be based on episodic, item-related memory rather than on the abstract cognitive representations (Caron et al., 2004; Maister et al., 2013).</td>
<td>P3: Wayfinding will be difficult if there is a lack of visual cues (e.g., landmarks) on the path to the destination and if those cues are visually isolated from each other (i.e., one cannot access a cue B right after accessing a cue A).</td>
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<td><strong>KK4</strong>: People on the AS have an increased sensitivity to early low-level stimulation (i.e., the first perceptual responses occurring in primary visual cortex) (Belmonte &amp; Yurgelun-Todd, 2003; Mottron et al., 2006; Mottron &amp; Burack, 2001). This may lead to excessively strong reaction to bright color and light, complex textures,</td>
<td>P4: High levels of visual stimuli can create a sensory overload.</td>
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<td></td>
<td>P5: Direct and indirect glare, flashing light and very bright light may be exhausting and may hinder the learning process.</td>
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76 The behavioral flexibility implies the flexibility in goal shifting as well.
contrasts and complex contours of objects (see Hilton et al., 2010).

<table>
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<tr>
<th>P6: Sharp contrasts of light and shadows, complex textures and visually expressive artwork may be distracting and disturbing.</th>
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<td>P7: Complex and unusual shapes may be highly distracting.</td>
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<td>P8: Bright and intense colors may become a reason for outbursts and stress.</td>
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</table>

**KK5:** Due to an increased lateral inhibition and enhanced low-level information processing (Mottron et al., 2006), people on the AS are sensitive to high spatial frequency (i.e., average number of spatial elements per unit area; Mottron & Soulieres, 2012). The sensitivity to HSF may account for unusual interest to explore the scene with high amount of details and may substitute the “global” perception (i.e., ability to seeing “forest” not “trees”) (see Happe & Frith, 2006; Mottron et al., 2006).

| P9: Objects with many details may enhance the local bias (i.e., detail-driven vision). This may reduce attention and cause distraction. |

**KK6:** People on the AS are very sensitive (i.e., “hyper-responsive”) to auditory stimuli and may have enhanced pitch perception (Bhatara et al., 2013; Stiegler & Davis, 2010; Mottron et al., 2006). This can cause strong negative reactions to inharmonic sounds (e.g., street noise) and loud high-pitch sounds (e.g., creaking door) (see Kanakri, 2012; Grandin, 1995). Harmonic sounds (e.g., classic music), however, can have a positive and even therapeutic effect (e.g., see Schwartzberg & Silverman, 2012).

| P10: Loud high-pitch sounds and noise can be highly distressing and may disturb the learning process. |
| P11: An environment should be able to accommodate the requirements of music therapy. Failure to do so may limit the therapeutic potential of a learning environment. |

**KK7:** Some people on the AS are highly reliant on visual cues in maintenance of postural stability and motoric functioning (see Molloy et al., 2003).

| P12: The lack of visual stimuli can cause clumsy movements and feelings of disorientation of some students on the AS. |
**KK8:** Some people on the AS can be hypersensitive to tactile stimuli (Hilton et al., 2010). Particularly strong reactions may be caused by high-frequency vibrations (Blackmore et al., 2006; Cascio et al., 2008), tactile experience of the “fine” textures (Blackmore et al., 2006) and hot or cold surfaces (Cascio et al., 2008).

**P13:** Interior materials with high heat conductivity and surfaces with fine, “tickling” textures can cause an overload in tactile stimulation and highly irritating experiences.

**KK9:** Enhanced visuospatial and auditory perception of people on the AS can be a basis for a developing of savant skills in drawing and music (Mottron et al., 2013).

**P14:** The school program and learning environment should be able to accommodate an interest in music and art.

**KK10:** Some people on the AS can start the development of savant abilities after an encountering with a certain material-catalyst (e.g., exposure to boiler can lead to further exploration of pipes in 3D drawings) (Mottron et al., 2013). A material-catalyst usually features a "structural redundancy" (e.g., calendars) (Mottron et al., 2013).

**P15:** Failure to provide an access to a specific learning material (i.e., visually clear and well-structured) for students on the AS will prevent them from reaching full potential and can hinder the access to culture and development of abstract thinking.

**KK11:** Savants with AS conditions can generalize their savant skills (i.e., special talents) from one material into another by cognitive mechanism called Veridical Mapping (VM). A generalization of skills through VM is based on a detection of structural similarities between two (or several) materials. (Mottron et al., 2013). VM can allow person on the AS to generalize his/her narrow interest (e.g., calendar calculations) into more complex and abstract materials (e.g., arithmetic calculations) thus allowing the development and learning. Though speculative, there is an assumption that VM may provide access to culture for those on the AS (see Mottron et al., 2013).

**P16:** A failure to encourage motion and physical exercises may lead to musculoskeletal problems for all students. People on the AS,
et al., 2009; Coffman et al., 2011). This may encourage the extensive withdrawal from active plays and physical activity (e.g., running) and lead to musculoskeletal problems. However, are in a greater risk for these problems.

**KK13:** Cerebellum is a brain region responsible for “monitoring” errors in thoughts and motoric actions (Wolf et al., 2009). There is a strong body of knowledge suggesting for atypical functioning of cerebellum in the AS (Sajdel-Sulkowska et al., 2011; Pierce & Courchesne, 2001; Whitney et al., 2008). People on the AS, therefore, may be inaccurate while executing tasks required a long sequence of complex actions (i.e., requiring long process of thinking and corresponding motoric actions). People on the AS, however, can use the compensatory mechanisms to accomplish such tasks (i.e., “systemizing”, which is the piecemeal strategy for task execution).

**KK14:** The concepts of places are critical components of people’s goal oriented behavior (Barsalou, 2009). When one is sitting in the room, for instance, and instantly decides to move in another room, one retrieves the concept of the room where he/she wants to go. A concept usually incorporates the contextual information retrieved from the memory (e.g., the objects in the room) (Barsalou, 2009). This helps to coordinate the goal-oriented behavior.

**P17:** Complex tasks consisting of a large number of required actions, especially multitasking, may be unusually challenging for students on the AS. A failure to accomplish task can be the reason for anxiety and reduction in a learning motivation.

**P18:** Elements of the environment that are not linked by a common visual feature (e.g., color) limit the abilities of those on the AS to construct concepts (i.e., mental images of objects or environments). This leads to a diminished capacity of action planning and hinders the goal-oriented behavior.

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77 People on the AS have limited ability to organize their actions (see “Executive Functioning” chapter and. Therefore, execution of the goal that implies a large consequence of actions can be difficult for those on the AS. For example, person on the AS can find difficult to get a glass of milk if it implies: (1) approaching the table, (2) opening the kitchen cabinet, (3) finding an appropriate glass, (4) opening the refrigerator, (5) taking milk bottle, (6) opening it and (7) pouring milk into glass. If the links between actions are permanent (i.e., lawful), people on the AS can learn them by realizing that if he/she will approach the table, he/she will always be able to open the cabinet, after opening the cabinet he/she will always see there the same glass and so on (refer to page x, “Hyper-Systemizing Account”). The change in one of this event, however, can cause a tantrum and stress of a person on the AS, thus the “lawfulness” is important (Kanner, 1943). However, it can be difficult to control the system if it has too much variables. Thus, the lawfulness of the sequence of actions can be better controlled if this sequence is short (e.g., (1) approach the table, (2) take a glass, (3) open the refrigerator, (4) take milk and (5) pour milk into glass). Also, short sequence of actions will be better learned by people on the AS due to their systematic manner of learning (i.e., learning the simple logical links between two events and then combining them into the full sequence of goal execution) (Baron-Cohen et al., 2009; Baron-Cohen, 2006).
and plan the actions. People on the AS, however, have difficulties with processing of the “context” since they may not notice the abstract relations between its elements (e.g., common function between the objects) (e.g. see Happe & Frith, 2006; Frith, 2003; Mottron et al., 2006). Nevertheless, the perception of the non-abstract reality is generally intact or enhanced in the AS (i.e., roughly the “bottom-up” perception) (Mottron et al., 2006). It means that people on the AS might be unable to construct the concepts that lie beyond the present-at-hand reality (e.g., concept of place based on its function) but be able to construct the concepts that are visually evident (e.g., table and chairs of the same color as a concept associated with a place for study).

**KK15:** People on the AS can have problems in perception of complex (i.e., second order) stimuli (Bertone et al., 2005). Such stimuli might include the movement of animate (e.g., man is walking) (Blake et al., 2003) and inanimate objects (e.g., motions of the leaves on the trees) in the real-world settings (for review see Bertone et al., 2005, 2003). This may lead to a reduced awareness about the any activity around (e.g., walking people; book falling from the shelf).

**P19:** Intrusions into personal space and undesirable encounters with other people are more likely since people on the AS are less aware about movements of others.

**P20:** Unstable objects can become a serious threat to safety in the LE.

**KK16:** The horizontal connections within the primary visual cortex are sensitive to the regularity of perceived stimuli. Studies suggest that these connections are enhanced when the collinear stimuli (i.e., objects set up on the same axis) is perceived (Bosking et al., 1997; Schmidt et al., 1997; Lamme et al., 1998). When connections are enhanced, the vision is enticed by this perceived regularity. Thus the sense of clarity and pleasantness can occur.

**P21:** The visually disorganized LE may hinder comprehension and diminish clarity.

**KK17:** The empirical work suggests that people on the AS have a decreased activity in anterior frontal regions, brain areas related to a cognitive control of a movement (Samson et al., 2012). This may lead to a diminished ability

**P22:** The environment that does not provide an easy physical access to functionally important items may seriously delimit functioning and performance of students.
of some individuals on the AS to perform the motoric tasks requiring the strong coordination of actions (e.g., trying to reach the book standing on the tiptoe) (e.g. see Duffield et al., 2013).

<table>
<thead>
<tr>
<th>KK18: Selection between two competing alternatives involves cognitive processes similar to an “action recall” (i.e., conscious and “strategic” recalling of information) (see Pertides, 2002). These processes are activated by mid-ventrolateral prefrontal cortex (VLPFC) believed to be limited in those on the AS (Samson et al., 2012).</th>
<th>P23: Choices for action that look similar may be confusing and may increase anxiety.</th>
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<tr>
<td>KK19: Due to the abnormally functioning immune system (i.e., “immune dysregulation”), people on the AS may have a weak immune defense against external infections (see Jyonouchi et al., 2011; Rossignol &amp; Frye, 2012).</td>
<td>P24: The environment where students are exposed to inappropriately low temperatures and infections may have a detrimental effect on students’ health. Such environments are particularly dangerous for people on the AS.</td>
</tr>
<tr>
<td>KK20: Due to the atypical functioning of amygdala (i.e., brain region related to emotion processing) (see Mori et al., 2012), people on the AS may exhibit “lack of fear in response to real dangers and excessive fearfulness in response to innocuous objects or situations” (APA, 2000; Turner &amp; Romanczyk, 2012).</td>
<td>P25: The interaction with objects and activities that may cause injuries (e.g., scissors) are particularly dangerous for students on the AS since they may not be able to adequately protect themselves.</td>
</tr>
<tr>
<td>KK21: Social motivation (SM) is the evolutionary derived tool that helps people maintain interest in collaborative environment and social cohesion. SM encourages a person to “seek acceptance and avoid rejection” by sharing the resources, maintaining friendliness etc. (see Chevallier et al., 2012). Literature suggest that people on the AS may have a diminished social motivation due to atypical neurological function (Chevallier et al., 2012). It is still unclear whether the impaired SM causes the problems with social cognition or impaired social cognition leads to problems with SM. However, it may be hypothesized that some people on the AS may struggle to initiate</td>
<td>P26: Students on the AS have diminished social motivation and impairments of social cognition. This can lead to avoidance of collaborative environments and negatively affect overall motivation for learning.</td>
</tr>
</tbody>
</table>

KK2: Due to the atypical functioning of amygdala (i.e., brain region related to emotion processing) (see Mori et al., 2012), people on the AS may exhibit “lack of fear in response to real dangers and excessive fearfulness in response to innocuous objects or situations” (APA, 2000; Turner & Romanczyk, 2012).
and sustain social relationships due to a different brain architecture.
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