Universal Design 2016: Learning from the Past, Designing for the Future
H. Petrie et al. (Eds.)

doi:10.3233/978-1-61499-684-2-314

Interaction Design in the Built Environment: Designing for the 'Universal User'

Cathy DALTON[1]
UCD SMARTlab/Ulster University, Ireland

Abstract. Concepts of responsive architecture have to date largely involved response to environmental context, in order to mediate ambient environmental factors and modify internal conditions for the comfort of users, with energy efficiency and sustainability as the main impetus. 'Smart' buildings often address little other than technically functional issues, with any ideas of 'design' as a unifying factor being disregarded. At the same time, music and performance art have been in the vanguard of creating digital interaction that intimately involves the user in aesthetic outcomes, in the creation of what Umberto Eco describes as an 'Open Work'. Environments made responsive through embedment of computational technologies can similarly extend usability and user-centred design towards universality, through careful consideration of the relationship between person, context and activity, and of the continuous and ultimately transactional nature of human occupation of built environment. Truly 'smart' environments will learn from and through usage, and can be conceived and designed so as to maximise environmental 'fit' for a wider variety of users, including people described as being 'neurodiverse'. Where user response becomes a significant component in managing a smart environment, the transactional relationship between user and environment is made explicit, and can ultimately be used to drive interaction that favours ease-of-use and personalisation. Inclusion of *affective computing* in human interaction with built environment offers significant potential for extending the boundaries of Universal Design to include people with autism, people with intellectual disability, and users with acquired cognitive impairment, including that arising from dementia. The same users frequently have issues with sensory–perceptual sensitivity and processing. The resulting mismatch between their individual needs and abilities, and the environments they typically occupy, can give rise to states of chronic and acute anxiety. Analysis of the characteristics of such users gives rise to various 'personas', whose functional and psychosocial needs may be best met by responsive environments which take consideration of affective state, that is, of mood and emotion. Human-computer interaction which marries responsive architecture and affective computing offers a new paradigm for smart environments, which are intrinsically user-centred as a consequence. The technical complexity of designing such an environment must always be balanced by the absolute necessity of utilising Universal Design principles to reduce the underlying technological complexity to a usable interface. This paper is a preliminary exploration of the principles underlying the design of one such responsive environment: an interactive sensory room for children with autism spectrum disorders, (ASDs), which aims to promote relaxation and thus reduce anxiety.

Keywords. Universal Design, affective computing, sensory environments, autism

[1] Corresponding Author, School of Mechanical & Materials Sciences, Belfield, Dublin 4, Ireland; E-mail: cathy.dalton@ucd.ie.

1. Introduction

While human occupants have always modified buildings through use, built environment remains largely static after completion, changing only slowly over time. Significant alterations are often costly and disruptive, and so the impact of architectural design on access and ease-of-use is hugely significant. Perhaps as a function of the longevity of built design, focus in designing for inclusivity has tended to remain on utility, rather than usability in the broader sense. At the outset, Universal Design in built environment dealt with little other than physical access, and much of that at the level of bare utility. Recently, there has been a welcome shift towards a more cohesive approach to the design of inclusive environments, rather than the tick-box approach which previously prevailed. Standards for Universal Design have begun to reflect to need to design for more than physical access, and to consider the needs of users with sensory impairments, intellectual disability, and cognitive impairment associated with ageing and dementia. The needs of a growing number of people who are described as being *neurodiverse* must also be taken into consideration. Reconciling the needs of these users can present a dauntingly complex task for the designer, as many people so described have different sensory-perceptual worlds, most especially users with autism spectrum disorders, who represent a growing population of users globally [1]. Significant challenges arise from adequately designing for a user who is not only hyper-sensitive to sensory phenomena such as light, colour and sound, but whose sensory-perceptual world may fluctuate from moment to moment [2]. Fluctuating perception, unsurprisingly, may become a source of significant anxiety. Similar sensory-perceptual problems can occur in people with dementia, where they arise from cumulative neural damage, rather than from atypical neural development, as in autism. The challenge is all the greater in architectural design, because of its inherently static nature, which can militate against flexibility and personalisation. In spatial terms, one size generally *must* fit all. However, the characteristics of internal environments can be manipulated, and the advent of sophisticated computational technologies presents the designer with an opportunity to harness them creatively, so that these challenges become opportunities.

2. Architecture and Wellbeing

The idea that physical and architectural context affects human wellbeing is a very old one, reiterated in the 20th century in the theoretical writings of Walter Gropius and Richard Neutra, among others. Some environments can be described as being '*psychosocially supportive*': that is, they optimise human wellbeing [3]. Environments which are merely functional serve only what are termed *'survival needs'* in terms of person-environment fit, and not the *'higher needs'* which contribute to wellbeing [4]. Gropius wrote extensively about the influence on the person of environmental factors, including colour: the study and detailed consideration of these 'energies', formed the basis of the Bauhaus education [5]. In 'Survival Through Design', Neutra writes that 'millions of sense receptors determine what design can actually do for us', and predicts the creation of technologically-enabled internal environments which facilitate nuanced control of light and colour [6]. Much is shared between all human users in perceptual terms (or there could be no consensus whatsoever on experience), but people who are not 'neurotypical' may have significantly different sensory experiences, as may users with sensory impairment. Without some degree of sensory flexibility, many environments are only barely usable for a large and growing number of people. Typically, in the case of people with autism, increased sensory sensitivity, coupled with inability to effectively interact with surroundings, contributes to creating states of acute stress and anxiety, thus impacting negatively on wellbeing. The desire to include users whose needs - whether physical, sensory or cognitive - can vary significantly from a largely non-existent 'norm', suggests that environmental flexibility is highly desirable, not only as it relates to function, but also in *sensory-perceptual* terms. While it may be the case that such flexibility of use is more readily achieved in interaction design for web interfaces and devices, the exponential development of computational technologies suggests that environmental designers must now consider the possibilities made available to them by deploying these tools. Architecture continuously absorbs new technologies and turns them to its own advantage: pervasive and embedded computing is the latest arrival. Adaptive and responsive environments offer designers a means to allow for *'extreme personalisation'*, defined as 'designing for a market of one user', thus extending the territory of environmental design towards true universality.

3. Transposing Definitions across Disciplines

Constructing a framework for the design of a responsive architectural environment calls for some alignment of definitions and principles from the different domains. It is immediately apparent that any evaluation of 'usability' in an architectural environment, whether responsive or not, will benefit from the application of principles which are well-established in interaction design. They also serve as a reminder that human interaction in architectural space is a continuous process, rather than a discrete event. Moreover, architectural places are a great deal less easy to 'leave' than an unsuccessful computational system interface (for example, a web-page), so that the user is forced to encounter what may be a hugely unsatisfying experience, which, given its spatial nature, is unavoidably both immersive and multisensory. The most vulnerable users are also the most likely to find themselves in a situation where they are literally unable either to leave, or to adapt their immediate surroundings for a better 'fit'. Don Norman and Jakob Nielsen define concepts around usability as follows [7]:

- **Utility** = whether it provides the features you need
- **Usability** = how easy & pleasant these features are to use.
- **Useful** = usability + utility

Utility in built environment is provided through basic physical and sensory accessibility, e.g. the availability of suitable means to enter and negotiate a building or environment, sufficient lighting levels, access to services. Usability is a somewhat more elusive commodity. In built environment, the *quality attributes* of usability, i.e. 'learnability', 'efficiency' 'memorability' 'errors' and 'satisfaction' [7], are equally valuable. They are inevitably bound up in three-dimensional design, and are collectively provided by characteristics such as clarity of layout, ease of way-finding, and availability of visual and other sensory cuing. More utilitarian aspects, such as lighting levels, also contribute to making an environment more navigable and usable for all users.

The Nielsen-Norman definition of 'User Experience' (UX) describes it as encompassing 'all aspects of the end-user's interaction with the company, its services, and its products' [7]. Transposing user experience to built environment, 'company' might be replaced by 'room', 'building' or even 'neighbourhood'. While Nielsen takes care to distinguish 'UX' and 'usability', nonetheless, in defining the quality attributes of usability, he refers to 'learnability' and 'satisfaction', both of which appear to refer to the user's overall experience of a system, so that to some degree the relationship between usability and user experience is reciprocal. The experience of a space or building *in its entirety* often informs the quality of experience more than the experience of any constituent part. If user experience is disassembled into its constituent parts during the design process, the coherence of the total experience must always guide the architectural outcome. Nonetheless, by considering architectural design in the manner of interaction design, we can work towards optimising usability, always bearing in mind that a successful design is far more than the sum of its parts.

4. Introducing Affective Interaction

In order to enhance the degree of 'fit' between person and environment, the design of a 'smart' interactive environment, like any exercise in interaction design, must take account of user, context, and user activity. Context is critical in both architecture and interaction design. As Malcolm McCullough eloquently expresses it, *'appropriateness is almost always a matter of context. We understand our better contexts as places, and we understand better design for places as architecture'.* [8] By extension, pervasive computing, where it is embedded in the fabric of the built environment, becomes understandable when framed by its physical context. The precise nature of any interaction is a function of the relationship between the user, the place where the user is physically located, and the action that the user undertakes. Where that interaction is between the user and an architectural space or place, the term 'context' has exactly the same meaning as in its architectural sense, i.e. the physical locale [8].

What happens to interaction when the user interface is a room or even an entire building? In imagining some of the potential design outcomes, it is useful to consider the transactional nature of human occupation of environment [9]: how human occupation alters an environment, which in turn acts on the occupant. As research into home management applications begins to take into account user presence and behaviour, this raises the question of whether and how *affective computing* might be utilised in 'smart' environments. Affective computing can be defined as *'computing that relates to, arises from, or deliberately influences emotions'* [10]. We now possess the means to conceive, design and make devices, interactions, and ultimately, whole environments which can respond to affect, by using feedback on the user's affective state to inform how computationally-enabled response is managed. The paradigm of including affect in architectural interaction initially emerged as a necessary component of a concept for responsive architecture which meets the particular needs of an elderly person with dementia, who has diminishing capacity to deal with environmental press [11]. It represents a step beyond the 'Internet of Things', to a coherent model of localised interaction, which is both user- and context-specific. Any system which incorporates data based on sensing of user affect becomes implicitly user-centred. In this model, affect is inferred on a continuous basis from sensed bio-signals, which must then be contextualised in environmental data in order to give a complete and continuous picture of the user’s interaction with her surroundings. The entire space or architectural environment thus becomes the system interface. In practical terms, there is still a perpetual trade-off between the value and usefulness of the information that can be acquired using bio-sensing, and the intrusiveness of the sensing method. Currently, this almost always involves using wearable sensors, which may be perceived by an already cognitively and sensorily overloaded user as an additional stressor. This suggests that embedding of sensors in built fabric as the optimal future solution for many, if not all users.

Consideration of user experience requires a holistic and synergistic approach to the design of responsive architectural environments, which includes flexible and intuitive interaction with less tangible environmental aspects such as lighting, colour and overall sensory environment. Through contextualised sensing of, and response to affect, the user is enabled to become part of a continuous feedback loop with his/her environment, creating and re-creating both functional and aesthetic outcomes on a continual basis. Affective feedback can ultimately be used to drive real-time interaction that favours ease-of-use and personalisation, and at the same time, addresses more complex human needs. By observing how the user is feeling, especially through measurement of physiological stress responses, we can also gain insights into the usability of the various interfaces and interactions which together make up an environmentally-embedded system. Sensing of affect can also be used to observe how a user reacts to changes in environmental stimulus. Ultimately, such an environment might be trained to ‘learn’ from patterns of use and behaviour. This is likely to be of particular value to users who are unable to readily communicate their needs. People with autism, together with older users with dementia, and people with intellectual disabilities, are therefore among those who stand to benefit most from the incorporation of affective technologies into interaction design.

The approach is underpinned by the seminal ‘Calm Technology’ paradigm [12], where computational technologies recede to the periphery until required, suggesting a minimal or ‘disappearing’ interface with the underlying, and often complex technologies required to drive user interaction and environmental responsivity. Digital technologies which articulate and mediate the unique and ever-evolving relationship between the individual user and his/her environment have been consciously exploited in interactive performance and art for the last couple of decades, but have been slow to diffuse into the realm of architecture, beyond discrete installations in architectural space. While the model of affective response in architecture may have most immediate application in therapeutic situations, beyond that, it suggests new scenarios for responsive architecture in general.

5. Creating a Persona for the ‘Universal User’

The design of a successful interface must take into account typical user characteristics, identifying key principles on which to base the design of both interface and interaction. The concept of creating a ‘persona’ is borrowed from web design and marketing, where it is used as a tool to create notional clients, or users, for a website, by identifying their demographic needs and expectations. The construction of a persona is intended to aid in identifying universal features and functionality. A potential problem with the approach in this piece of design research is the adage ‘if you’ve seen one person with autism, you've see one person with autism'. Notwithstanding this received wisdom, the intention is to carefully create a detailed persona, by combining a literature review with ethnographic studies involving SEN schools.

The literature review reveals an extremely complex persona, who may have co-occurring intellectual, socio-developmental and physical disabilities. Autism is a complex neurodevelopmental disorder, with different underlying causes, which include genetic and environmental factors. The mechanism by which these factors combine to produce autism in an individual is not yet fully understood. It may appear spontaneously in a family, and is typically diagnosed after the age of 2 ½ years, when a child has not reached normal developmental milestones, including having delayed speech and social interaction. Rates of autism appear to be rising, though some of this increase is attributable to improved diagnosis, and also of correct diagnosis of autism co-occurring with intellectual disability (ID), rather than a diagnosis of ID alone. Approximately 1.5% of the Irish population has a diagnosis of an autism spectrum disorder [13], with similar rates in the UK and US [1]. Males outnumber females by almost five to one. Diagnosis is made on the basis of a 'triad of deficits': difficulties with communication, difficulties with social interaction, and restricted activities and interests. In order to merit a diagnosis, the person must exhibit deficits in all three areas, but may perform better in some areas than others. These deficits lead to a lack of skills in the areas of social reciprocity, social perception and memory, joint attention (understanding that one's concept of an object or situation are shared by another), and perspective-taking (understanding other people's point of view). Between 50 and 70% of autistic people also have an intellectual disability (ID) [14]. People who are more severely autistic may be unable to verbalise, while some autistic people are 'selectively mute' (possibly to conserve cognitive effort). Non-verbal autistic people sometimes communicate their thoughts and feelings in writing. Autism is associated with learning difficulties including ADHD, and dyslexia, though people with Asperger Syndrome may have enhanced skills in non-social areas. Motor problems associated with autism can affect co-ordination, giving rise to dyspraxia and dysgraphia. Gastro-intestinal sensitivity is also prevalent. Studies suggest that almost all children with autism have sensory processing abnormalities [15]. The literature suggests that approximately 40% of children with ASDs have a co-morbid anxiety disorder of some description [16]. Anxiety levels increase from adolescence onwards [17], and can have a major effect on quality-of-life. Many people with autism, especially people described as 'high-functioning', (i.e. with normal IQ, of 70 or above) are very aware that they are 'different', and may find trying to 'fit in' extremely emotionally taxing. This is exacerbated by difficulty in communicating personal experience, particularly in relation to identifying or describing emotions, further compounded by difficulty in deciding how to act appropriately in a given situation. It is perhaps worth noting that standard IQ tests take little account of sensory-perceptual or other difference, and may ultimately prove an inherently prejudiced and unreliable measure of assessing intellectual capability. Epilepsy is estimated to affect between 11% and 30% of people with autism, and is associated with co-morbid autism and ID [18]. In short, this is a user with a range of very complex disabilities and needs. The person in with autism is, in may ways the 'Universal User', for whom the designer may need to simultaneously address needs arising from cognitive, sensory, intellectual and physical disability.

6. The Sensory-perceptual World of Autism

Although at present, diagnosis is based solely on behaviour, many of the issues associated with autism appear to originate in sensory sensitivity and perceptual fluctuation [19]. Autistic self-advocates including Donna Williams and Temple Grandin do not see their autism as a collection of symptoms, or a 'triad of impairments', but rather as the manifestation of information-processing problems and cognitive and sensory-processing issues [20]. For example, perceptual and processing difficulties may make it difficult to interpret other people's facial expressions. Videos made by people with autism give an interesting insight into their sensory-perceptual world [21], where at times nothing is as it seems, and the overall impression created is of a sensory world which is not constant or dependable; a world where the autistic person's internal 'controls' for sound, brightness and stimulus intensity are 'broken', so that the perceived intensity of any stimulus can vary without warning. A level of stimulus which is bearable one day may be intolerable on another; extraneous objects in a visual scene can contribute to distraction and confusion. Similarly, aurally 'busy' environments can be difficult to process and interpret: for example, singling out and understanding a single voice in a roomful of people can be extremely cognitively taxing, if not impossible. Sensory issues and attentional issues are closely connected: 'In order to avoid sensory information overload, autistic people acquire voluntary and involuntary strategies and compensations, such as mono-processing, when they focus their attention to one single channel, or so-called 'tunnel perception' (narrowly focused attention), when they concentrate on a detail instead of a whole' [22]. Sensory-perceptual issues are also the likely root of repetitive behaviours such as 'stimming' (self-stimulation) [23]. Stimming may either be a form of blocking sensory over-stimulus, or of sensory self-stimulus, to compensate for hypo-sensitivity. Self-reporting suggests that 'meltdowns', involving a complete loss of behavioural control, result from sensory and cognitive overload [24]. Not all sensory-perceptual differences are dysfunctional. For example, many autistic people, like most designers, are very visual thinkers: this can be an asset in the appropriate context [25]. Sensory perception is of obvious interest to the environmental designer, and provides a means by which to constructively approach design for autistic people. Interestingly, autistic people themselves describe a need for 'sensory rooms' and 'escape spaces', among other desirable architectural attributes [26].

The development of the user persona will also be informed by user data which is currently being compiled using questionnaires, open-ended interviews with SEN school staff, and visits to existing quiet/sensory rooms, to evaluate equipment already in use. Further stages in the research, prior to finalising the digital content, will include observation of use of existing quiet/sensory rooms, evaluation of use and acceptance of existing digital technologies by the research participants, and review by end-users of sample digital content. Wearable sensors will be used to gauge the effect of the proposed sensory environment on its users in real-time, and so, pilot usability testing of sensors will also form part of the preliminary research.

7. Designing an Interactive Sensory Environment for an Autistic Child

The author's current research involves the design and testing of interactive digital media for use in 'quiet rooms' for children with autism spectrum disorders. These rooms are commonly provided in Special Educational Needs (SEN) schools, usually adjacent to classrooms. The research specifically addresses an identified need to provide restorative spaces and experiences, as relief from sensory and cognitive overload, and in order to avoid 'meltdowns'. It also takes account of the known prevalence of anxiety and related mood disorders in people who are 'on the (autism) spectrum', especially from early adolescence on. The research is structured as a piece of iterative design research, so that the application will be developed incrementally, beginning with a reduced version for the purposes of the postdoctoral research, and progressively adding additional content and functionality. Final testing of the interactive digital media application will take place in SEN schools, with participants who are aged approximately 9-13 years old, with a diagnosis of an autism spectrum disorder. The persona which emerges from the literature review, and from preliminary research with end-users, suggests the following basic guidelines for the design of an interactive environmental application for autistic children, and specifically, for an application intended to promote restoration and relaxation.

- **'Device-agnostic, content specific'**
  Much assistive technology involves the development of user- or disability-specific devices. While this is sometime the best solution, it often has the drawback of greatly increased cost, and difficulties with obsolescence and repair. This mantra in this instance is that insofar as is possible, content and interaction will be specific to the user, context and intention, but *device-agnostic*, in order to maximise accessibility (in the broader sense of having access to the necessary hardware) for future users.

- **Minimisation of cognitive load: minimal interface, simplified interaction**
  Sensory-processing issues in autism imply that interaction in an environment intended to provide relief from stress and restore attention should minimise cognitive load. Here, interaction will be limited to simple and intuitive touchscreen gestures, which may be translated into gestural or eye-gaze interaction in further iterations. The content can also be used without any requirement for interaction. In this phase of the research, sensing of affect will be used only to gauge the nature of the user's experience. Future iterations hope to incorporate response to patterns of affect or to specific events. Minimisation of cognitive load is also supported by use of already-familiar technologies. This has informed a decision to utilise tablet devices and a large-scale touchscreen, for which minimal or no instruction in use is required, to deliver the content. System controls will consist of simple pictorial icons and sliders on a tablet device, with a limited number of icons per screen. Children with autism are less likely to initiate interaction on their own behalf, and can appear quite passive. Minimum effort should therefore be involved to produce a recognisable response to interaction with the system/ environment. The concept of making interaction very explicit, for example by generating a sound or some other overt sensory signal in response to action on the part of the user, is already recognised in designing sensory environments for children with autism. The design of the interface and content should also suggest or coach interaction.

- **Controllability of sensory stimulus**
  Given that autism, and in particular sensory sensitivity, can manifest itself in very different ways in individual users, the application must allow for content to be controlled during use, so that it can be tailored for each individual user, from a selection of image and sound sequences. This principle also suggests in-application control of brightness, colour saturation, and volume. This can help to compensate for perceptual fluctuation. One of the most striking queries to come out of discussions with carers and teachers was the recurring request to be enabled to 'turn off' sound at will, though music and sound are of known therapeutic benefit. The sensory sensitivity of an individual can vary to the extent that, on some days, the inclusion of a soundtrack is simply too much, and can tip an individual into sensory overload.

- **Extreme personalisation**
  Controllability of sensory stimulus also serves a need for personalisation. The importance of tailoring the sensory content to the individual user suggests automatic storage of individual preferences to allow for a quick-start in subsequent sessions, and in future iterations, the facility to upload personal media, for complete personalisation of in-app audio-visual media.

- **Reduction/elimination of errors**
  Use of familiar hardware and simple gestures to access and manage content reduces the possibility of user error, which might contribute to anxiety. This is critically important for the child who is autistic, most especially in a design context where the intended outcome is relaxation. This principle is equally important for users with dementia, extrapolating from Corcoran & Gitlin [27].

8. Conclusion

Affective response in architecture can extend its existing capacity as a setting for human action within the built environment, by facilitating more intuitive and inclusive user interaction. The exact nature of responsive environments will vary, as does interaction design, depending on context, user and function/activity, in the manner in which architectural design outcomes have always varied. At its best it will more comprehensively address ease-of-use, improving both functional and psychosocial fit, and by the same means, also satisfy sensory and aesthetic considerations in a manner particular to context, user, and use. An adaptive sensory environment also permits the possibility of offering solutions to problems which arise over the course of time, through changes in a user's ability to interpret or interact. Mapping interaction design techniques from other domains onto interaction in a spatial context identifies means to improve usability, and to optimise user experience. The development of a user persona is a particularly useful exercise in deriving a set of basic design principles for an interactive environment for a user with autism. These recommendations transpire to align well with established principles of Universal Design.

References

[1] M. Elsabbag, G. Divan, Y. J. Koh et al. Global prevalence of autism and other pervasive developmental disorders. *Autism Res*. **5(3)** (1995):160–79.
[2] O. Bogdashina, *Sensory-perceptual Issues in Autism and Asperger Syndrome: Different sensory perceptions-different perceptual worlds*, Jessica Kingsley, London, 2003.
[3] A. Dilani, Psychosocially Supportive Design: A salutogenic approach to the design of the physical environment, *1st International Conference on Sustainable Healthy Buildings.* Seoul, Korea, 2009.
[4] S. Boyden, 'Biological Determinants of optimal health', in Vortster, D J M, (Ed) *'The human biology of environmental change'*, (conference proceedings), Blantyre, Malawi, 1971.
[5] W. Gropius. *Scope of Total Architecture.* Collier Books. New York, 1962.
[6] R. Neutra *Survival Through Design,* Oxford University Press, New York, 1954.
[7] J. Nielsen, Usability -101-Introduction to Usability, [online resource], 2012. Found at
[8] https://www.nngroup.com/articles/usability-101-introduction-to-usability/
[9] M. McCullough, *Digital Ground: Architecture, Pervasive Computing and Environmental Knowing.* Cambridge, Ma: MIT Press, 2004.
[10] R. Barris et al, Occupation as interaction with the environment. In: G. Kielhofner, ed. *A Model of Human Occupation: Theory and Application,* Williams and Wilkins, Baltimore, US, 1985.
[11] R. Picard, *Affective Computing*, MIT Press, Cambridge, Ma, 1997.
[12] C. Dalton, Including Smart Architecture in Environments for People with Dementia, *Springer Handbook of Smart Homes, Healthcare and Well-being*, Springer, Switzerland, 2014.
[13] M. Weiser, J. Seely Brown, *The Coming Age of Calm Technology*, Xerox PARC, US, 1996.[Epub] Found at https://www.cs.ucsb.edu/~ebelding/courses/284/papers/calm.pd
[14] A. M. Boilson, A. Staines, A. Ramirez, M. Posada, M. R. Sweeney, Operationalisation of the European Protocol for Autism Prevalence (EPAP) for Autism Spectrum Disorder prevalence Measurement in Ireland. 2016. *J Autism Dev Disord* 2016 Jun 30. [Epub ahead of print]
[15] J. L. Matson, M. Shoemaker, Intellectual disability and its relationship to autism spectrum disorders. *Res Dev Disabil*. **30(6)** (2009), 1107-14.
[16] S. D. Tomchek, W. Dunn, Sensory processing in children with and without autism: A comparative study using the Short Sensory Profile, *American Journal of Occupational Therapy*, **61**, (2009) 190–200.
[17] F.J. A. van Steensel, S. M. Bögels, S. Perrin, Anxiety Disorders in Children and Adolescents with Autistic Spectrum Disorders: A Meta-Analysis, *Clin Child Fam Psychol Rev*. **14(3)** (2011), 302–317.
[18] S. W. White, D. Oswald, T. Ollendick, L. Scahill, Anxiety in Children and Adults with Autism Spectrum Disorders. *Clin Psychol Rev*. **29(3)** (2009): 216–229.
[19] P. Bolton et al., Epilepsy in autism: features and correlates The British Journal of Psychiatry, **198(4)** (2011) 289-294.
[20] O. Bogdashina, *Sensory-perceptual Issues in Autism and Asperger Syndrome: Different sensory perceptions-different perceptual worlds*, Jessica Kingsley, London, UK, 2003.
[21] O. Bogdashina, Sensory Perceptual Issues in Autism: Why we should listen to those who experience them, *Annales Universitatis Paedagogicae Cracoviensis: Studia Psychologica,* **IV** (2011) 145-160.
[22] 5 Autism Simulations to Help You Experience Sensory Overload [online resource] Found at http://mashable.com/2014/04/23/autism-simulations/#Ne_q6S0yDuqR
[23] A. V. Joosten, A. C. Bundy, Sensory processing and stereotypical and repetitive behaviour in children with autism and intellectual disability, *Australian Occupational Therapy Journal,* **57** (6), (2010) 366–372.
[24] O. Bogdashina, *Sensory-perceptual Issues in Autism and Asperger Syndrome: Different sensory perceptions-different perceptual worlds*, Jessica Kingsley, London, UK, 2003.
[25] D. Lipsky, *From Anxiety to Meltdown: How Individuals on the Autism Spectrum Deal with Anxiety, Experience Meltdowns, Manifest Tantrums, and How You Can Intervene Effectively.* Jessica Kingsley, London, UK, 2011.
[26] T. Grandin, How does visual thinking work in the mind of a person with autism? A personal account *Philos Trans R Soc Lond B Biol Sci* **364:**1522 (2009), 1437–1442.
[27] M. Kinnaer, S. Baumers, A. Heylighen, Autism-friendly architecture from the outside in and the inside out: An explorative study based on autobiographies of autistic people. *Journal of Housing and the Built Environment* **31:**2 (2016) 179-195.
[28] M. Corcoran, L. N. Gitlin, Environmental Influences on Behavior of the Elderly with Dementia: Principles for Intervention in the Home. *Physical and Occupational Therapy in Geriatrics,* **9**(3-4), pp. 5-2, 1991.