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Research paper

Evaluation of the main sensitivity drivers in relation to indoor comfort for individuals with autism spectrum disorder. Part 2: Influence of age, co-morbidities, gender and type of respondent on the stress caused by specific environmental stimuli

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ABSTRACT

Variations of environmental parameters, like thermo-hygrometric, acoustic, visual and indoor air quality can influence the sensitivities of individuals on the spectrum. This paper presents research on this issue, studied by means of questionnaires administered to parents and professional caregivers taking care of people with Autism Spectrum Disorder (ASD).

The study highlights that there are clear differences if the indirect evaluations are performed by parents or professional caregivers, in relation to the specific identification of stress sources. Additionally, acoustic domain is identified as the one causing the major stress, especially caused by strong noises and particular sounds such as voices, animal sounds and impacts, and its dependence on the severity of autism is evidenced. Furthermore, a lower impact of thermal, visual and IAQ factors is determined, with the exception of some specific stimuli like light contrast (glare), high illumination, particular light sources or stale air. Finally, this paper provides evidence of the influence of age, severity of autism and co-morbidities on perceived stress.

1. Introduction and background

Field studies are needed to assess the indoor well-being of people with special needs, since the comfort standards may not be applicable (Wang et al., 2018; Cena and De Dear, 2001; Chappells and Shove, 2004; Del Ferraro et al., 2015; Kumar and Mahdavi, 2001; Zaniboni et al., 2020; Heylighen et al., 2008; Devos et al., 2018). When dealing with people with an altered perception of the environment, the challenges can even be greater, since as a consequence increased reactions or behavioral problems might occur (Devos et al., 2018; van Hoof et al., 2010). Specifically, the five basic senses of people on the spectrum can be altered by hypo- and hyper-sensitivity (Mostafa, 2014; Wali and Sanfilippo, 2019; Belek, 2019; Schofield et al., 2020; Gaines et al., 2016; Jones et al., 2020; Dival, 2019; Shell, 2019; Minshawi et al., 2014), causing dangerous environmental conditions and behaviors, including violent reactions.

In the literature, studies on the lighting preferences of individuals with autism are available (Mostafa, 2020; Kaul, 2018), highlighting that diffuse daylight is preferred. In some qualitative and experimental studies on the acoustic perception, consistency in the results (Talay-Ongan and Wood, 2000; Bishop et al., 2013; Law et al., 2015; Danesh et al., 2015; Gomes et al., 2004; Jones et al., 2009; Boer et al., 2013; Lawson et al., 2015; Remington and Fairnie, 2017; Kuiper et al., 2019; Park et al., 2017) has been found about the participants' recognition of a higher acoustic sensitivity, but no details or thresholds appear to have been tested nor provided. Furthermore, these studies present a limited number of case studies, which means that a clear determination of their sensitivity is not individuated yet, nor those results can be generalized. Thus, they cannot be used to scientifically determine that this is a general condition and a much wider sample is needed.

In general, the following disturbances were reported to be recurrent: hyper- or hypo-acuity, hyperacusis and tinnitus, differences in auditory discrimination, general auditory impairments, sensitivity and annoyance to noises such as planes, trains, alarms or television. In addition, indoor air quality has been studied in relation to the sensitivity of autistic people's olfactory sense (Galle et al., 2013; Ashwin et al., 2014; Fadda et al., 2018), while, at present, the study of thermal pain has been the main driver of the studies of thermal stimuli (Vaughan et al., 2020; Williams et al., 2019). Studies and recommendations regarding the design of environments for people on the spectrum are available, especially related to schools and facilities built to support children;

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they highlight the importance of sensory aspects, generally recommending that echo, loud and background noises should be avoided, as should disturbing lighting phenomena such as glare and flickering (Mostafa, 2014; Gaines et al., 2016; Shell, 2019; Mostafa, 2020; Kanakri et al., 2017; Martin, 2016). An exploratory investigation on the perception of Indoor Environmental Quality (IEQ) by people with ASD was carried out by Noble et al. (2018), who performed a comparison between online anonymous surveys among adults on the spectrum and a control group. Discomfort scales (from 1 to 7) were used to rate home and work environments, while an "avoidance scale" (from 1 to 7) was used to rate the different factors in generic built-in environments. The study concludes that there is a clear need for further research to understand the reason why some factors have a larger impact on people with autism, as well as the implications of these findings.

Furthermore, it is acknowledged that various levels of severity characterize autism, as well as possible intellectual disabilities or comorbidities (Christensen et al., 2018; Rimland and Edelson, 1995), ranging from Level A (low severity) to Level C (high severity), with increasing severity, presence of co-morbidities and amount of support required. Specifically, non-autonomous individuals feature B and C levels (American Psychiatric Association, 2013). Detailed investigations about the environmental stimuli that affect B and C autistic people's perception can lead to more comfortable and less stressful environments, which can even reduce the symptoms and decrease the need for assistance (Taylor et al., 2014; Kargas et al., 2015; Wolbring and Leopatra, 2013; Burleson et al., 2012; Chuah and Diblasio, 2012; Cook et al., 2003; Schafer et al., 2016a,b).

In all the presented cases, a clear link with the autism severity, age and co-morbidities have not been determined, specifically related to level B and C. Furthermore, to the authors' knowledge, at present the available research is mainly approached from medical, neurological and design points of view, not focusing on how different environmental stimuli could affect the perception of people on the spectrum, from an indoor well-being perspective.

For the above-mentioned reasons, there is a clear need to investigate how people with autism approach the built environments as users, from an indoor environmental well-being point of view focusing on the influence of co-morbidities, age and severity of autism. This work presents the second part of our research. The first part (Caniato et al., 2022) deals with autistic individuals who are not able to live alone and have a normal life, using questionnaires administered to proxy respondents (parents and professional caregivers, referred to as "caregivers" from now on). In that work, the approach was applied to investigate how differently people with ASD perceive the four comfort domains (thermo-hygrometric, acoustic, visual and Indoor Air Quality — IAQ). The present paper further explores that analysis, focusing on the specific detailed environmental stimuli, using the questionnaires to understand the perception to the indoor environment and related stress. Quantitative methods and statistical tests are conducted in order to analyze the results in depth, with the following aims:

1. Identifying the differences (if any) between the parents and caregivers' answers and perspectives;
2. Detecting the environmental stimuli that mainly affect individuals with autism;
3. Checking the impact of gender, severity of autism, presence of co-morbidities and age on the sensitivity to the different environmental stimuli.

It has here to be clearly specified that autism is identified as a neurodiversity (Fenton and Krahn, 2007). According to the Declaration of Helsinki (World Medical Association, 1991), in situ tests should be avoided with fragile people (Schüklenk, 2000). As such, no direct assessment should be performed involving autistic individuals (at least featuring level B – medium severity or C- high severity), as this could be unethical. Then, an indirect approach should be used as more suitable for the evaluation of indoor stress perception caused by environmental stimuli (Wang et al., 2017; Fergus Nicol, 2011; Huang et al., 2013).

The study provides a first contribution to the study of global sensitivity assessment among individuals with autism. Indeed, standards do not include sections dedicated to autistic people and no specific guidelines for their indoor comfort have been found within. Since people on the spectrum have a very specific and particular sensitivity to sensorial stimuli, it is necessary to identify which of all the possible stimuli from the environment affect them differently than standard users. It is essential to consider these results when designing living and healthcare environments for people on the spectrum, in terms of architecture and HVAC plants.

2. Materials and methods

2.1. Questionnaires

Anonymous Italian, English and German questionnaires were developed with the help of psychologists and experts in contact with people with autism, as well as parents and caregivers. Due to the limited autonomy of many of the individuals involved, the questionnaires were developed focusing on: 1. professional caregivers in extended-care units and parents in households as anwerers, during two surveys (online survey and local survey, see Caniato et al., 2022); 2. sensitivity to the environmental stimuli, according to the following levels:

- Absent (0), with no abnormal stress levels
- Minor (1), with limited and/or non-systematic intensity/frequency of higher stress levels
- Average (2), with average intensity/frequency systematic growth of the stress level
- Extreme (3), with high intensity/frequency systematic growth of the stress level
- Sporadic (S), to be used together with the levels above (1–3), when, due to few observations or low repeatability and predictability, the higher sensitivity cases were observed in a sporadic or non-systematic way
- Hypo-sensitive (H), with no reaction despite the presence of an obvious stimulus.

Further details on the questionnaires development and administration are reported in Part 1 of our work (Caniato et al., 2022). The flow chart describing questionnaire fill in procedure is reported in Fig. 1. The whole questionnaire is available as Supplementary File.

2.2. Data processing

In order to identify possible biases and the different perspectives of the type of respondent, a statistical test was performed to identify possible differences in the answers provided by parents and caregivers. The analysis was performed on the following two samples:

1. *Control sample*, consisted of those individuals evaluated twice during the local survey, both by parents and caregivers respectively;

2. *Overall sample*, comprising all the questionnaires from both surveys.

An additional analysis was developed on the overall sample, by means of descriptive statistics, separately for parents and

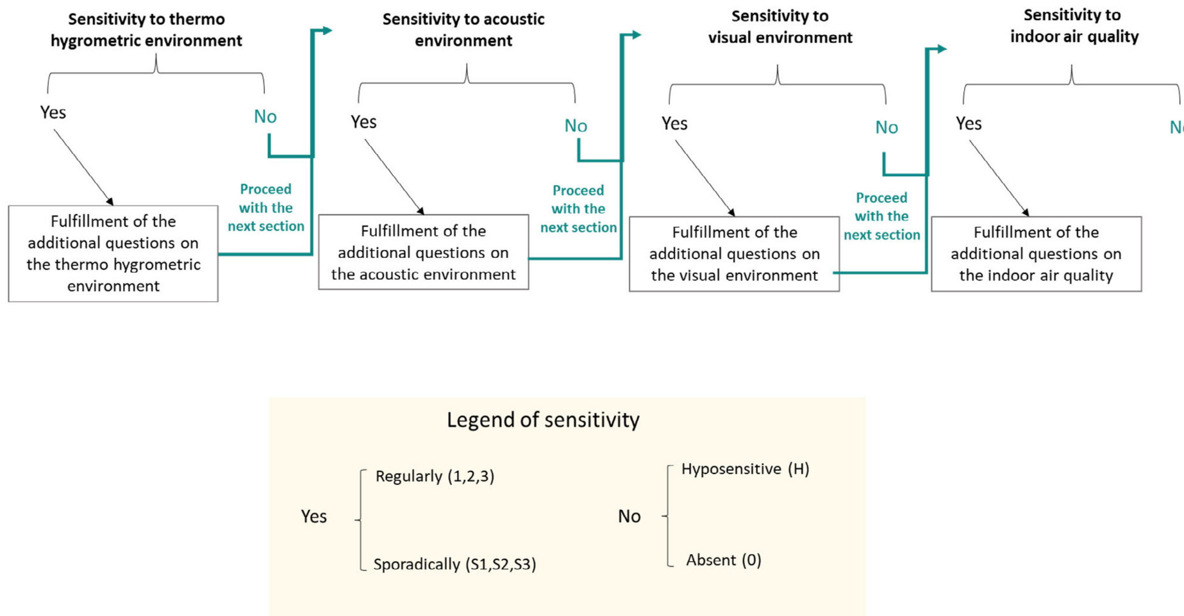

Fig. 1. Guide to filling in the questionnaire.

Fig. 2. Pictures of the extended care facility where the local survey was conducted.

caregivers, comparing the percentages for each level of sensitivity in each answer. This investigation made it possible to both identify the stimuli which affected mainly autistic people and to further emphasize the possible different evaluations by parents and caregivers.

ANOVA test and Tukey HSD test (Hinkin and Tracey, 1999) were used to check the data distribution of severity of autism and age, comparing parents and caregivers (overall sample). Mann–Whitney tests (Caniato et al., 2022; Zaniboni et al., 2020; Statistics Solutions, 2020; Lane et al., 2017) were performed focusing on the *overall sample* comparing:

1. females and males;
2. different severities of autism, distinguishing between low severity (Level A) and higher severities (Level B and Level C);
3. presence or absence of co-morbidities (accordingly to DSM-V classification);
4. different age groups, divided as reported in Table 4 of Caniato et al. (2022).

Moreover, respondents who evaluated "0" (hypo-sensitive) to the general question on the sensitivity for a domain (A1, B1, C1 or D1) were not required to answer the specific questions on that domain (Section 2.1). For this reason, their answers were added as "0" also to all the specific stimuli regarding that domain. In all cases, when tests were statistically significant, the mean differences between the evaluated samples were indicated in order to evaluate which sample gave the higher sensitivities.

2.3. Research ethics and proxy respondents

The procedure was implemented in order to comply with the Declaration of Helsinki (World Medical Association, 1991). The first page of the questionnaire clearly included the aim and scope of the research and the informed consent for the study. Start, fill in and conclude any of the survey was not mandatory, so all the participants were volunteers. The presented research is part of wider study, approved by Ethics Committee of the Free University of Bozen-Bolzano. Furthermore, to include all the autism severities, the survey considered the proxy respondents. The use of proxy respondents is a common practice especially in health and disability surveys, as this makes it possible to collect information about persons who may be unable to directly participate (Iezzoni et al., 2000; Loeb et al., 2018; Neumann et al., 2000). For this specific case, the invitation to fill in was specifically addressed to parents and caregivers who are regularly in touch with individuals with ASD.

3. Results and discussions

3.1. Population

As reported in Caniato et al. (2022), caregivers constitute the highest share of respondents in both online and local surveys. In the online survey, the age of respondents was higher, as well as

Table 1
ANOVA test between the two types of proxy respondents (parents and caregivers), analyzing the distribution of the autism severity of individuals with ASD.

ANOVA Parents (1); Caregivers (2)					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.401	2	0.2	0.815	0.445
Within Groups	33.222	135	0.246		
Total	33.623	137			

Table 2
ANOVA test between the two types of proxy respondents (parents and caregivers), analyzing the age distribution of individuals with ASD.

ANOVA Parents (1); Caregivers (2)					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.983	5	0.397	1.654	0.15
Within Groups	31.64	132	0.24		
Total	33.623	137			

the general severity of autism and the number of co-morbidities detected (see Section 3.1 of Caniato et al. (2022)).

In order to find out whether there was homogeneity in terms of autism severity and age between the answers provided by parents and caregivers, an ANOVA test combined with Tukey HSD test was performed. Results of Tables 1 and 2 show absence of statistical differences between the two groups of parents and caregivers in the overall sample (local + online surveys), when considering age and severity of autism. The homogeneity of data between the two proxy respondents' groups in the overall sample demostrates the statistical reliability of comparisons between caregivers and parents. Tukey HSD test was not performed due to the absence of statistical significance.

3.2. Influence of the type of respondent

Table 3 shows the statistical tests results related to the comparisons of answers given by parents and caregivers in the *overall sample* and in the *control sample*. From these analyses the following findings can be highlighted:

1. In the *overall sample*, parents and caregivers expressed similar sensitivities on the comfort domains as a whole, as regards questions A1 and B1 . Differences were found in the questions regarding the specific stimuli, in the cases of: low humidity (question A2b, p-value < 0.1), heat/cold at the extremities (A4, p-value < 0.01), rumbling sounds and particular noises (B2b and B3, p-values < 0.1), general visual environment (C1, p-value < 0.1), high illumination (C1a, p-value < 0.05), low lighting levels (C1b, p-value < 0.1), high contrast and glare (C2, p-value < 0.01) and general *IAQ* (D1, p-value < 0.05). When tests are significant, the mean difference always highlights a higher stress indicated by parents.
2. In order to verify if the significancies were due to the different individuals considered, the *control sample* was analyzed. In this group, no further significancies were detected, while among the ones detected in the overall sample, only those linked to specific rumbling sounds and particular noises stimuli (B2b and B3), visual environment (C1) and in high levels of illumination (C1a) were confirmed.

In general, these differences could be due to two main reasons: (a) different environments and time (moment of the day and duration) of observation they are referring to; (b) different background and sensitivity of parents and caregivers. In this framework, stimuli reporting different sensitivities only within the *overall sample* and not within the *control sample*, might be more dependent on the individual considered than on the respondent's perspective.

3.3. Thermo-hygrometric environment — descriptive statistics

Both parents and caregivers (Table 4) indicated that a low percentage (6%–7%) of individuals are hypo-sensitive to the thermo-hygrometric environment (question A1), while around 50% are sensitive (from "1-minorly" to "3-extremely" sensitive). Considering both hypo and hyper-sensitive individuals, most of them are minorly sensitive (32% and 30% by parents and caregivers respectively).

When hyper-sensitivity was reported, the causes were well distributed among the possible stimuli (A1a-A4), with levels consistent with the general response. The main differences between the two groups of respondents regarded higher sensitivities ("2-averagely" and "3-extremely") for heat exposure (A1a), excessive humidity (A2a) and heat/cold at the extremities (A4). However, only for questions A2a and A4 the higher percentages expressed by parents for higher sensitivity levels were found to be statistically significant (Section 3.2).

Since mainly no or minor sensitivities were found, the results are partially in agreement with what was reported by Shell (2019) and Noble et al. (2018), that highlighted how, at present, thermal conditions in people with ASD are not a probable cause of stress.

3.4. Acoustic environment — descriptive statistics

From Table 5, we can highlight that the acoustic domain has a very strong impact on autistic individuals (question B1), with a high percentage of parents and caregivers indicating "2-averagely" sensitive (39% by parents and 36% by caregivers) and "3-extremely" (24% by parents and 19% by caregivers). This demonstrates that sounds can strongly disturb the quietness and cause discomfort for people on the spectrum. On the other hand, negligible percentages of hypo-sensitive individuals were also present in this case.

The most disturbing elements indicated by the participants were high noise levels from indoors (question B1a) or outdoors (question B2a), rumbling sounds (question B2b) and particular sounds such as voices, impacts, animals sounds and calls (question B3). In general, parents and caregivers mainly disagreed on sensitivities for high noises from outside (B2a), rumbling sounds (B2b) and particular noises (B3), for which parents indicated a higher percentage of "3-extremely" sensitivities. The difference was statistically significant only in questions B2b and B3 (see Section 3.2).

Recommendations in the literature say to avoid loud noises as well as echo and background noises in building designs for autistic people (Mostafa, 2014; Gaines et al., 2016; Shell, 2019; Mostafa, 2020; Park et al., 2017; Kanakri et al., 2017; Martin, 2016; Noble et al., 2018). However, these are usually based on single case studies or very small samples. By means of the presented analysis it is possible to generalize these findings and report also specific noise sources to be avoided.

Table 3
Results of the Mann–Whitney test comparison on the answers of parents and caregivers, considering the overall sample and the control sample. (N_p: Number of parents; N_c: Number of caregivers). P-values results presented in columns refer to the comparison between parents and caregivers' answers in relation to the overall sample and control group. In the cases where a statistically significant difference was found, the mean difference between the samples is reported.

	Question	P-value	
		Overall sample	Control sample
	Number of answers (N_P = number of questionnaires filled in by parents; N_C = number of questionnaires filled in by caregivers)	$N_P = 58$; $N_C = 80$	$N_P = 19$; $N_C = 19$
THERMO-HYGROMETRIC	(A1) Thermo-hygrometric environment	0.479	0.405
	(A1a) Heat exposure	0.597	0.233
	(A1b) Cold exposure	0.686	0.840
	(A2a) Excessive humidity	0.159	0.418
	(A2b) Low humidity (dryness)	**0.088*** $\boldsymbol{\mu_P - \mu_C = 0.140}$	0.271
	(A3) Drafts and air movement	0.733	0.708
	(A4) Heat/cold at extremities	**0.007***** $\boldsymbol{\mu_P - \mu_C = 0.350}$	0.116
ACOUSTIC	(B1) Acoustic environment	0.241	0.435
	(B1a) High noise levels in the environment where she/he is	0.131	0.146
	(B1b) Low noise levels in the environment where she/he is	0.603	0.130
	(B2a) High noise levels coming from outside	0.201	0.402
	(B2b) Rumbling sounds	**0.069*** $\boldsymbol{\mu_P - \mu_C = 0.353}$	**0.015**** $\boldsymbol{\mu_P - \mu_C = 0.895}$
	(B3) Particular noises (voices, impacts, animal calls, etc.)	**0.072*** $\boldsymbol{\mu_P - \mu_C = 0.325}$	**0.096*** $\boldsymbol{\mu_P - \mu_C = 0.632}$
VISUAL	(C1) Visual environment	**0.072*** $\boldsymbol{\mu_P - \mu_C = 0.096}$	**0.098*** $\boldsymbol{\mu_P - \mu_C = 0.263}$
	(C1a) High levels of illumination	**0.027**** $\boldsymbol{\mu_P - \mu_C = 0.302}$	**0.046**** $\boldsymbol{\mu_P - \mu_C = 0.579}$
	(C1b) Low lighting levels	**0.052*** $\boldsymbol{\mu_P - \mu_C = 0.217}$	0.385
	(C2) High levels of light contrast (glare)	**0.009***** $\boldsymbol{\mu_P - \mu_C = 0.340}$	0.488
	(C3a) Prevalence of artificial lighting	0.647	0.817
	(C3b) Prevalence of natural lighting	0.825	0.109
	(C4) High levels of color contrast or particular colors	0.831	0.271
	(C5) Light color tones (warm light/cold light)	0.204	1.000
	(C6) Particular light sources (fluorescent lamps, incandescence, etc.) or particular phenomena (flash, flicker, etc.)	0.901	0.159
IAQ	(D1) Indoor Air Quality	**0.048**** $\boldsymbol{\mu_P - \mu_C = 0.222}$	0.203
	(D2) Stale air conditions (due to the presence of people)	0.117	0.339
	(D3) Particular odors (animals, food, chemicals, etc.)	0.121	0.644

* = test significant at 10% significance level; ** = test significant at 5% significance level; *** = test significant at 1% significance level;
$\boldsymbol{\mu_P}$ = average value reported in the parents' sample; $\boldsymbol{\mu_C}$ = average value reported in the caregivers' sample.

3.5. Visual environment — descriptive statistics

From Table 6, it can be noticed that visual stimuli did not result so impactful for people with autism, according to both parents and caregivers (question C1). Nevertheless, the two groups of respondents showed a substantial difference, as more individuals were evaluated as being "0-not sensitive" (63%) by caregivers, while parents indicated a higher number of people being "1-minorly" sensitive (39%) or "hypo-sensitive" (10%). This difference in evaluation was also found to be statistically significant (see Section 3.2).

The two types of respondents also showed slight disagreement between the specific stimuli creating hyper-sensitivity, since more "2-averagely" sensitive individuals were indicated by caregivers regarding the high level of illumination (C1a), the prevalence of artificial lighting (C3a) and particular light sources (C6). On the other hand, parents indicated a slightly higher number of autistic people being sensitive to high levels of light contrast (glare) (C2). Nevertheless, statistical analyses in Section 3.2 revealed that significant differences were found only in questions C1a, C1b and C2, with parents indicating a higher average sensitivity.

These results partially agree with the literature, which recommends avoiding fluorescent lamps, glare and particular light phenomena such as flickering, on the other hand ensuring daylight (Mostafa, 2014; Gaines et al., 2016; Shell, 2019; Mostafa, 2020; Martin, 2016; Noble et al., 2018). Thus, in this case we can state that the visual environment cannot be considered a cause of major stress as such, but it depends on the indoor environment. This can be explained by the fact that parents evaluated individuals with ASD at homes, while caregivers gave their opinion based on what they see in autistic dedicated facilities, mostly designed to minimize stress.

3.6. IAQ environment — descriptive statistics

As the results indicate (Table 7), a low percentage of hypo-sensitivity was found also for IAQ. Additionally, the IAQ was not found to be very stressful on people with ASD, since 46% of the parents and 66% of the caregivers evaluated it as causing no reactions ("0-not sensitive"). Substantial differences were found between the two types of respondents, as this domain was evaluated as more impactful by parents (confirming what was detected with the statistical test in Section 3.2).

Compared to caregivers, parents also indicated a slightly higher percentage of individuals being "2-averagely" sensitive to stale air conditions (D2) and particular odors (D3). However, this difference was not found to be statistically significant (Section 3.2).

These results are partially in accordance with Noble et al. (2018), who report smells and air quality as causing more discomfort among autistic people than in a control group.

Table 4
Perception of the indoor thermo-hygrometric environment detected by parents and caregivers (overall sample). The table differentiates between systematic and sporadic answers; the latter are indicated with the notation "(S)". Note that respondents who indicated a level different than "H" or "0" in question A1, needed to indicate which specific stimuli gave hypo- hyper- or no sensitivity (questions A1a–A4).

	Parents					Caregivers				
	H	0	1	2	3	H	0	1	2	3
A1) Thermo-hygrometric environment	7%	39%	29% + 3 % (S)	15% + 2 % (S)	5% + 0 % (S)	6%	47%	25% + 5 % (S)	9% + 4 % (S)	4% + 0 % (S)
	7% of parents declared a **Hyposensitivity** and **39%** declared that the ASC individual was **not sensitive** to thermo-hygrometric environment. For these persons, the other questions of Section A were not required be filled in.					**6%** of caregivers declared a **Hyposensitivity** and **47%** declared that the ASC individual was **not sensitive** to thermo-hygrometric environment. For these persons, the other questions of Section A were not required to be filled in.				
	H	0	1	2	3	H	0	1	2	3
A1a) Heat exposure	2%	10%	15% + 3 % (S)	12% + 2 % (S)	10% + 0 % (S)	3%	9%	15% + 0 % (S)	9% + 5 % (S)	5% + 1 % (S)
A1b) Cold exposure	2%	22%	15% + 5 % (S)	7% + 0 % (S)	2% + 2 % (S)	4%	11%	18% + 4 % (S)	5% + 1 % (S)	4% + 0 % (S)
A2a) Excessive humidity	3%	22%	15% + 2% (S)	8% + 2 % (S)	2% + 0 % (S)	1%	28%	13% + 1 % (S)	3% + 0 % (S)	1% + 0 % (S)
A2b) Low humidity (dryness)	3%	24%	19% + 2% (S)	0% + 3 % (S)	3% + 0 % (S)	1%	32%	9% + 4 % (S)	1% + 0 % (S)	0% + 0 % (S)
A3) Drafts and air movement	3%	22%	17% + 2 % (S)	5% + 2 % (S)	3% + 0 % (S)	0%	20%	16% + 4 % (S)	4% + 1 % (S)	1% + 0 % (S)
A4) Heat/cold at extremities	3%	12%	15% + 5 % (S)	8% + 0 % (S)	8% + 2 % (S)	1%	28%	10% + 0 % (S)	6% + 1 % (S)	0% + 0 % (S)

□ = 0 – 9 %; ■ = 10 – 19 %; ■ = 20 - 29 %; ■ = 30 - 49 %; ■ = 50 – 100 % ;
H= hyposensitive; 0=absent; 1=minorly sensitive; 2=averagely sensitive; 3=extremely sensitive; S= sporadically sensitive

Table 5
Perception of the acoustic environment detected by parents and caregivers (overall sample). The table differentiates between systematic and sporadic answers; the latter are indicated with the notation "(S)". Note that respondents who indicated a level different than "H" or "0" in question B1, needed to indicate which specific stimuli gave hypo- hyper- or no sensitivity (questions B1a–B3).

	Parents					Caregivers				
	H	0	1	2	3	H	0	1	2	3
B1) Acoustic environment	2%	7%	22% + 7 % (S)	34% + 5 % (S)	19% + 5 % (S)	1%	22%	20% + 1 % (S)	30% + 6 % (S)	18% + 1 % (S)
	2% of parents declared **Hyposensitivity** and **7%** declared that the ASC individual was **not sensitive** to acoustic environment. For these, the fulfillment of the other questions of Section B was not required.					**1%** of caregivers declared a **Hyposensitivity** and **22%** declared that the ASC individual was **not sensitive** to acoustic environment. For these, the fulfillment of the other questions of Section B was not required.				
	H	0	1	2	3	H	0	1	2	3
B1a) High noise levels in the environment where she/he is	0%	3%	19% + 5 % (S)	41% + 4 % (S)	17% + 5 % (S)	0%	4%	19% + 1 % (S)	30% + 6 % (S)	15% + 1 % (S)
B1b) Low noise levels in the environment where she/he is	5%	53%	19% + 3 % (S)	7% + 0 % (S)	3% + 2 % (S)	0%	49%	14% + 1 % (S)	5% + 3 % (S)	4% + 0 % (S)
B2a) High noise levels coming from outside	0%	14%	32% + 3 % (S)	19% + 3 % (S)	15% + 5 % (S)	0%	14%	22% + 1 % (S)	28% + 4 % (S)	9% + 0 % (S)
B2b) Rumbling sounds	0%	22%	22% + 7 % (S)	15% + 0 % (S)	22% + 3 % (S)	0%	20%	27% + 1 % (S)	18% + 3 % (S)	9% + 0 % (S)
B3) Particular noises (voices, impacts, animal calls, etc.)	2%	12%	22% + 7 % (S)	20% + 3 % (S)	24% + 2 % (S)	1%	16%	14% + 0 % (S)	29% + 6 % (S)	9% + 1 % (S)

□ = 0 – 9 %; ■ = 10 – 19 %; ■ = 20 - 29 %; ■ = 30 - 49 %; ■ = 50 – 100 %
H= hyposensitive; 0=absent; 1=minorly sensitive; 2=averagely sensitive; 3=extremely sensitive; S= sporadically sensitive

3.7. Dependence of sensitivity on gender, severity of autism, presence of co-morbidities and age

Table 8 shows the outcomes of the Mann Whitney test evaluating the statistical differences between: 1. Gender (second column); 2. Autism severity: A Low severity and higher levels (levels B and C) (third column); 3. Absence or presence of co-morbidities (fourth column). The following observations can be made:

1. Gender influenced the sensitivities to cold exposure (question A1b) to heat/cold at the extremities (question A4), low noise levels (B1b), natural lighting (C3b), particular colors or color contrasts (C4) and stale air (D2). Except for sensitivity to natural light, females were reported to have a higher sensitivity in all the other statistically significant cases.
2. The severity of autism clearly influenced acoustic perception (B1) and all the specific stimuli regarding this environmental comfort domain (B1a, B1b, B2a and B3), with the exception of rumbling sounds (B2b). Moreover, it influenced the sensitivity to low lighting levels (C1b). The mean difference analysis shows that an increase in the severity of autism means a higher sensitivity to these stimuli.

Table 6
Perception of the indoor visual environment detected by parents and caregivers (overall sample). The table differentiates between systematic and sporadic answers; the latter are indicated with the notation "(S)". Note that respondents who indicated a level different than "H" or "0" in question C1, needed to indicate which specific stimuli gave hypo- hyper- or no sensitivity (questions C1a–C6).

	Parents					Caregivers				
	H	0	1	2	3	H	0	1	2	3
C1) Visual environment	10%	34%	32% + 7 % (S)	8% + 3 % (S)	5% + 0 % (S)	0%	63%	13% + 3 % (S)	13% + 3 % (S)	5% + 1 % (S)
	10% of parents declared **Hyposensitivity** and **34%** declared that the ASC individual was **not sensitive** to visual environment. For these, the fulfillment of the other questions of Section C was not required					**0%** of parents declared **Hyposensitivity** and **63%** declared that the ASC individual was **not sensitive** to visual environment. For these, the fulfillment of the other questions of Section C was not required				
	H	0	1	2	3	H	0	1	2	3
C1a) High levels of illumination	0%	12%	22% + 2 % (S)	10% + 2 % (S)	3% + 5 % (S)	0%	5%	9% + 0 % (S)	18% + 1 % (S)	0% + 4 % (S)
C1b) Low lighting levels	2%	29%	12% + 3 % (S)	2% + 2 % (S)	5% + 2 % (S)	1%	14%	10% + 3 % (S)	6% + 1 % (S)	1% + 0 % (S)
C2) High levels of light contrast (glare)	0%	14%	17% + 2 % (S)	15% + 3 % (S)	3% + 2 % (S)	1%	6%	9% + 3 % (S)	9% + 1 % (S)	6% + 1 % (S)
C3a) Prevalence of artificial lighting	2%	29%	12% + 2 (S)	5% + 3 % (S)	3% + 0 % (S)	1%	9%	8% + 3 % (S)	11% + 1 % (S)	4% + 0 % (S)
C3b) Prevalence of natural lighting	2%	29%	14% + 3 % (S)	7% + 2 % (S)	0% + 0 % (S)	0%	15%	8% + 1 % (S)	6% + 3 % (S)	4% + 0 % (S)
C4) High levels of color contrast or particular colors	0%	36%	8% + 3 % (S)	2% + 3 % (S)	3% + 0 % (S)	0%	18%	4% + 0 % (S)	8% + 4 % (S)	3% + 1 % (S)
C5) Light color tones (warm light/cold light)	0%	42%	5% + 2 % (S)	3% + 0 % (S)	2% + 2 % (S)	1%	15%	5% + 5 % (S)	9% + 1 % (S)	0% + 0 % (S)
C6) Particular light sources (fluorescent, incandescence, etc.) or phenomena (flash, flicker, etc.)	0%	22%	14% + 7 % (S)	5% + 2 % (S)	5% + 2 % (S)	1%	6%	5% + 0 % (S)	14% + 5 % (S)	4% + 1 % (S)

□ = 0 – 9 %; ■ = 10 – 19 %; ■ = 20 - 29 %; ■ = 30 - 49 %; ■ = 50 – 100 %
H= hyposensitive; 0=absent; 1=minorly sensitive; 2=averagely sensitive; 3=extremely sensitive; S= sporadically sensitive

Table 7
Perception of the IAQ environment detected by parents and caregivers (overall sample). The table differentiates between systematic and sporadic answers; the latter indicated with the notation "(S)". Note that respondents who indicated a level different than "H" or "0" in question D1, needed to indicate which specific stimuli gave hypo- hyper- or no sensitivity (questions D2 and D3).

	Parents					Caregivers				
	H	0	1	2	3	H	0	1	2	3
D1) Indoor Air Quality	8%	46%	22% + 3 % (S)	12% + 3 % (S)	3% + 2 % (S)	4%	66%	16% + 5 % (S)	6% + 0 % (S)	3% + 0 % (S)
	8% of parents declared **Hyposensitivity** and **46%** declared that the ASC individual was **not sensitive** to indoor air quality. For these, the fulfillment of the other questions of Section D was not required					**4%** of caregivers declared **Hyposensitivity** and **66%** declared that the ASC individual was **not sensitive** to indoor air quality. For these, the fulfillment of the other questions of Section D was not required				
	H	0	1	2	3	H	0	1	2	3
D2) Stale air conditions (due to the presence of people)	3%	14%	10% + 0 % (S)	10% + 2 % (S)	5% + 2 % (S)	0 %	11%	9% + 4 % (S)	6% + 0 % (S)	0% + 0 % (S)
D3) Particular odors (animals, food, chemicals, etc.)	2%	7%	14% + 2 % (S)	14% + 0 % (S)	5% + 3 % (S)	1 %	4%	10% + 3 % (S)	6% + 1 % (S)	5% + 0 % (S)

□ = 0 – 9 %; ■ = 10 – 19 %; ■ = 20 - 29 %; ■ = 30 - 49 %; ■ = 50 – 100 %
H= hyposensitive; 0=absent; 1=minorly sensitive; 2=averagely sensitive; 3=extremely sensitive; S= sporadically sensitive

3. Co-morbidities influenced the sensitivity to air draft (A3) and to the visual environment (C1), especially as regards light color tones or contrast (C4 and C5) and particular light sources (C6), with a higher sensitivity in individuals with co-morbidities (mean difference always negative).

Table 9 depicts how answers were statistically influenced by the age of the individuals participating in the survey. The three thresholds of 18, 30 and 40 provided statistically valuable samples that made it possible to analyze the potential variations in perception according to age. These thresholds are reported respectively in the second, third and fourth columns. In each column, the statistical comparison of the samples under and over the corresponding threshold is reported.

In most cases, a progressive change of perception to the given stimulus can be identified with the increase of the age threshold. The difference in perception between people under-and over-18 persists beyond the age of 30 in the following cases: cold exposure (A1b), high noise levels in the environment (B1a), prevalence of natural light (C3b) and light color tones (C5). On the other hand, the perceptual differences with these stimuli decrease when considering people under- and over-40. Moreover, in three cases out of four (A1b, B1a and C3b), the significance level is higher when considering the 30-year-old threshold. For these reasons, people in the age range of 30–39 can be identified as the ones who mostly manifested differences in the perception of the indoor environment for the aforementioned issues. Conversely, the perceptual differences for the age threshold under-

Table 8
Results of the Mann–Whitney test comparison on the answers with gender, severity of autism and presence of co-morbidities, considering the overall sample. P-value results presented in columns are referred to the comparison between Males versus Females, A versus B+C levels of autism and individuals with no co-morbidities versus individuals with co-morbidities. In the cases where a statistically significant difference was found, the mean difference between the samples is reported.

	Question	P-value		
		Gender	Level of autism	Co-morbidities
	Number of answers (N_F = number of questionnaires regarding females; N_M = number of questionnaires regarding males; N_A = number of questionnaires regarding individuals with autism Level A; N_{B+C} = number of questionnaires regarding individuals with autism Level B or C; N_{NC} = number of questionnaires regarding individuals with no co-morbidities; N_C = number of questionnaires regarding individuals with co-morbidities)	$N_F = 42$; $N_M = 94$	$N_A = 48$; $N_{B+C} = 90$	$N_{NC} = 53$; $N_C = 85$
THERMO-HYGROMETRIC	(A1) Thermo-hygrometric environment	0.419	0.303	0.105
	(A1a) Heat exposure	0.532	0.382	0.436
	(A1b) Cold exposure	0.018** $\boldsymbol{\mu_F - \mu_M =}$ **0.218**	0.938	0.316
	(A2a) Excessive humidity	0.555	0.832	0.383
	(A2b) Low humidity (dryness)	0.613	0.844	0.160
	(A3) Drafts and air movement	0.369	0.811	**0.050**** $\boldsymbol{\mu_{NC} - \mu_C =}$ **−0.377**
	(A4) Heat/cold at extremities	**0.083*** $\boldsymbol{\mu_F - \mu_M =}$ **0.176**	0.895	0.329
ACOUSTIC	(B1) Acoustic environment	0.167	**0.001***** $\boldsymbol{\mu_A - \mu_{B+C} =}$ **−0.628**	0.192
	(B1a) High noise levels in the environment where she/he is	0.292	< 0.001*** $\boldsymbol{\mu_A - \mu_{B+C} =}$ **−0.839**	0.133
	(B1b) Low noise levels in the environment where she/he is	< 0.001*** $\boldsymbol{\mu_F - \mu_M =}$ **0.444**	**0.003***** $\boldsymbol{\mu_A - \mu_{B+C} =}$ **−0.379**	0.111
	(B2a) High noise levels coming from outside	0.352	**0.021**** $\boldsymbol{\mu_A - \mu_{B+C} =}$ **−0.451**	0.308
	(B2b) Rumbling sounds	0.388	0.123	0.661
	(B3) Particular noises (voices, impacts, animal calls, etc.)	0.987	< 0.001*** $\boldsymbol{\mu_A - \mu_{B+C} =}$ **−0.673**	0.162
VISUAL	(C1) Visual environment	0.389	0.467	**0.005***** $\boldsymbol{\mu_{NC} - \mu_C =}$ **−0.721**
	(C1a) High levels of illumination	0.381	0.735	0.102
	(C1b) Low lighting levels	0.539	**0.091*** $\boldsymbol{\mu_A - \mu_{B+C} =}$ **−0.136**	0.296
	(C2) High levels of light contrast (glare)	0.210	0.956	0.102
	(C3a) Prevalence of artificial lighting	0.449	0.841	0.080
	(C3b) Prevalence of natural lighting	**0.008***** $\boldsymbol{\mu_F - \mu_M =}$ **−0.298**	0.475	0.153
	(C4) High levels of color contrast or particular colors	< 0.001*** $\boldsymbol{\mu_F - \mu_M =}$ **0.474**	0.661	**0.098*** $\boldsymbol{\mu_{NC} - \mu_C =}$ **−0.372**
	(C5) Light color tones (warm light/cold light)	0.272	0.263	**0.025**** $\boldsymbol{\mu_{NC} - \mu_C =}$ **−0.328**
	(C6) Particular light sources (fluorescent lamps, incandescence, etc.) or particular phenomena (flash, flicker, etc.)	0.517	0.268	**0.024**** $\boldsymbol{\mu_{NC} - \mu_C =}$ **−0.598**
IAQ	(D1) Indoor Air Quality	0.740	0.631	0.567
	(D2) Stale air conditions (due to the presence of people)	**0.053*** $\boldsymbol{\mu_F - \mu_M =}$ **0.175**	0.468	0.677
	(D3) Particular odors (animals, food, chemicals, etc.)	0.388	0.898	0.238

* = test significant at 10% significance level; ** = test significant at 5% significance level; *** = test significant at 1% significance level;
μ_F = average value reported in the female sample; μ_M = average value reported in the male sample;
μ_A = average value reported in the sample with autism level A; μ_{B+C} = average value reported in the sample with autism level B or C;
μ_{NC} = average value reported in the sample without co-morbidities; μ_{B+C} = average value reported in the sample with co-morbidities.

and over-30 also persist with under- and over-40-year-olds with the following stimuli: draft and air movements (A3) and high levels of color contrast or particular colors (C4). This result shows how people between 18 and 29 years of age are the ones who mostly influence the different sensitivity to these two stimuli among the different age thresholds. In the question C4, a higher level of significance was found when considering the threshold of 30 years old.

In the case of high levels of light contrast/glare (C2) only a discontinuity of perception between under- and over-18-year-olds was detected. Consequently, with this stimulus, the difference in perception is attributable to the under 18 group: when aggregated with under-30s and under-40s, its influence is attenuated. For the same reason, people over-40 was found to have a different perception of rumbling sounds (B2b).

However, for thermo-hygrometric environment (A1) and heat/cold at the extremities (A4) stimuli, another approach needed to be used to investigate the influence of age on the stress caused on individuals with autism. Indeed, Table 9 shows significant differences only in the under- and over-30-year-olds for these stimuli. Therefore, an age progression cannot be clearly identified. For this reason, a further Mann–Whitney test was conducted for questions A1 and A4. The answers were divided according to the four age ranges ($\leq$17, 18–29, 30–39 and $\geq$40) to better investigate the causes driving the perceptual difference in the 30-year-old threshold. Table 10 shows that a significant discrepancy between the ranges 18–29 years old and 30–39 years was identified in answers regarding the thermo-hygrometric environments (A1). For this reason, the 30–39 age range can be identified as the sample that influenced the perception of stress from the thermo-hygrometric environment.

On the other hand, no significant differences were found as regards heat/cold at the extremities with the same analysis: the significant difference identified in Table 9 with this stimulus could be related to data aggregation and not to ages of involved individuals. Note that when a significant difference is present, the level of sensitivity increases with age (mean differences all negative).

4. Limitations of the study

The scope of the present research is to verify which specific environmental stimuli cause stress in individuals with autism, affecting them differently from standard users. Data from a sample of 138 people were collected from parents and professional caregivers, in order to overcome communication limitations with individuals with higher severity of autism. Individuals with different ages, severity of autism, co-morbidities and in different environments (with no or little information on their characteristics) were considered. In particular, the use of the methodology involving proxy respondents could provoke some uncertainties in the evaluations, however limited by robust statistical tests. All these factors could give bias in the answers and were therefore analyzed separately in order to identify common trends and possible dependences of stress on these individualities. Future research, involving a higher number of people, is needed to confirm the outcomes of this study.

5. Future perspectives

It is evident that additional research is needed as regards well-being of people with autism. As highlighted, many of the preferences could change according to age, severity of autism and in few cases gender. It would then be desirable to expand the research including a larger sample of participants. It would be also interesting to expand the control sample to include both autistic individuals and proxy respondents, in order to make a detailed analysis of the perception incidence of dedicated stimuli. A longitudinal study comprising several participants, featuring new approaches of investigation would be very useful to discover if (i) long-term exposure to the four comfort domains stress people with autism differently, (ii) the conventional physiological model could be used or there is a need implementation.

Finally, it would be interesting to adapt the proposed questionnaire for other neurodevelopmental or neurocognitive disorders, with the support and help of neuropsychiatry or psychology experts. An analysis could then be made to understand if the different types of individuals involved, show similar or different well-being evaluations.

6. Conclusions

In this paper, the perception of people with ASD regarding specific stimuli coming from the four environmental comfort domains was investigated. Questionnaire surveys were completed by parents and caregivers, due to the limited autinomy of many of the individuals with ASD involved. Results were studied by means of descriptive and statistical analyses. This paper confirmed some of the literature outcomes. In particular, we found that acoustic was one of the main sources of stress as also confirmed by literature, especially for loud and background noises (Mostafa, 2014; Gaines et al., 2016; Shell, 2019; Mostafa, 2020; Park et al., 2017; Kanakri et al., 2017; Martin, 2016; Noble et al., 2018), while rumbling noises and particular sounds such as voices, impacts and animal sounds were not previously deeply investigated. Visual stimuli were found to have a limited impact on autistic people, particularly glare and flickering. Moreover, high level of illumination and prevalence of artificial lighting were detected to be problematic. Also thermo-hygrometric and IAQ stimuli were less impactful on the well-being of prople with autism. Speaking about the acoustic domain, a dedicated user-centered design is recommended in order to avoid the high levels of background noise.

The study leads to the following main conclusions:

1. Parents and caregivers groups were statistically comparable featuring distribution homogeneity of age and severity of autism.
2. Parents and caregivers mostly showed a higher agreement in answers regarding the general sensitivity to a comfort domain than in the evaluations of the specific stimuli causing the stress conditions: in particular, parents generally indicated a higher sensitivity to these stimuli. The different evaluations of the two groups could be due to the environments where the observations were conducted or the different backgrounds of the two types of proxy respondents.
3. Both parents and caregivers did not indicate a high sensitivity to the thermo-hygrometric environment. Moreover, age was shown to have an impact on the perception of thermo-hygrometric stimuli, such as “cold exposure” “heat/cold at the extremities” and “draft”, with a generally higher sensitivity after 30. These latter two, particularly, resulted also to be influenced by the presence of comorbidity for “air draft” and by gender of the individuals for “heat/cold at the extremities”.
4. Acoustics was considered as the main source of stress, highlighting how, among the four comfort domains, this can be the main source of crises among individuals with the autism spectrum condition. Loud or rumbling noises were identified as particularly disturbing, as well as some particular sounds such as voices, impacts and animal sounds. Acoustic sensitivity was found to be very impactful for all ages. In addition, stimuli linked to acoustics were observed to be more significant with higher severities of autism. No influence of the presence of comorbidities was identified in the analyses conducted, while gender resulted to influence the sensitivity on “low noise levels”.

Table 9
Results of the Mann–Whitney test comparison on the answers regarding subjects under and over different age thresholds considering the overall sample. P-values results presented in columns are referred to the comparison between age thresholds. In the cases where a statistically significant difference was found, the mean difference between the samples is reported.

	Question			
	Threshold age	**18**	**30**	**40**
	N. of answers (N_U = number of questionnaires regarding subjects under the age threshold; N_O = number of questionnaires regarding subjects over the age threshold)	$N_U = 59$; $N_O = 79$	$N_U = 107$; $N_O = 31$	$N_U = 124$; $N_O = 14$
THERMO-HYGROMETRIC	(A1) Thermo-hygrometric environment	0.683	**0.012**** $\boldsymbol{\mu_U - \mu_O = -0.466}$	0.168
	(A1a) Heat exposure	0.4312	0.117	0.486
	(A1b) Cold exposure	**0.099*** $\boldsymbol{\mu_U - \mu_O = -0.226}$	**0.032**** $\boldsymbol{\mu_U - \mu_O = -0.368}$	0.307
	(A2a) Excessive humidity	0.779	0.237	0.281
	(A2b) Low humidity (dryness)	0.883	0.230	0.186
	(A3) Drafts and air movement	0.345	**0.013**** $\boldsymbol{\mu_U - \mu_O = -0.343}$	**0.014**** $\boldsymbol{\mu_U - \mu_O = -0.585}$
	(A4) Heat/cold at extremities	0.767	**0.040**** $\boldsymbol{\mu_U - \mu_O = -0.300}$	0.230
ACOUSTIC	(B1) Acoustic environment	0.102	0.270	0.461
	(B1a) High noise levels in the environment where she/he is	**0.097*** $\boldsymbol{\mu_U - \mu_O = -0.269}$	**0.032**** $\boldsymbol{\mu_U - \mu_O = -0.306}$	0.115
	(B1b) Low noise levels in the environment where she/he is	0.244	0.488	0.742
	(B2a) High noise levels coming from outside	0.683	0.347	0.213
	(B2b) Rumbling sounds	0.995	0.129	**0.062*** $\boldsymbol{\mu_U - \mu_O = -0.281}$
	(B3) Particular noises (voices, impacts, animal calls, etc.)	0.130	0.711	0.752
VISUAL	(C1) Visual environment	0.191	0.179	0.215
	(C1a) High levels of illumination	0.119	0.949	0.336
	(C1b) Low lighting levels	0.416	0.189	0.163
	(C2) High levels of light contrast (glare)	**0.034**** $\boldsymbol{\mu_U - \mu_O = -0.275}$	0.285	0.255
	(C3a) Prevalence of artificial lighting	0.441	0.298	0.744
	(C3b) Prevalence of natural lighting	**0.054*** $\boldsymbol{\mu_U - \mu_O = -0.251}$	**0.032**** $\boldsymbol{\mu_U - \mu_O = -0.285}$	0.338
	(C4) High levels of color contrast or particular colors	0.237	**0.025**** $\boldsymbol{\mu_U - \mu_O = -0.313}$	**0.076*** $\boldsymbol{\mu_U - \mu_O = -0.224}$
	(C5) Light color tones (warm light/cold light)	**0.061*** $\boldsymbol{\mu_U - \mu_O = -0.169}$	**0.075*** $\boldsymbol{\mu_U - \mu_O = -0.130}$	0.369
	(C6) Particular light sources (fluorescent lamps, incandescence, etc.) or particular phenomena (flash, flicker, etc.)	0.473	0.237	0.650
IAQ	(D1) Indoor Air Quality	0.119	0.957	0.417
	(D2) Stale air conditions (due to the presence of people)	0.166	0.568	0.126
	(D3) Particular odors (animals, food, chemicals, etc.)	0.123	0.525	0.462

* = test significant at 10% significance level; ** = test significant at 5% significance level; *** = test significant at 1% significance level;
μ_U = average value reported in the sample under the age threshold; μ_O = average value reported in the sample over the age threshold.

5. Visual stimuli were not found to strongly impact people on the autism spectrum condition. The higher influence of some visual elements such as "light contrast (glare)", "high level of illumination", "prevalence of artificial lighting" or "particular light sources or phenomena" was noticed. Sensitivity to visual environment stimuli were linked to gender, age and co-morbidities.
6. *IAQ* was not found to be strongly impactful, even though the number of individuals who were sensitive to this element was not negligible. Parents reported a higher impact of this domain compared to caregivers. Moreover, "stale air" sensitivity resulted to be influenced by gender.
7. The conclusions mentioned above also underline how differences in the sensitivity strongly depend on individual differences. This aspect was also highlighted by gender dependence in the stress from some stimuli such as "cold exposure" "heat/cold at the extremities", "low noise levels", "prevalence of natural lighting", "high levels color contrast or particular colors" and "stale air conditions". Moreover, sensitivity to some thermal, acoustic and visual stimuli seemed to slightly increase with age.

This research provides the first contribution to the study of the influence of environmental stimuli to the sensitivity of autistic individuals, in terms of comfort topics. The results highlight the importance of considering the higher sensitivity of autistic people to environmental stimuli (especially acoustic), when designing living and extended-care unit environments. Avoiding the elements which cause disturbances (through for instance good acoustic insulation) is essential for the well-being and safety of

Table 10
Results of the Mann–Whitney test comparison on the answers A1 and A4 regarding subjects of different age ranges considering the overall sample. P-values results in columns are referred to the comparison between age ranges. In the cases where a statistically significant difference was found, the mean difference between the samples is reported.

Age ranges compared	Question	P-values
≤17 years old & 18–29 years old	(A1) Thermo-hygrometric environment	0.401
	(A4) Heat/cold at extremities	0.503
≤17 years old & 30–39 years old.	(A1) Thermo-hygrometric environment	0.114
	(A4) Heat/cold at extremities	0.263
≤17 years old & ≥40 years old	(A1) Thermo-hygrometric environment	0.246
	(A4) Heat/cold at extremities	0.373
18–29 years old & 30–39 years old	(A1) Thermo-hygrometric environment	**0.026**** $\mu 1 - \mu 2 = -\mathbf{0.655}$
	(A4) Heat/cold at extremities	0.124
18–29 years old & ≥40 years old.	(A1) Thermo-hygrometric environment	0.803
	(A4) Heat/cold at extremities	0.952

* = test significant at 10% significance level; ** = test significant at 5% significance level; *** = test significant at 1% significance level;
μ_1 = average value reported in the first sample; μ_2 = average value reported in the second sample

individuals. Moreover, the age of the subjects, the severity of autism and the co-morbidities are elements to be considered, adopting different solutions depending on the purpose and the future users of the designed facilities. Due to the individual differences, there is a need for further studies to integrate the present one, in order to help develop guidelines for the HVAC and architecture design of living and healthcare environments. In particular, all the elements where individuals with autism are found to have a different level of sensitivity are worth studying in more depth and analyzed, in order to set the proper environmental quality thresholds or customization of indoor environments and of the design practices, which are likely to be different to those set for neurotypical users.

CRediT authorship contribution statement

Marco Caniato: Conceptualization, Data curation, Data interpretation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Luca Zaniboni:** Data Interpretation, Writing – original draft, Writing – review & editing. **Arianna Marzi:** Formal analysis, Data interpretation, Writing – original draft, Writing – review & editing. **Andrea Gasparella:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.egyr.2022.01.011.

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