Fireworks, Autism, and Animals

What "fun" noises do to sensitive humans and our beloved pets.

By Max E. Valentinuzzi

In a previous article in *IEEE Pulse*, autism was reviewed, and we discovered, not without surprise, that the condition as now recognized is barely more than 100 years old [1]. In the same article, a graphical user interface designed specifically for children with autism spectrum disorder (ASD) was presented.

Given the rather widespread custom (at least in the West) of using fireworks (that is, *making noise*, more or less controlled, depending on the place) as a means of celebration on certain specific days—Christmas, New Year's Eve, the Fourth of July in the United States, Mardi Gras or Carnival, and sometimes local religious festivities in small communities—this column discusses the potential damage of such noise to autistic children. Damage to pets and animals in general should also be considered. Moreover, the following questions should be posed:

- Are we acting like civilized people?
- Is there anything the authorities or ordinary citizens can do about the issue?

Autism Disorder Spectrum

Stuart Neilson was diagnosed with Asperger's syndrome in 2009 at the age of 45. After many years of ineffective psychiatric treatment, he became involved in higher education and research, including statistics, medical information systems, disability, and, currently, autism studies. He has contributed to a number of books, including guides to multiple sclerosis, motor neuron disease, and Asperger's syndrome. His work is quite an outstanding example that deserves to be referred to, as it represents a firsthand case that also presents a good account of the subject [2].

Adolescence, the transition between childhood and adulthood, is a period of remarkable physiological, psychological, and social change. A variety of physiological developments coincide with the dynamic transition, which is evident in the regulation and responsivity of the limbic–hypothalamic–pituitary–adrenocortical axis. Specifically, elevations in diurnal basal cortisol levels have been reported as well as higher cortisol in response to perceived stressors. Although this enhanced responsivity may help prepare the individual to adapt to increased demands and new challenges, it may also mark a time of increased vulnerability in populations already prone to enhanced physiological arousal and poor adaptation to change, such as those with autism.

To date, most studies investigating the integrity of the limbic–hypothalamic–pituitary–adrenocortical axis in children with ASD have shown more variable diurnal regulation and a pattern of enhanced responsivity to stress. There is also evidence of more marked reactivity over the course of their development, suggesting that adolescence may be a time of increased risk for pronounced physiological arousal and social stress. This critical review briefly summarizes the literature to date on autism and adolescence. It suggests an enhanced interplay between social functioning and stress in ASD during this period of life [3].

Hypersensitivity to Noise

Dickie et al., in 2009, described the sensory experiences of children with and without autism. The parents of 66 preschoolers (29 exhibiting typical development and 37 with autism) characterized situations in which their child had "good" and "bad" sensory experiences and their perception of how these situations felt to the child. The most common unpleasant experiences for both groups related to sound; the most common pleasant experiences involved touch and movement.

Children with autism were reported to have more extreme or unusual experiences and negative food-related experiences than their peers who were developing more typically. The parental explanations for the children's responses focused on the qualities of the child, the stimulus, or the context. The parents of children with autism were more likely to recognize elements in their children's experiences as being sensory and to attribute those responses to aspects of autism. The parents' positive response to the interview itself was an unexpected result, with clinical relevance [4].

More than half of young people with ASD have sensory overresponsivity (SOR), an extreme negative reaction to sensory stimuli. However, little is known about the neurobiological basis of SOR, and there are few effective treatments. Understanding whether SOR is due to an initial heightened sensory response or to deficits in regulating emotional reactions to stimuli has important implications for intervention. The objectives set by Green et al., in 2015, were to determine differences in brain responses, habituation, and connectivity during exposure to mildly aversive sensory stimuli in youth with ASD *and* SOR compared with youth with ASD *without* SOR and also compared with typically developing control subjects; a particular goal was to observe the apparent minor differences between the groups *with* and *without* SOR.

Green et al. used functional magnetic resonance imaging to examine the brain

Digital Object Identifier 10.1109/MPUL.2018.2856961
Date of publication: 26 September 2018

responses and habituation to mildly aversive auditory and tactile stimuli in 19 high-functioning youths with ASD and 19 age- and IQ-matched typically developing youths (age range, 9–17). The brain activity was related to the parents' ratings of the children's SOR symptoms. The functional connectivity between the amygdala and orbitofrontal cortex was compared between ASD subgroups with and without SOR and the typically developing controls without SOR. The study dates were March 2012 through February 2014. The relative increases in blood-oxygen-level-dependent signal response across the whole brain and within the amygdala during exposure to sensory stimuli were measured and compared with fixation as well as correlation between blood-oxygen-level-dependent signal change in the amygdala and orbitofrontal cortex.

The mean age in both groups was 14 years, and the majority in both groups (16 of 19 each) were male. Compared with the neurotypical control participants, the participants with ASD displayed stronger activation in primary sensory cortices and the amygdala ($P < 0.05$). This activity was positively correlated with SOR symptoms after controlling for anxiety. The ASD-with-SOR subgroup had decreased neural habituation to stimuli in sensory cortices and the amygdala compared with groups without SOR. Youths with ASD without SOR showed a pattern of amygdala downregulation, with negative connectivity between the amygdala and orbitofrontal cortex ($P < 0.05$). The Merriam-Webster dictionary defines *downregulation* as the process of reducing or suppressing a response to a stimulus; specifically, it is a reduction in a cellular response to a molecule (as insulin) due to a decrease in the number of receptors on the cell surface.

The authors concluded that youths with ASD and SOR show sensorilimbic hyperresponsivity to mildly aversive tactile and auditory stimuli, particularly to multiple modalities presented simultaneously; this hyperresponsivity is due to failure to habituate. In addition, the findings suggest that a subset of youths with ASD can regulate their responses through prefrontal downregulation of amygdala activity. The implications for intervention include minimizing exposure to multiple sensory modalities and building coping strategies for regulating the emotional response to stimuli [5].

According to the Autism Society, one in 68 children born in the United States will exhibit some degree of autism. The incidence of autism increased 119.4% from 2000 to 2010 and is a fast-growing disability. These children come with a special list of needs that are critical to their development. One of the most common symptoms of autism is extreme noise sensitivity. Autistic children can often hear things well before nonautistic children or their parents can catch the sound. Everyday noises can cause extreme pain, noise paranoia, screaming fits, and anxiety.

There are five common types of noise sensitivity in autistic children:

- hyperacusis
- specific frequencies hypersensitivity
- recruitment
- phonophobia
- misophonia [6].

Children who experience noise as an unpleasant sensation, or even as physical pain, develop defensive reactions (such as covering their ears) and avoidance reactions (seeking places without noise). The most immediately obvious consequence is a loss of social opportunity. Normally, children are noisy, school is noisy, many workplaces are noisy, and most socializing outside the home is centered around noise. Avoiding these experiences means avoiding elements of childhood play, education, employment, and adult friendships that other people take for granted.

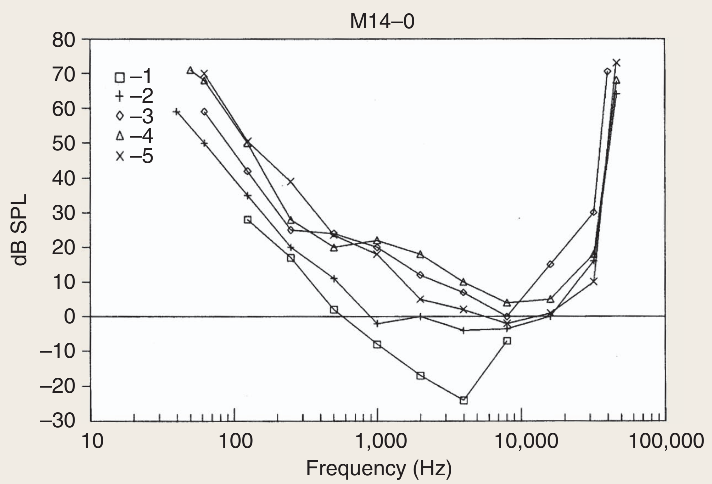

FIGURE 1 Audiograms compiled from several published references [8]. Frequency is displayed on a logarithmic scale from 10 to 100,000 Hz, while stimulus intensity is given in decibels, from –30 to 80 dB. Curve 1 was determined from an undisclosed breed, while curves 2, 3, 4, and 5 correspond, respectively, to the poodle, dachshund, Saint Bernard, and chihuahua. SPL: sound pressure level.

Discussion

Obvious risks become apparent, as an autistic child in a spell of panic produced by fireworks may leave his or her home, get lost, and even suffer a serious accident. But not only human beings may fall prey to unpleasant noises. While humans have learned to expect fireworks when festivities take place, such noise can be quite startling to dogs and other animals.

Dogs have keen senses that make fireworks a more intense experience for them. Not only do pyrotechnics produce intense sounds and sights but also an odor to which dogs may be sensitive. Dogs feel the same kind of startled response we do when surprised by a loud noise. This may mean an increase in heart rate, a rush of adrenaline, and a burst of stress hormones. Dogs, however, can be trained to accept intense noises, as witnessed in special breeds like Labradors and German shepherds that work with police and military units. Good advice on helping dogs deal with fireworks can be found in [7].

How well dogs and other animals hear is a relevant question that deserves to be addressed. The answer, however, is not straightforward. Testing in animals differs from the methods commonly used with humans.

When determining the frequency range in animals, an investigator usually must first train the animal to respond to a presented sound stimulus by selecting between two actions and using rewards. Often, this response is an attempt to drink or eat from one of two dispensers when a sound is heard. The sounds are randomly presented from one side or the other, and the subject must select the correct dispenser (on the same side as the stimulus) to get the reward; otherwise, no food or drink is dispensed. This is done with the animal hungry or thirsty to motivate a response. The stimuli are different pure tones at varied frequencies, expressed in Hertz, and at different intensities, in decibels. The investigator then plots the responses on an audiogram. The plot of responses is a bowl-shaped curve, steeper on the high-frequency end. A series of five typical audiograms for different breeds of dog (*Canis canis*) is shown in Figure 1.

In general, dogs had greater sound sensitivity (detected lower-intensity sounds) than humans, and cats had greater sensitivity than dogs, indicated by how low on the *y* axis points were located. Choosing the frequencies for reporting the frequency range for dogs is difficult. Nevertheless, Table 1 reports the approximate hearing range for different species in an attempt to apply the same cutoff criteria to all [9]. Regrettably, because different experimental methods were used in the different studies, too much value should not be placed on the comparisons [10].

TABLE 1. THE APPROXIMATE HEARING RANGE FOR A VARIETY OF ANIMAL SPECIES.

Species	Approximate Range (Hz)
Human	64–23,000
Dog	67–45,000
Cat	45–64,000
Cow	23–35,000
Horse	55–33,500
Sheep	100–30,000
Rabbit	360–42,000
Rat	200–76,000
Mouse	1,000–91,000
Gerbil	100–60,000
Guinea pig	54–50,000
Raccoon	100–40,000
Ferret	16–44,000
Opossum	500–64,000
Chinchilla	90–22,800
Bat	2,000–110,000
Beluga whale	1,000–123,000
Elephant	16–12,000
Porpoise	75–150,000
Goldfish	20–3,000
Catfish	50–4,000
Tuna	50–1,100
Bullfrog	100–3,000
Canary	250–8,000
Parakeet	200–8,500
Owl	200–12,000
Chicken	125–2,000

Conclusions

Let us end by returning to the two questions raised at the beginning of this article:

- Are we acting like civilized people?
- Is there anything the authorities or ordinary citizens can do about the issue of autistic people and noise?

Unfortunately, we find ourselves in an essentially hopeless position because it becomes extremely difficult to go beyond simple advice and calls for understanding, among both experts and ordinary people. This article perhaps contributes a grain of sense to the discussion. Has bioengineering any useful suggestions?

Max E. Valentinuzzi (maxvalentinuzzi@ieee.org) *is a professor emeritus with the Universidad Nacional de Tucumán, Argentina, and investigator emeritus with Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina. He is a Life Fellow of the IEEE.*

References

[1] E. Pérez, S. D. Ponce, D. J. Piccinini, N. López, and M. E. Valentinuzzi, "Autism: Historic view and a current biomedical engineering approach," *IEEE Pulse*, vol. 6, no. 5, pp. 40–46, 2015.

[2] S. Neilson. (2018, June 29). Motion and attention in the classroom (or workplace), [Online]. Available: wordpress.stuartneilson.com; also S. Neilson. (2017, Dec. 13). Autism and identity in the DSM. [Online]. Available: http://wordpress.stuartneilson.com/2017/12

[3] B. A. Corbett and D. Simon. (2013, Mar. 1). Adolescence, stress and cortisol in autism spectrum disorders. *Open Access Autism*. [Online]. 1(1). Available: http://www.oapublishinglondon.com/oa-autism#

[4] V. A. Dickie, G. T. Baranek, B. Schultz, L. R. Watson, and C. S. McComish, "Parent reports of sensory experiences of preschool children with and without autism: A qualitative study," *Amer. J. Occupat. Therapy*, vol. 63, pp. 172–181, Mar. 2009.

[5] S. A. Green, L. Hernandez, N. Tottenham, K. Krasileva, S. Y. Bookheimer, and M. Dapretto, "Neurobiology of sensory overresponsivity in youth with Autism Spectrum Disorders," *JAMA Psychiatry*, vol. 72, no. 8, pp. 778–786, 2015.

[6] Hush Baby. (2016, Mar. 9). Autistic children can have extreme hearing sensitivity. [Online]. Available: https://www.shophushbaby.com/blogs/news/113833731-autistic-children-can-have-extreme-hearing-sensitivity

[7] Purina. Why are dogs scared of fireworks? 5 reasons dogs and fireworks don't always get along—and what to do about it. [Online]. Available: https://www.purina.com/dogs/dog-articles/behavior-and-training/why-are-dogs-scared-of-fireworks

[8] R. R. Fay, *Hearing in Vertebrates: A Psychophysics Databook*. Winnetka, IL: Hill-Fay Associates, 1988.

[9] D. Warfield, "The study of hearing in animals," in *Methods of Animal Experimentation*, vol. 4, W. Gay, Ed. London: Academic, 1973, pp. 43–143.

[10] Louisiana State University. How well do dogs and other animals hear? [Online]. Available: http://lsu.edu/deafness/HearingRange.html

[11] J. Lingelbach, *Carnival in Rome*, [Online]. Available: https://commons.wikimedia.org/w/index.php?curid=12438133