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Analysis of Human Participants in the *Journal of the Audio Engineering Society*

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This paper explores issues of equity, diversity, and inclusion in the Audio Engineering Society. It provides an overview of recent initiatives and publications on the participation of various groups in the audio industry and the Audio Engineering Society community. It also discusses the concept of justice in human research and its relevance to the recruitment of participants in audio studies. The paper analyzes the demographic data of participants in *Journal of the Audio Engineering Society* publications, using a corpus of 134 papers from 2022 to 2024. The results of the meta-analysis reveal that the age and gender distributions of the participants do not reflect the general population. The paper discusses the implications of these findings and concludes by calling for a discussion of best practices for increasing participant diversity in audio research.

0 INTRODUCTION

0.1 Context

This paper explores issues of equity, diversity, and inclusion in the Audio Engineering Society (AES). This brief overview of recent initiatives begins with the creation in December 2016 of the AES Diversity, Equity, and Inclusion Committee [1].

Several papers have since reported on the low representation of various groups in the society and industry overall. Members of the AES Diversity, Equity, and Inclusion Committee performed an analysis of participant identity for people who attended the 154th Convention of the AES, finding that most participants identified as white ("overwhelmingly") and male (70%) [2]. Bridges et al. found that of 210 *Billboard* top-ten charting songs from 2000 to 2020, 96% of credited producers were male [3]. Gaston-Bird et al. combined multiple survey results, including a 2019 survey of AES members and community analyses, to conclude that "...underrepresentation within the field of immersive audio is just as pervasive as it is within the audio industry as a whole" [4].

Other papers have tried to explain the reasons for these imbalances. Gaston-Bird et al. did a high school recruitment activity to study the factors in low female application rates to a recording arts program. The results were not conclusive but showed that female students envisioned themselves in less technical roles [5]. Buckingham and Ronan also examined factors that contributed to imbalance in the industry finding that "...women reported that they were unsuitable for technical and managerial roles...." [6]. Brooks et al. carried out a survey with 387 studio personnel respondents and reported the presence of "...highly significant and systemic gender inequalities within the field...." Their results revealed hostile production environments: serious problems with sexually inappropriate comments, unwanted comments about physical appearance, and challenges to authority, among many other findings [7].

There have also been proposed solutions. McNally and Pras reported in "Audio+," a research forum on "...music production cultures, innovative technologies, and the pressing need for increased equity, diversity and inclusion...." [8]. Mathew et al. outline women's contributions in music technology and production and discuss initiatives to support women in the industry [9].

Outside this brief overview, there have been many other analyses of participation rates, factors contributing to inequality, and examples of support to equity-deserving groups. These publications have focused on participation in the audio industry and the AES community. However,

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the authors believe that there is another important consideration for the AES: human participants recruited for audio research.

0.2 Background

From the context of the authors' institution's home country, the Canadian Research Tri-Council, which provides significant funding for research at Canadian institutions, has guidance related to the sampling of populations for research involving human participants. Specifically, in the statement on *Ethical Conduct for Research Involving Humans*, Chapter 4, "Fairness and Equity in Research Participation," the Tri-Council states that "The principle of Justice holds that particular individuals, groups or communities should neither bear an unfair share of the direct burdens of participating in research, nor should they be unfairly excluded from the potential benefits of research participation" [10]. In the context of the *Journal of the Audio Engineering Society* (*JAES*), the authors propose thinking critically about participants who might be unfairly excluded from the potential benefits of research participation.

In the same policy statement, the Tri-Council also states that "...some groups have been unfairly included in research because they are convenient populations for research" [10]. A brief review of research papers in the AES e-library shows some possible trends that warrant more exploration. In academic settings, some studies use student populations as samples, which might be seen as a convenient population. In corporate settings, some studies use company employees as samples, which might also be seen as a convenient population. If convenient populations are used, they may not represent the general population well. If research outcomes vary across different populations and convenient populations are common, then the overlooked populations may be unjustly deprived of the potential benefits of the research.

From the context of the AES headquarters, The United States Secretary's Advisory Committee on Human Research Protections also uses comparable language. In *Consideration of the Principle of Justice 45 CFR part 46*, the committee advises that "One consequence of injustice, whether it manifests as inappropriate exclusion from participation or as exploitation of "populations of convenience," is the belief that human subjects research serves the interests of the privileged and powerful and therefore perpetuates economic, racial, religious, sexual, gender, and cultural biases" [11]. They also advise that "...even if individual researchers are treating their research subjects fairly, and even if institutional review boards are taking care to assure that subjects are selected fairly within a particular institution, unjust social patterns may nevertheless appear in the overall distribution of the burdens and benefits of research" [11].

Finally, "Both the Belmont Report and the Common rule were primarily reactions to egregious examples of inappropriate inclusion of research subjects (as populations of convenience and/or members of groups vulnerable to exploitation). The result of this focus is an ethically necessary tradition of protections from inappropriate inclusion, but these protections have been imperfectly applied and have not been balanced by equally necessary attention to participation in research and its subsequent benefits" [11].

Examples were collected for how perception may differ across population segments to understand how research benefits might not be equally shared by different groups. One recent example comes from a series of studies on headphone spectral response preferences. In 2015, Olive and Welti reported that "On average, the female listeners preferred about 1 dB less bass and almost 2 dB less treble compared with their male counterpoints" [12]. This finding should be interpreted with caution because the authors mention possible confounding variables and only 11% of the total participant pool was female. They also found that "...younger listeners, on average, preferred more bass and treble in their headphone music reproduction than the older listeners." Additionally, they reported that the "...real deviation in preference occurs in the oldest listening group" [12].

In 2018, Olive et al. reported that the variable "Gender" had a significant effect on the preference ratings of different headphone equalization curves. They also report that "Program and Gender produce smaller effects and interactions with headphones. The effects were small and not the focus of this paper" [13]. In 2019, the same authors reanalyze the data from 2018 with a focus on clustering participants with similar preferences. This resulted in three clusters of people, "Harman target lovers," "more bass lovers," and "less bass lovers" [14]. They note that cluster 3 was mostly "untrained" participants and was skewed toward female and older participants. Cluster 2 skewed toward male, younger, and "trained" participants.

In the context of head-related transfer functions (HRTFs), Christensen investigated in 2015 how ear length changes with age for male and female subjects. They observed that female ear length was relatively stable, but male ear length increased by 1 to 1.5 cm in later years [15]. They reported that this increase could cause +/− 4 to 5 dB variations in different frequency bands of the HRTFs for some sound source directions [15]. In 2019, Kaneko et al. examined ear shape in different population groups. They discovered that "...average ear shape seems to be dependent on the subject's race and gender..." and that "...male ears tend to be larger than female ears...." [16].

In 2001, McTigue explored the effect of artificial reverberation on sound source localization in a nonindividualized binaural context. They found that "Gender differed significantly with respect to distance judgement" and "there were interactions between gender and azimuth (azimuth judgement)" [17].

0.3 Motivation

Based on the above studies, some experiments in sound perception showed significant differences in the results when grouping participants by some demographic variables. This, along with the possibility of underrepresentation of some groups in experiments, points to questions

about the demographic data of participants reported in *JAES* research papers. This appears to be a relatively unexplored area of inquiry. A relevant example comes from a conference paper, "Unveiling the Female Ear," where Pras, Brereton, and Ambrose report on a study of a collection of papers. The most relevant was "Corpus A", which contained all the papers cited in [18] published by the Institute of Electrical and Electronics Engineers. A meta-analysis of the collection led to these results [19]:

- Perceptual testing was reported in 33 works cited.
- The gender distribution of participants was not reported in 48% of those works.
- All-male participants were reported in 21% of those works.
- No works reported all-female participants.
- Mixed-gender groups were reported in 30% of those works.
- The total number of participants in all the studies in the corpus was almost 500, and only 9.7% of those participants were known to be female based in the data reported.
- None of the papers reported whether gender affected the main findings.

The research project reported here aims to answer the following questions for papers from the *JAES*:

- What is the number of papers that include human participants?
- What are the common descriptive variables for listening-test participants?
- Do those variables match the general population's distribution?
- Are specific population subsets or the general population studied?
- What is the typical number of participants used?
- How many studies use convenient populations for their sample? How can those populations be characterized?

1 METHODOLOGY

1.1 Corpus

This study used a corpus of all "papers" published in the *JAES* from volume 70, issue 1/2 to volume 72, issue 4, a total of 127 papers from years 2022 to 2024. Other types of articles were not included ("Communications," "Engineering Reports," etc.). The papers were downloaded as PDFs from the AES E-Library with a member account. A database was created with the citation metadata and the analysis parameters below.

1.2 Meta-analysis

The meta-analysis of the corpus involved a research team member reading each paper, extracting the relevant data, and adding it to the database. The analysis was flexible, so the number of data points/columns could initially change over time. The aim was to collect as much data as possible about the human participants in experiments while keeping a consistent data format for the whole corpus. When new columns or data points were added to the database, previously analyzed papers were reanalyzed on those points.

After analyzing the first 70 papers, the research team finalized the data points to be collected. The most common variables reported about human participants were the number of participants, their experience profile, age and gender, and whether listeners had "normal hearing." The level of detail and the type of statistics varied in each publication. The final data points are displayed in Table 1.

1.3 Exceptions and Special Cases

- When a publication presented the findings of more than one study with human participants, they were separated into multiple entries in the database, one for each study. The reason for this decision was to allow for accurate recording of the data presented without having to aggregate studies.
- When numeric values were given with a range, they were recorded as exact numeric values. For example, 5+ years was recorded as 5 years. Twenty-one to 25 years was recorded as 23 years. The reason for deciding to convert all data to the same numeric format was so that the data could be aggregated across all studies. In making the translation from ranges to exact numeric values, the median value of a range was used when possible. For ranges without two endpoints (ex: 5+ years), the decision was more difficult. Unfortunately, when ranges are provided without endpoints, the distribution of the underlying data is not known, so it is difficult to decide on a central tendency representation. Therefore, in those cases, the only known end-point was selected as the representative value of the range.
- For some studies, the numeric values were not given in the same format as the database but could be calculated to match the format of the database. For example, a study may have reported 40% female participants. In this case, the number of female participants was derived from the percentage and the total number of participants given.

2 ANALYSIS

Out of all the entries in the database (n = 141), 54% of them (n = 76) presented the outcomes of an experiment with human participants [20–81]. The following analysis focuses on that subset of studies. (The difference in the number of database entries and works cited stems from the exception and special case discussed above: "when a publication presented the findings of more than one study with human participants, they were separated into multiple entries in the database, one for each study.")

Table 1. The data points analyzed for the corpus of papers.

Name	Type	Values	Comments
Human participants	Categorical	True, false	Whether or not the paper reported on a study using human participants.
Number of participants	Numerical		The total number of participants recruited for the study.
Participant experience Description	Categorical	Audio engineer/producer, expert listener, audio student, musician, naïve, listening tests, spatial audio, researcher, artistic director, acoustics*	Some participant groups were reported as having specific previous experience. The experience description was coded into these categories.
Participant experience years	Numerical	Years	The average number of years of experience (of the type labeled above) across all participants.
Population of convenience	Categorical	True, false	If the population sampled was a population of convenience.†
Participation type	Categorical	Listening test, interview, questionnaire/survey, HRTF measurement, musician, student	How the participants participated in the experiment. The experiment described in the paper was coded into these categories.
Gender (woman)	Numerical		The total number of participants identifying as a woman.
Gender (man)	Numerical		The total number of participants identifying as a man.
Gender (unspecified)	Numerical		The total number of participants reporting an unspecified gender.‡
Age (mean)	Numerical		The average age of all participants.
Age (SD)	Numerical		The standard deviation of the age of all participants.
Age (minimum)	Numerical		The lowest age value reported in the study.
Age (maximum)	Numerical		The highest age value reported in the study.
Normal hearing	Categorical	True, false	Whether the participants were reported as having "normal hearing."§

Note. "NA" was entered if the data were not available.
*The category "listening tests" was for participant groups with previous experience in listening tests/experiments. The category "spatial audio" was for participant groups with previous experience listening to immersive audio. The category "acoustics" was for participant groups with acoustics experience.
†A "population of convenience" was defined as a sample of people drawn from a part of the population that is easy to access. In this case, "easy to access" was defined as most of the sample being from the researcher's institution, company, close professional network, or close personal network.
‡The term "unspecified" is the term used by several papers in the corpus and was a selection option presented to participants. For example, participants were given the choice between three options on a survey: "man," "woman," or "unspecified."
§The term "normal hearing" is a common but not exclusive term found in the papers. The way this information was collected varied in the studies in the corpus. For example, some studies asked participants to self-report if they had "normal hearing" and some studies did audiometric tests on their participants to measure their hearing sensitivity at different frequencies.

2.1 Number of Participants

Most studies (97%) stated the number of participants. The distribution of the number of participants used in each study is shown in Fig. 1. The median number of participants used was 16 (25th to 75th percentile = 11 to 23).

2.2 Participant Experience

Seventy-four percent of studies recruited participants from a specific population subset. Sixty-five percent could be regarded as recruiting participants from a population of "experienced listeners." The breakdown of those participant groups is displayed in Table 2. Some of these studies (n = 15) also reported the average number of years of experience participants had. The median of these averages was 9 years of experience (25th to 75th percentile = 4 to 11).

2.3 Population of Convenience

The work here labels a study as recruiting from a population of convenience if the sample of people was drawn from a part of the population that was easy to access. In this case, "easy to access" was defined as most of the sample being from the researcher's institution, company, close professional network, or close personal network. Twenty-six percent of the studies were labeled as using a population of convenience, 4% of studies were confirmed as not using a population of convenience, and there was not enough information to make a determination for the remaining studies.

2.4 Experiment Type

For the experiments that included human participants, the participant type was recorded. Most of the studies had listeners take a "listening test." The percentage distribution is shown in Table 3.

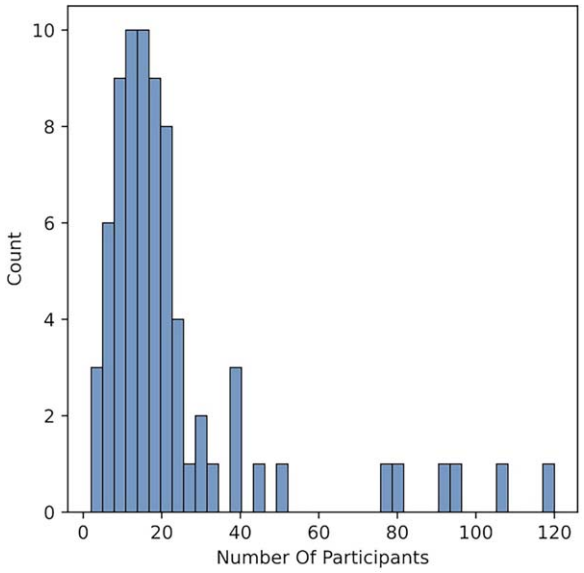


Fig. 1. A histogram showing the distribution of the number of participants used in each study.

Table 2. Percentage of studies recruiting from a specific group of listeners.

Population group	Percentage
No specific population	26%
Audio engineers/producers	14%
Naïve	9%
Audio engineers/producers + audio student	7%
Expert listeners	5%
Musicians	5%
Audio engineers/producers + musicians	3%
Expert listeners + listening tests + researchers	3%
Audio engineer/producers + expert listeners + audio students + listening tests	3%
Audio students + spatial audio	3%
Researchers	3%
Remaining combinations of experience types*	19%

*The remaining 19% of studies recruited participants with experience in multiple categories (e.g., experience A + experience B + experience C). These remaining combinations were aggregated into one table entry because there are many of them and only constitute a very small percentage each.

2.5 Gender and Age

It was not clear whether all studies were using a consistent definition of the term "gender," or if it may have also been associated with the meaning of "sex." The following results are reported using the term "gender." Statistics on the gender distribution were reported by 55% of the studies involving human participants. Most studies used the binary categories of "woman/female" and "man/male," but n = 3 studies included a third category of "unspecified." When combining all participants with known gender into one large pool, 34% are reported as women, 66% as men, and 0.1% as unspecified. Some observations at a per-study level are that some studies had only men participants and none had only women participants.

Table 3. Percentage of studies that used the following experiment types.

Experiment type	Percentage
Listening test	74%
Student education	8%
Questionnaire/survey	7%
Interview	3%
HRTF measurement	1%
Musician performance	1%

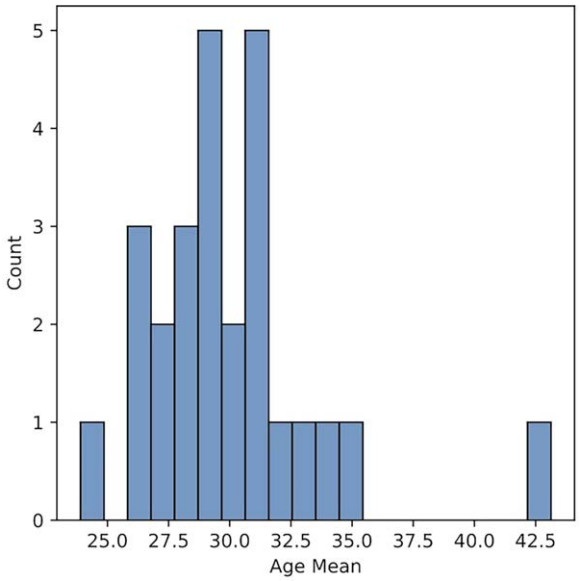


Fig. 2. A histogram showing the distribution of mean ages for each study that provided that data.

Out of the studies that involved humans, 50% of them reported statistics about the age of participants. Sometimes the statistics presented were mean/standard deviation (SD), and other times they were minimum/maximum or age bins. Fig. 2 shows the distribution of mean ages from the studies that reported them (34%). The median of the mean ages was 30 years old (25th to 75th percentile = 28 to 31 years) with a median of the SDs of 5 years.

Thirty-nine percent of studies reported the minimum and maximum age of participants. The median of the minimum age was 21 years (25th to 75th percentile = 20 to 24 years), and the median of the maximum age was 42 years (25th to 75th percentile = 35 to 49 years).

2.6 "Normal Hearing"

Out of the studies that conducted an experiment with human participants, 62% did not report on the participants' hearing. Thirty-six percent reported participants all had "normal hearing," and 2% reported some participants without "normal hearing."

3 DISCUSSION

Generally, recent studies in the *JAES* provide very little information about human participants involved in ex-

periments. The analysis above shows that only around half of publications with participants report more than the total number of people involved. For example, the entire corpus consists of 1719 participants, and the gender is unreported for 799 people (46%). When information is reported, it rarely includes more than the basic details of gender identity, age, and whether participants were from a population with specific prior experience.

It is also evident from this meta-analysis that audio research recently published in the *JAES* does not represent the population fairly. This discussion will compare the population statistics of Canada, where the authors' institution is based, with the analysis results. According to 2021 Canadian census data, the population's gender identity is 49.99% women, 49.99% men, and 0.14% nonbinary [82, 83]. The above analysis reveals a lack of women (34%), an excess of men (66%), and no studies that included the option "nonbinary." Some studies included the option "unspecified," but the authors did not consider that equivalent to "nonbinary." The analysis also found that 5 studies had all men participants, and no studies had all women participants.

According to 2021 Canadian census data, the average age of the population is 41.6 years (SD = 23.1) [83]. However, it might be more appropriate to look at the average age of people over 18 years old. Most studies in the corpus involved adult human participants, as shown by the median of the minimum ages reported (21.0 years). In Canada, the average age of people 18 years and older is 49.5 years (SD = 18.4) [84]. No matter which population statistic that is used, participants in the experiments in this corpus are much younger (30 years) and have a much smaller range of ages (SD = 5 years).

This information leads to the question of what caused the unequal representation in age and gender. The following hypothesis is used. In this corpus of papers, 26% of the studies were identified as using a population of convenience. This term is defined as "the majority of the sample being taken from people associated with the researcher's institution, company, close professional network, or close personal network." For studies using human participants, the primary affiliation of the first author was a university for 88% of the studies and a company for the remaining 12%. It is hypothesized here that when a researcher recruits from a convenient population in those contexts, it would often be students/staff and employees, respectively.

The introduction to this paper mentioned known gender imbalances in the industry and some examples of gender imbalance in audio programs at universities. Student populations also result in natural age imbalances, and staff would likely skew toward common working ages. By sampling from populations of convenience, researchers might be sampling from groups of people that do not match the gender and age distributions of the general population.

A similar hypothesis could be made when considering sampling of "experienced listeners," which 57% of the experiments in this corpus did. If the pool of experienced listeners does not match the demographics of the general population, the expectation here is that the participants in the study will not match the general population statistics either.

In presenting these findings, the authors do not intend to suggest that each individual audio study needs to recruit participants that match the demographics of the general population. For example, studying specific groups, like women or children, would help balance the overall representation of all people in *JAES* studies. However, returning to the concept of fairness as discussed in the SEC. 0.2 (Background) above, if in aggregate across all audio studies some human groups are not equally represented, then those groups are systemically excluded from the benefits of overall research participation.

Another topic to consider is the selection of participants based on their hearing attributes. Thirty-eight percent of papers in the corpus reported asking or measuring listeners' hearing. Almost all of those papers stated that the listeners in the experiments had "normal hearing." The different methods used to collect this data make it hard to assess reliability, combine, and interpret, but they might still be useful for comparison. Statistics Canada reports that "38% of adults aged 20 to 79 have hearing loss" and that 60% of Canadians aged 19 to 79 have either hearing loss, tinnitus, or both [84]. The above metrics vary a lot by age, but this suggests that either the corpus participants were pre/postscreened for "normal hearing," or that the sampling methods resulted in groups with low rates of self-known/measurable hearing loss. With these preliminary findings, it is hoped that future work can examine pre/postscreening processes in listening tests to evaluate their potential impact on recruiting diverse and representative samples of populations.

4 CONCLUSION

A meta-analysis was undertaken of 127 papers published in the *JAES* from 2022 to 2024. A database was set up to record data points for each paper related to the human participants that took part in audio experiments. The data points gathered for each paper (when available) included the number of participants, experience profile, age, gender, and whether listeners had "normal hearing." The following conclusions were drawn from the analysis of the database:

- Out of the papers in the corpus, 76 studies (54%) presented the results of an experiment with human participants.
- In general, studies did not provide much information about the human participants who took part in the experiments. When information was provided, it usually only covered the basics of gender identity, age, and whether participants had some specific prior experience.
- The median number of participants involved in a study was 16 (25th to 75th percentile = 11 to 23).
- The age and gender distributions of the participants did not reflect the general Canadian population. There were fewer females, more males, younger on average, and a smaller range of ages.

- Sixty-five percent of studies said they recruited "experienced listeners."
- Twenty-six percent of studies were found to sample from "populations of convenience," often students, staff, or employees linked to the researcher institution.

This research project aimed to find out whether the human participants who took part in research reported in the *JAES* represented the general population. In aggregate, it is clear that some people are systemically not included in the benefits of research participation; this is an issue of fairness. Also, some of the experiments in sound perception covered in the literature review showed significant differences between different demographic groupings. So, it might also be an issue of generalization. The authors support continued discussions around best practices for increasing participant diversity in population samples. They also support guidelines and requirements related to participant recruitment for research published by the AES. "Issues of justice inspire demands for quick action, but it is far easier to identify problems than to craft meaningful and sustainable solutions" [11]. The authors believe that this study has contributed to the identification of a problem and look forward to contributing to solutions with future work.

5 ACKNOWLEDGMENT

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