Using Sound Level Meter Apps To Raise Noise Pollution Awareness - New York City Case Study

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ABSTRACT

Media reports in the United States and the United Kingdom have reported increasingly high sound levels in restaurants over the past ten years, but accurate sound measurements are lacking. The Zagat survey found noise to be the most common complaint among diners in urban metro areas while the noise exposure of venue employees potentially endangers their hearing health. While there is a plethora of literature on the dangers of loud noise, more action is needed, notably via the employment of technology and mobile apps that can collect invaluable sound level data.

The first large-scale study conducted on sound levels, using the novel SoundPrint smartphone app, of more than 2250 venues in New York City shows that the average sound level of restaurants is not conducive to conversation for patrons and a great number of venues potentially endanger the hearing health of venue employees. The analysis and dissemination of the data via the SoundPrint app and through its social media channels can help raise noise pollution awareness for policy makers, agencies and the general public to show just how pervasive noise pollution is.

1 INTRODUCTION

Noise pollution is a widespread issue that a plethora of studies, both in the United States and abroad, have addressed. A small number of these studies have focused on the sound levels of restaurants and the impact of noise on health and hearing. There have also been an increasing number of media articles from several cities stating that eating and drinking establishments are getting increasingly loud either because of background music or architectural design that enhances rather than abates interior sounds.[1,2]

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High sound levels in restaurants can negatively impact the health and quality of life of patrons and employees as hearing loss is the third most common chronic physical condition in the U.S.,[3] and noise is the most common 'modifiable environmental cause' of hearing loss which is present in 24% of adults.[4] Noise is also associated with tinnitus, a noise or ringing in the ears, which affects approximately 11% of adults and hyperacusis, an increased sensitivity to sound, which affects approximately 6% of adults.[5,6,7] Research also shows that noise can contribute to exhaustion and also release cortisol in the body as it is linked to increased stress, hypertension, ischaemic heart disease, stroke and obesity.[8, 9, 10,11] A recent study showed that a large number of U.S. adults may be exposed to noise levels above the EPA recommended daily noise dosage limit of 70 dBA.[12] And another study of more than 4,500 adults in New York City suggested that nine out of ten adults exceeded the same EPA daily noise dosage limit.[13] To address the dangers of noise pollution, the Center for Disease Control and Prevention (CDC) recommends avoiding prolonged exposure to loud environments to prevent noise-induced hearing loss (NIHL).[14, 15]

Noise pollution also affects the quality of life.[16] Even for people with normal hearing, noise is a barrier to the enjoyment of communicating, socializing and connecting with colleagues, friends and families through intimate conversation. The focus of this study is on indoor noise, specifically in restaurants. Restaurants are not just eating establishments, but social spaces important for gathering and communicating and noise has hindered and negatively affected customers' dining experience.[17] And for those with hearing loss, the difficulty of hearing others in loud venues can lead many to withdraw from social situations, leading to increased isolation.[18]

The advances of smart-phone technology is providing new ways to capture sound levels with digital sound level meters which could become a valuable tool for improving the public's noise pollution awareness.[19] Ideally, a database would be maintained by a local governmental entity and have frequent and recurring precise sound level measurements of long duration for all venues in a city. And similar to the health grades that are prominently displayed on venue windows, a noise grade would enable patrons to know the general sound level of each venue. Unfortunately, this is impractical due to the high costs of labor, equipment and time. While some people do employ a digital sound level meter on their smart phone to take real-time measurements, such data is not collected, aggregated and widely disseminated for public consumption. What is suggested is a method to systematically quantify the noise levels of a large number of venues employing digital sound level meters and making such information easily accessible to the public.

This exploratory study is based on an effort to capture the sound level data on a large-scale basis in an urban environment (New York City) using the SoundPrint app ("SoundPrint"), a free digital sound level meter available on the iPhone at no cost to users, that measures, aggregates, categorizes and displays the average sound levels of venues into quiet, moderate, loud or very loud categories on an ongoing basis and is easily accessible to the public.

We believe the public lacks sufficient awareness in determining whether a certain auditory environment is quiet or loud. For most people without digital sound level meters, such determination is merely subjective. If most venues are loud, people may erroneously believe that such noise levels are the "norm" and therefore, acceptable and safe. This study aims to compare people's subjective interpretation and reporting of sound levels to actual quantitative measurements.

Another purpose of this study is to determine whether the recent increase in the number of media articles and qualitative surveys indicating that venues are too loud is true and accurate. In answering this, data from SoundPrint was utilized to explore the following question: What percentage of venues in Manhattan are quiet or loud?

2 METHODOLOGY

2.1 Timeline and Geography

The exploratory study was conducted between July 2015 and June 2017 in Manhattan restaurants located between 86th street and the lower edge of Manhattan, otherwise known as the Financial District. Note that the collection is still ongoing, but for the purposes of this study, June 2017 is the last month of data analyzed for this report.

2.2 Venues measured

A total of 3,137 venues were measured at least once for their sound levels. To qualify for inclusion in the analysis, however, each venue had to be measured a minimum of three times during prime days and hours and many were measured more than three times.[b,c] A total of 2,376 venues met this minimum requirement for inclusion in this report. Only restaurants that had on-the-premise seating with waiter-based service were included in this analysis; venues that had pick-up-at-the-counter service or no waiters were excluded.

2.3 Instrument and timing of measurement

The measurements were conducted with the SoundPrint app, a free digital sound level meter and aggregator available on the iPhone platform. SoundPrint measures dBA with slow response and automates the sound level calibration across different iPhone hardware devices for a more consistent measurement. The main output is the average dBA (an arithmetic average) as this represents sufficient information for individuals to measure, understand and employ in making decisions about whether to patronize a venue.

The SoundPrint app's sound level measurement accuracy was tested in two separate ways. First the app's sound measurement capabilities were tested side by side with a Type-1 sound level meter at various levels of pink noise. Agreement was within +/- 0-1.2 dB at all levels.[d] And second, it was compared to the Faber Sound Meter 4 iPhone app, referred to as the SoundMeter app and available on the Apple store, which was found by Chuck Kardous at NIOSH to be the most accurate within 0.2% of an OSHA-certified sound level meter.[20] Results show that across seven different

[b] The highest number of times a venue was measured was 18.

[c] The breakdown of the number of venues measured "x" times is as follows: 1 measurement: 366 venues; 2 measurements: 395 venues; 3 measurements: 861 venues; 4 measurements: 718 venues; 5 measurements: 381 venues; 6 measurements: 233 venues; 7 measurements: 107 venues; 8 measurements: 48 venues; 9 measurements: 18 venues; 10 measurements: 4 venues; 11 measurements: 2 venues; 12 measurements: 0 venues; 13 measurements: 1 venue; 14 measurements, 0 venues; 15 measurements, 1 venue; 16 measurements, 1 venue; 17 measurements, 0 venues; and 18 measurements, 1 venue.

[d] The tests were conducted using four iPhone 6 models and an iPhone 7 by Lily M. Wang and Kieren Smith (Durham School of Architectural Engineering and Construction, University of Nebraska – Lincoln).

general static sound level decibel ranges, SoundPrint was within +/- 0-1 dBA of the SoundMeter app.[e]

The measurements were collected during prime-time days and hours which included: Wednesdays from 7:00PM-9:00PM, Thursdays from 7:00PM-9:30PM, Fridays from 7:00PM-10:00PM and Saturdays from 7:00PM-10:00PM.

2.3 Instrument and timing of measurement

The data is segmented into four sound level categories: (1) Quiet (2) Moderate (3) Loud (4) Very Loud. All four categories have sound level thresholds that are guided by hearing health safety standards, but the Moderate and Loud categories are also guided by the threshold sound level where the ability to hear and converse with others becomes either easier or difficult.

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(i) Less than 70 dBA (Quiet)

In 1972, The National Institute of Occupational Safety and Health (NIOSH) stated that average, not peak, sound levels over a time-weighted eight-hour period above 85 dBA is the threshold by which employers should enact hearing conservation programs to protect against the danger of noise induced hearing loss. This was a standard specifically set for employers and employees in occupational settings for the standard eight-hour work day. Yet guidelines were also needed for the general public to account for their noise exposure for the full 24-hours in a day. Two years later, the Environmental Protection Agency (EPA) calculated a safe noise exposure level for the general public on a daily basis to be 70 dBA.[21] This means that, on average, during a typical 24-hour day, one's noise exposure should be 70 dBA or lower to protect against noise-induced hearing loss according to the EPA. This threshold has been supported by the World Health Organization (WHO) that has recommended people avoid sound level exposures above 70 dBA.[22] Hence the Quiet category reflects an average dBA of 70 or lower.

(ii) 81 dBA or louder (Very Loud)

Notwithstanding the above, NIOSH's 85 dBA standard is not meant to protect all workers as NIOSH acknowledged that 8% of workers could still develop material hearing loss under their guidelines. Also, the 85 dBA threshold level assumes that the employee has no further noise exposure during the remaining 16 non-working hours each day and accounted for only 40 occupational-work years for noise exposure rather than the 80-year life expectancy today.[23,24] In 2003, the European Parliament established new, and more stringent, standards for acceptable

[e] Note that SoundPrint measures dBA in whole integers whereas SoundMeter measures to the 1/10th decibel. To illustrate, in a quiet room where SoundMeter measured at 43.8 dBA, it was rounded to 44 dBA. SoundPrint measured at 45 dBA. We do not know if SoundPrint's dBA to the 1/10th level was 44.5, 44.6, 44.7, 44.8, 44.9, 45.0, 45.1, 45.2, 45.3, or 45.4.

occupational noise exposure levels as it lowered the threshold by which companies must make hearing protection available from 85 dBA to 80 dBA.[25] Thus, SoundPrint employs the more conservative 80 dBA as the threshold for a venue being Very Loud and potentially dangerous to one's hearing health.

(iii) Between 71 and 75 dBA (Moderate) and Between 76 and 80 dBA (Loud)

The EPA has shown that normal hearing people have difficulty following a conversation above 75 dBA. [26] This is supported by Lebo et al.'s description of restaurants with noise levels of 75+ dBA as those that made conversation difficult for patrons with normal hearing and very difficult for those with hearing loss.[27] Loud noise could alternatively be described as an auditory environment where people must raise their voice to be heard by someone sitting within three feet of them. And in 1990, The National Institute of Health Consensus Development Conference on Noise and Hearing Loss stated that 75 dBA is the threshold by which, if the sound level is lower, is unlikely to cause permanent hearing loss.[28] This implies that as the sound level increases above 75 dBA, the likelihood of incurring permanent hearing loss increases. Hence SoundPrint sets 75 dBA as the threshold between the Moderate and Loud categories.

2.4 Limitations

There are several limitations to this exploratory study. First, the SoundPrint digital sound level meter app was used rather than a highly advanced sound level measuring instrument. Although SoundPrint provides a reasonable approximate measurement of the sound level, it is not sufficiently accurate for legally-based measurements. Second, only one variable, the average dBA was measured and aggregated as other variables that could provide additional insight such as minimum or maximum sound levels, occupational density and/or reverberation or other room characteristics such as clarity were not measured. Third, the length of the recordings is typically shorter than the measurements conducted in prior restaurant noise studies. This was due to the restrictive timeframe for primetime days and hours, the large number of venues needed for measurement at least three times and the limited amount of human resources to complete the measurements.

Fourth, there is no uniform recording length for each submission as the length of the recording varies since it the user's decision as to when to stop each recording, despite there being a minimum 15 seconds. The vast majority of submissions were under one minute. Fifth, due to the nature of the app being a crowdsourcing app and despite giving instructions to collectors and users, there is not a verifiable way to ensure they followed precise instructions (i.e. record from the center of the room, ensure at least three feet of space in a 360 degree angle) during their measurements. Additionally, the resulting average sound levels for a particular venue could differ from the sound levels during other times on the same day. It is possible that a collector took a measurement of a venue that was quieter or louder at a specific time and then an hour later the venue produces a louder or quieter sound level that may be more typical for the venue.

3 DATA AND DISCUSSION

3.1 Significant majority of restaurants are too loud for conversation

As Table 1 suggests, the number of venues that are Loud or Very Loud is significantly high. For Mainstream Restaurants, 71% produce average sound levels above the threshold that is likely to be too difficult to have a conversation without the need to raise one's voice. This is supported by the average sound level being 78 dBA which means that if a patron were to patronize a randomly selected restaurant during peak days and hours in Manhattan, it would likely be Loud.

Table 1: Sound levels by categories for Mainstream restaurants

		Below 71	71 - 75	76+	76-80	81+	Avg
	Total	Low	Mod	High	Loud	Very Loud	dBA
Chinatown	4	25%	50%	25%	25%	0%	73.0
Upper West Side	55	11%	33%	56%	44%	13%	75.8
Koreatown	5	0%	60%	40%	40%	0%	76.4
Upper East Side	119	8%	32%	60%	41%	18%	76.5
Midtown West	212	11%	27%	62%	36%	25%	76.8
Midtown East	114	11%	33%	55%	29%	26%	76.9
Little Italy	34	0%	47%	53%	38%	15%	77.3
Tribeca	41	5%	24%	71%	44%	27%	77.5
Financial District	30	7%	23%	70%	37%	33%	78.0
Chelsea	58	5%	17%	78%	47%	31%	78.2
Murray Hill	63	8%	17%	75%	35%	40%	78.8
[1] West Village	214	1%	20%	79%	43%	36%	78.9
[2] Soho	35	0%	11%	89%	49%	40%	79.0
[3] Flatiron/Gramercy	102	1%	19%	80%	45%	35%	79.0
[4] East Village	152	3%	13%	84%	45%	39%	79.1
Lower East Side	56	0%	9%	91%	38%	54%	81.0
Total	**1294**	**6%**	**23%**	**71%**	**40%**	**31%**	**78.0**

[1] Includes West Village, Greenwich Village

[2] Includes Murray Hill, Kips Bay

[3] Includes Flatiron, Gramercy, Union Square

[4] Includes SoHo, Nolita

This data lends credence to the anecdotal comments, recent surveys and increasing number of media articles that suggest that restaurants are most often too loud for conversation and socializing.

3.2 A significant number of restaurants are dangerous to people's hearing health

Approximately 31% of Mainstream restaurants have sound levels during peak days and hours that are potentially dangerous to the hearing health of their patrons, and even more importantly, to their employees (i.e. waiters, hostesses, bartenders, chefs and managers) who are often subject to a longer duration of exposure to occupational noise.

A venue employee's hearing health could be in serious jeopardy since noise-induced hearing loss often does not appear until years later, which by then is too late. [29,30] And for patrons, their hearing health also depends greatly on the amount and degree of noise exposure they experience during the rest of their 24-hour day, that is whether their average daily noise exposure falls below the 70 dBA threshold recommended by the EPA.

3.3 Some neighborhoods are louder than others

Manhattan neighborhoods are well-known for their diversity and that is also reflected in the data. Neighborhoods known to skew younger in age and those that have a more vibrant nightlife also tend to have a higher percentage of restaurants that are Loud or Very Loud including the Lower East Side, SoHo, East Village, West Village, Chelsea, Flatiron and Murray Hill - all have more than 75% of their venues as Loud or Very Loud.

That these neighborhoods are comparatively louder than other neighborhoods is not a surprise. The Upper West Side and Upper East Side are known to be more family-oriented, residential, skew older in age and have less of a vibrant night life. Midtown West and Midtown East are neighborhoods with a mix of residential units and business offices with less people frequenting restaurants during the evening hours compared to the daytime. There are still a good number of venues that are well attended in the evenings, just less so compared to their downtown brethren.

This data could assist people by informing them of the neighborhoods that have quieter or noisier restaurants and bars based on their sound level preference and could be a deciding factor in choosing which neighborhood to live in. The data could also assist local governance in Manhattan, notably the community boards that represent certain districts and recommend various policies to government agencies. These community boards now have access to data that, should they deem it an important health issue, could help them undertake and direct noise pollution awareness efforts.

3.4 Sound level trends over time – to be determined

There appears to be an increase in the sound levels of restaurants over the past 10 years as noted by the number of articles in the media, qualitative surveys and anecdotal comments about the so-called 'increasing din' of restaurants. Thus, it would be beneficial to quantifiably gauge whether restaurants are actually getting louder over time. Because this is the first exploratory study, we cannot determine trends or make comparisons at this time. However, we aim to collect additional

data and conduct comparative analyses to this study's data on an annual or biennial basis in the future.

4 CONCLUSION AND RECOMMENDATIONS

In this exploratory study, the data suggests that the increasing number of media articles and anecdotal comments from qualitative noise surveys about sound levels being too loud are correct. In New York City, a significant number of restaurants in New York City have average sound levels that (1) approach levels that are too difficult for patrons to have a conversation without the need to raise their voice and (2) approach levels that are known to be dangerous to hearing health. The average dBA for mainstream restaurants is 78 dBA. A person randomly walking into a restaurant in New York City during prime days and hours is more likely than not to encounter a Loud or Very Loud auditory environment.

Furthermore, the sound levels of venues in New York City tend to be correlated with certain neighborhoods, possibly as a reflection of the venues in that neighborhood that attract a certain demographic.

Because current scientific sound level measurement practices are time and labor-intensive, it makes large-scale collection of sound level data on individual venues difficult. This results in a public that lacks accessibility to and knowledge about the sound levels of venues in their neighborhood. Such access could help people determine whether a particular venue is likely to be quiet or loud. Hence, going forward, it is suggested that local agencies encourage the public and venue employees to employ digital sound level meters to collect and crowdsource sound level data so it is available and accessible to the public.

4 ACKNOWLEDGEMENTS

A thank you to Arline Bronzaft, Daniel Fink and Lily Wang for their support, encouragement and helpful comments on earlier versions of the paper. Special thanks to Kieren Smith for her work on the validation measurements and statistical analyses.

5 REFERENCES

1 Reiley L. All that racket a lose-lose situation for restaurants. Tampa Bay Times, 2007 Sep 13. [Last cited on 2017 Dec 1]. Available from: http://www.sptimes.com/2007/09/13/Food/All_that_racket_a_los.shtml.

2 Reader Comments. The 'daunting' din: readers react to noisy restaurants. The New York Times, 2015 Sep 9. [Last cited on 2017 Dec 1]. Available from: https://www.nytimes.com/2015/09/10/dining/the-daunting-din-readers-react-to-noisy-restaurants.html.

3 Blackwell DL, Lucas JW, Clarke TC. Summary health statistics for U.S. adults: national health interview survey, 2012. Vital Health Stat 2014;10:1–161

4 Carroll YI, Eichwald J, Scinicariello F, Hoffman HJ, Deitchman S, Radke MS, *et al*. Vital Signs: Noise-Induced Hearing Loss Among Adults — United States 2011–2012. MMWR Morb Mortal Wkly Rep. ePub 2017;66:139-44.

5 Goodson S, Hull R. Hyperacusis. American Speech-Language-Hearing Association. Audiology Information Series: Hyperacusis 2015.

6 American Tinnitus Association, Understanding Facts and Causes Page [Internet]. Washington D.C. [Last cited on 2017 Dec 1]. Available from: https://www.ata.org/understanding-facts/causes

7 Noise-Induced Hearing Loss. NIH 2014;14-4233. [Modified 2017 Feb 7, Last cited on 2017 Dec 1]. Available from: https://www.nidcd.nih.gov/health/noise-induced-hearing-loss.

8 Fritschi L., Brown L., Kim R., Schwela D., Kephalopoulos S., editors. Burden of Disease from Environmental Noise—Quantification of Healthy Life Years Lost in Europe. WHO Regional Office for Europe; Copenhagen, Denmark: 2011.

9 Ohrstrom E, Skanberg A, Svensson H, Gidlof-Gunnarsson A. Effects of road traffic noise and the benefit of access to quietness. J Sound Vibrat. 2006;295:40–59.

10 Babisch W. Cardiovascular effects of noise. Noise Health 2011;13:201-4

11 Pyko A, Eriksson C, Oftedal B, Hilding A, Ostenson C, Krog, NH, *et al*. Exposure to traffic noise and markers of obesity. Occup Environ Med 2015.

12 Flamme GA, Stephenson MR, Deiters K, Tatro A, VanGessel D, Geda K, *et al*. Typical noise exposure in daily life. Int J Audiol 2012;51S3-11.

13 Neitzel RL, Gershon RR, McAlexander TP, Magda LA, Pearson JM. Exposures to transit and other sources of noise among New York City residents. Environ Sci Technol 2012;46:500-8.

14 Carroll YI, Eichwald J, Scinicariello F, Hoffman HJ, Deitchman S, Radke MS, *et al*. Vital Signs: Noise-Induced Hearing Loss Among Adults — United States 2011–2012. MMWR Morb Mortal Wkly Rep. ePub 2017;66:139-44.

15 Themann CL, Suter AH, Stephenson MR. National research agenda for the prevention of occupational hearing loss—part 1. Semin Hear 2013;34:145–207.

16 National Academies of Sciences, Engineering, and Medicine. Hearing Health Care for Adults: Priorities for Improving Access and Affordability. Washington, DC: The National Academies Press 2016.

17 Musinguzi, D. The Impact of Restaurant Noise on Customers' Dining Experience in Kowloon, Hong Kong. Intl J of Hospitality & Tourism Systems 2010;3-1:80-5.

18 Dewane, C. Hearing Loss in Older Adults — Its Effect on Mental Health. Social Work Today 2010;10-4:18.

19 Carroll YI, Eichwald J, Scinicariello F, Hoffman HJ, Deitchman S, Radke MS, *et al*. Vital Signs: Noise-Induced Hearing Loss Among Adults — United States 2011–2012. MMWR Morb Mortal Wkly Rep. ePub 2017;66:139-44.

20 Kardous, C. A., Shaw, P. B. Evaluation of smartphone sound measurement applications (apps) using external microphones – A follow-up study. The Journal of the Acoustical Society of America 2016;140(4),186-92.

21 U.S. Environmental Protection Agency, Office of Noise Abatement and Control. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. EPA 1974;Appendix D:Table D-1

22 World Health Organization, Night noise guidelines for Europe. WHO 2009. Available from: http://www.euro.who.int/en/health-topics/environment-and-health/noise/publications.

23 National Institute for Occupational Safety and Health. *Criteria for a Recommended Standard: Occupational noise Exposure*, Cincinnati, OH: 1998.

24 Fink, D. What is a Safe Noise Level for the Public? American Journal of Public Health 2017;107-1.

25 European Agency for Safety and Health at Work. Directive 2003/10/EC of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents. 2003 Feb 6.

26 U.S. Environmental Protection Agency, Office of Noise Abatement and Control. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. EPA 1974;Appendix D:Table D-1.

27 Lebo CP, Smith MF, Mosher ER, Jelonek SJ, Schwind DR, Decker KE, *et al*. Restaurant noise, hearing loss, and hearing aids. Western J of Med 1994;161(1):45-9.

28 Noise and Hearing Loss. NIH Consensus Statement Online 1990;8(1):1-24.

29 Le Prell CG, Hensley BN, Campbell KC, Hall JW , Guire K. Evidence of hearing loss in a normally-hearing college-student population. Int J Audiol 2011;50(Suppl 1):S21–31.

30 Rota-Donahue C, Levey S. Noise-induced hearing loss in the campus. Hear J 2016;69:38–9.