# Examining the Interplay of Socioeconomic Status and Hearing Loss on Neurocognition in Pediatric Cancer Survivors

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**All figures were created by student researcher unless otherwise stated**

**ABSTRACT**

There are many factors that can influence a pediatric cancer survivor's quality of life following remission. For instance, cisplatin– a type of chemotherapy used to treat cancer– has been found to cause hearing loss in cancer survivors. Furthermore, a 2024 study found that low socioeconomic status (SES) was associated with worse neurocognitive outcomes in patients, including low crystalized verbal intelligence scores. Due to these adverse effects and dangers to neurodevelopment, this study aimed to examine the interplay of SES and hearing loss on neurocognition in pediatric cancer survivors. SES was determined by whether the participant used public or private health insurance, hearing loss was determined by whether the participant was recommended hearing aids, and neurocognition was determined using crystalized verbal intelligence and functional communication scores. Additionally, the amount of craniospinal irradiation received (centigrays) and the age at initial cancer diagnosis (months) were controlled for during the analysis. Following IRB exemption, data was extracted from 105 medical records from participants receiving care at the same pediatric hospital. Data analysis was then conducted on de-identified data with One-Way Analyses of Covariance (ANCOVAs), Two-Way ANCOVAs, and a Chi-Square Test for Independence. The results showed that insurance type had a significant impact on crystalized verbal intelligence ($p$ = .001), and a relationship approaching significance with functional communication ($p$ = .053). However, when hearing loss was added as an independent variable, there was a non-significant effect on neurocognition. This indicated that SES was a stronger predictor than hearing loss of neurocognition. There was also a non-significant relationship between the patient's insurance type and their likelihood of being recommended hearing aids. Thus, SES had a greater impact on patients' neurocognition than their hearing. Overall, this study can raise awareness of the negative effects that lack of equity in the medical field has on patients.

## TABLE OF CONTENTS

## INTRODUCTION

*Cisplatin-Induced Hearing Loss*

Cisplatin is an alkylating antineoplastic agent used to treat various types of cancer. A frequent side effect of this platinum-based chemotherapy is ototoxicity, or damage to the ears as a result of the medication. Ototoxicity may lead to irreversible sensorineural hearing loss, especially in pediatric patients (Brock et al., 2018). According to a report from the Children's Oncology Group, 47% of children treated with < 400 $mg/m^2$ of cisplatin had severe hearing loss when measured using the third version of the Common Terminology Criteria for Adverse Events (CTCAEv3) scale, and the likelihood increases in certain patient subsets, such as younger age, exposure to other chemotherapy drugs, higher doses of cisplatin, and cranial irradiation (Landier et al., 2014).

In 2022, the U.S. Food and Drug Administration approved the use of sodium thiosulfate as an otoprotectant– a treatment used to protect hearing– to reduce the likelihood of cisplatin-induced hearing loss in pediatric patients with localized, non-metastatic, solid tumors (FDA, 2024). However, this otoprotectant was only proven effective at reducing the cumulative incidence of hearing loss by approximately 50% (Freyer et al., 2016). Also, it has not been approved for all patients who are susceptible to ototoxicity from cisplatin. Thus, cisplatin-induced hearing loss remains an issue for many pediatric cancer survivors and will continue to impact numerous areas of their lives.

*Impacts of Hearing Loss on Neurocognition*

Hearing loss can have long-term impacts on people and their quality of life in several ways, including by harming the patient's neurocognition. Pediatric patients are highly susceptible to this effect because they are still in the process of developing many necessary life skills and functions (Çelik et al., 2021). The impact of hearing loss on neurocognition was demonstrated in a systematic review, which found that children with cochlear implants or hearing aids had significantly lower scores in many cognitive domains when compared with their normal-hearing peers (Lima et al., 2023).

Furthermore, ototoxicity has been shown to result in reading difficulties in pediatric survivors of embryonal brain tumors. Patients in this population with severe sensorineural hearing loss were compared to peers with normal hearing and mild-to-moderate hearing loss. The participants with severe hearing loss had significantly lower scores when tested on their phonemic skills, phonetic decoding, reading comprehension, and speed of information processing ($p \leq .05$), and their scores in these areas had a sharper decline over time (Olivier et al., 2019).

Additionally, hearing loss impacts language development skills, as hearing is a primary component of spoken language (Lovcevic et al., 2022). One example of these language skills, functional communication (FC), is parent-reported and measures ability to share feelings and basic needs effectively (Pearson, 2016). A study from 2024 tested whether FC could be used to predict crystalized verbal intelligence (CVI) in pediatric cancer survivors with cisplatin-induced hearing loss (Blackman, 2024). CVI refers to the accumulation of knowledge and skills through written and spoken language, and is determined through neuropsychological testing (Pearson, 2020). Although the relationship between FC and CVI was not significant, the study found that the median income within the patient's zip code had a significant impact on CVI (Blackman, 2024). The results from this past research motivated the current study to further examine the impacts of socioeconomic status (SES) on CVI and FC in cancer survivors.

### *Role of Socioeconomic Status*

A patient's socioeconomic status has been found to impact their health in a myriad of ways, including their neurocognition. When comparing brain tumor survivors with varying SES, patients with low SES received worse scores on cognitive tests on average than patients with high SES. Additionally, it was found that the discrepancy between the different SES groups' average intelligence quotients, reading skills, and math skills widened over time after exposure to radiation therapy (Torres et al., 2021).

Another study found that individuals with hearing loss are more likely to be unemployed, have lower educational attainment, and have lower incomes. It also found that individuals with hearing loss and low SES were less likely to receive hearing care or wear hearing aids compared to individuals with hearing loss and high SES (Malcolm et al., 2023). Clearly, hearing loss can impact a person's SES, and a person's SES can impact their ability to receive resources to address their hearing loss, leading to a challenging cycle for those who wish to pursue hearing aids or cochlear implants. This dilemma is supported by the idea that hearing care is a "catastrophic expense" for 77% of Americans with functional hearing loss (Jilla et al., 2020).

### *Health Insurance and Socioeconomic Status*

Socioeconomic status can be effectively predicted by an individual's type of health insurance coverage: public or private. Public insurance is run by the government and is aimed at providing affordable healthcare to all citizens. Alternatively, private insurance is offered by individual corporations, and while it may be more expensive, it can offer notable benefits to the patient (Chan, 2022). In 2021, Lee et al. found that individuals with high income were more likely to have private insurance (51.3–78.2% likely for private vs. 8.9–25.8% likely for public), while individuals with low income were more likely to have public insurance (39.0–54.5% likely for public vs. 4.9–17.4% likely for private). The same study also found that race/ethnicity was independently associated with lack of insurance, and an analysis using a combined variable of income and race showed that low-income minorities with bad health were 68% less likely to be insured than high-income white individuals with good health (Lee et al., 2021). Evidently, health insurance can logically be used as an indicator of SES.

### *Gap in the Knowledge and Purpose*

This study aimed to examine the interplay between SES (as determined by type of health insurance) and hearing loss on neurocognition in pediatric cancer survivors. Limited information is currently known about the relationships among audiology, neuropsychology, and SES. Research has been conducted on each of these variables independently, and on the interactions between two of the three variables at a time, but not yet on all three. Furthermore, research on this topic rarely focuses on cancer survivors, a population with unique struggles and characteristics.

In addition to this study's goal of bridging the gap between audiology, oncology, and neuropsychology, the study was also intended to improve the understanding of mechanisms by which cognition is impacted in pediatric cancer survivors by examining hearing loss and SES. The research had an objective of determining the impacts of SES on neurocognition, as well as the effects of the interaction between hearing loss and SES. This information can help fill the gap in the knowledge surrounding the neurocognitive effects of ototoxicity, allowing researchers and medical professionals to address this issue more accurately.

Lastly, by unveiling a relationship between SES, hearing loss, and neurocognition, this study will highlight the need for equity in the healthcare system. This is a key issue that society is grappling with, and advocacy for patients and their families may increase with the results of this study.

### *Research Questions*

1) How do socioeconomic status and hearing ability affect crystalized verbal intelligence and functional communication scores for pediatric cancer survivors?
2) Is there an interaction effect of low socioeconomic status and hearing loss on neurocognitive outcomes?

### *Hypotheses*

1) Cancer survivors with low socioeconomic status and hearing loss will have worse CVI and FC t-scores when compared to peers with high socioeconomic status and/or average hearing.
2) An interaction effect exists that causes cancer survivors with low socioeconomic status and hearing loss to have worse neurocognitive scores than any other group.

## METHODOLOGY

*Participants*

This study included 105 participants, all of whom were pediatric cancer survivors that received cancer treatment at an urban children's hospital in Los Angeles, California. After the study was declared exempt by the IRB, relevant medical data was extracted, de-identified, and entered into a secure online database.

Of the 105 participants, 51% were female and 49% were male. Additionally, 55% of participants were Hispanic or Latinx, 25% of participants were Caucasian (non-Hispanic), 9% of participants were Asian, 5% of participants were multiracial, 4% of participants were Black, 2% of participants were Native Hawaiian/Pacific Islander, and the background of 1% of participants was unknown. At the time of each participant's initial cancer diagnosis, the minimum age was 2 months, the maximum age was 198 months, and the median age was 54 months. Furthermore, 64% of participants had a brain tumor, and 45% of participants received craniospinal irradiation. The most common type of tumor was medulloblastoma, with 48% of participants having this diagnosis, and there were a total of 15 different cancer types represented in this study.

*Neurocognitive Measures*

Crystalized verbal intelligence was determined using the fifth edition of the Wechsler Intelligence Scale for Children (WISC-V) from Pearson Assessments. This test was conducted by a medical professional during a patient's post-treatment neuropsychological evaluation. The results of this test were presented as a t-score with a mean of 50 and a standard deviation of 10. Higher scores signified a better performance during the evaluation.

Functional communication was determined using either the "Functional Communication" scale of the Behavior Assessment System for Children (BASC), or if this test was not administered to the participant, the "Communication" scale of the Adaptive Behavior Assessment System (ABAS). The results for BASC were presented as t-scores with a mean of 50 and a standard deviation of 10. The ABAS scores were originally presented as scaled scores, but later converted to t-scores using a psychometric conversion table to allow for easier interpretation and analysis. Like the CVI scores, this variable was entered into the patient's medical chart upon testing, and later mined for during the study.

*Variables*

The independent variables for this study were socioeconomic status and hearing loss. SES was characterized by whether the participant used public (n = 72) or private (n = 33) insurance. Hearing loss was determined by whether the participant was (n = 47) or was not (n = 58) recommended a hearing aid by their audiologist before the date of their neuropsychological evaluation. The dependent variables were CVI and FC t-scores. This study also controlled for the amount of craniospinal irradiation received (centigrays) and the age at initial cancer diagnosis (months) by setting these variables as covariates during the data analysis.

*Data Collection*

Data was collected from participants by licensed medical professionals in the fields of neuropsychology, oncology, and audiology. This data was then gathered from the participants' digital medical records, de-identified, and entered in a secure online database created via Microsoft Excel. Approval to participate in this study was granted for researchers on the condition that they passed certification courses on good clinical practice and human research ethics. The research complied with HIPAA laws at all times. All identifiable data was encrypted and password-protected, and anonymized prior to being exported for data analysis.

*Data Analysis*

After data for all 105 participants was recorded, the database was converted into a CSV file and exported to IBM Statistical Package for the Social Sciences (SPSS) Statistics (IBM SPSS, 2022). Descriptive statistics were calculated to summarize the data set, and the following statistical analyses were performed using SPSS.

I. <u>One-Way ANCOVAs</u>

When analyzing the data, several One-Way Analyses of Covariance (ANCOVAs) were run to determine the statistical variance between groups while controlling for additional variables, known as covariates. This test was selected because it allowed for the examination of the relationships between insurance type, hearing status, and neurocognition. Additionally, One-Way ANCOVAs ensure that any potential effects of covariates are mitigated, making this test a better option for the study than an Analysis of Variance (ANOVA).

One-Way ANCOVAs rely on five key assumptions being met by the data. These assumptions were tested before continuing with the data analysis, and include:

1. Covariates were measured prior to treatment or experimentation.
2. Covariates were measured reliably.
3. Covariates correlate with the dependent variable but not with each other.
4. The relationship between covariates and the dependent variable is linear.

5. The relationship between covariates and the dependent variable is homogeneous across all groups.

The covariances for all ANCOVAs in this study were 1) the amount of craniospinal irradiation received by the participant (centigrays); and 2) the age at initial cancer diagnosis (months). The One-Way ANCOVAs conducted for this research are detailed below:

a. Effect of socioeconomic status on crystalized verbal intelligence
    - Independent variable: insurance type
    - Dependent variable: CVI t-score
b. Effect of socioeconomic status on functional communication
    - Independent variable: insurance type
    - Dependent variable: FC t-score

Before the next two One-Way ANCOVAs were conducted, the participants were divided into four socioeconomic/hearing groups. These groups were: 1) private insurance without hearing loss; 2) private insurance with hearing loss; 3) public insurance without hearing loss; and 4) public insurance with hearing loss. The details of the One-Way ANCOVAs conducted with these groupings are stated below:

c. Effect of socioeconomic/hearing group on crystalized verbal intelligence
    - Independent variable: socioeconomic/hearing group 1-4
    - Dependent variable: CVI t-score
d. Effect of socioeconomic/hearing group on functional communication
    - Independent variable: socioeconomic/hearing group 1-4
    - Dependent variable: FC t-score

II. Two-Way ANCOVAs

Two-Way ANCOVAs are used when there are multiple independent variables. In this study, Two-Way ANCOVAs were conducted to examine the effects of the interaction of socioeconomic status and hearing loss on neurocognition. The same assumptions that were tested for the One-Way ANCOVAs were applied, and the covariates remained the amount of craniospinal irradiation and the age at cancer diagnosis. All the Two-Way ANCOVAs conducted for the study are listed below:

a. Effect of socioeconomic status and hearing loss on crystallized verbal intelligence
    - Independent variables: insurance type and hearing aid recommendation
    - Dependent variable: CVI t-score
b. Effect of socioeconomic status and hearing loss on functional communication
    - Independent variables: insurance type and hearing aid recommendation

- Dependent variable: FC t-score

III. Chi-Square Test for Independence

A Chi-Square Test for Independence demonstrates the relationship between two categorical variables. For this study, the two variables were the type of insurance and whether or not a hearing aid was recommended. By choosing to conduct this analysis, the rate of hearing loss for different socioeconomic statuses was explored.

**RESULTS**

I. One-Way ANCOVAs

**Figure 1** shows the results of the first One-Way ANCOVA, with insurance type as the independent variable and crystalized verbal intelligence as the dependent variable. After adjusting for craniospinal irradiation and age, there was a significant difference between CVI scores for different insurance types, $F(1, 75) = 11.455$, $p = .001$, partial eta squared = .132.

**Tests of Between-Subjects Effects**

Dependent Variable: CVI

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 1716.089[a] | 3 | 572.030 | 5.496 | .002 | .180 |
| Intercept | 39376.951 | 1 | 39376.951 | 378.330 | <.001 | .835 |
| CSI | 56.861 | 1 | 56.861 | .546 | .462 | .007 |
| Dx.Age | 518.877 | 1 | 518.877 | 4.985 | .029 | .062 |
| Insurance | 1192.257 | 1 | 1192.257 | 11.455 | .001 | .132 |
| Error | 7806.063 | 75 | 104.081 | | | |
| Total | 170850.000 | 79 | | | | |
| Corrected Total | 9522.152 | 78 | | | | |

a. R Squared = .180 (Adjusted R Squared = .147)

**Figure 1: One-Way ANCOVA results showing that insurance type had a significant effect on crystalized verbal intelligence ($p = .001$)**

**Figure 2** shows the results of the second One-Way ANCOVA, with insurance type as the independent variable and functional communication as the dependent variable. After adjusting for craniospinal irradiation and age, there was not a significant difference between FC scores for different insurance types, $F(1, 84) = 3.853$, $p = .053$, partial eta squared = .044.

**Tests of Between-Subjects Effects**

Dependent Variable: FC

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 1024.371[a] | 3 | 341.457 | 3.014 | .034 | .097 |
| Intercept | 69549.344 | 1 | 69549.344 | 613.971 | <.001 | .880 |
| CSI | 421.636 | 1 | 421.636 | 3.722 | .057 | .042 |
| Dx.Age | 6.060 | 1 | 6.060 | .053 | .818 | .001 |
| Insurance | 436.512 | 1 | 436.512 | 3.853 | .053 | .044 |
| Error | 9515.345 | 84 | 113.278 | | | |
| Total | 190273.000 | 88 | | | | |
| Corrected Total | 10539.716 | 87 | | | | |

a. R Squared = .097 (Adjusted R Squared = .065)

**Figure 2: One-Way ANCOVA results showing that insurance type had a non-significant effect on functional communication (*p* = .053)**

**Figure 3** shows the results of the third One-Way ANCOVA, with socioeconomic/hearing group as the independent variable and crystalized verbal intelligence as the dependent variable. After adjusting for craniospinal irradiation and age, there was not a significant difference between CVI scores for different groups, $F(3, 77) = 2.318$, $p = .082$, partial eta squared = .083.

**Tests of Between-Subjects Effects**

Dependent Variable: CVI

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 1202.551[a] | 5 | 240.510 | 2.829 | .021 | .155 |
| Intercept | 36914.846 | 1 | 36914.846 | 434.219 | <.001 | .849 |
| CSI | 51.872 | 1 | 51.872 | .610 | .437 | .008 |
| Dx.Age | 398.824 | 1 | 398.824 | 4.691 | .033 | .057 |
| HLInsGrp | 591.169 | 3 | 197.056 | 2.318 | .082 | .083 |
| Error | 6546.099 | 77 | 85.014 | | | |
| Total | 170113.000 | 83 | | | | |
| Corrected Total | 7748.651 | 82 | | | | |

a. R Squared = .155 (Adjusted R Squared = .100)

**Figure 3: One-Way ANCOVA results showing that socioeconomic/hearing group had a non-significant effect on crystalized verbal intelligence (*p* = .082)**

**Figure 4** shows the results of the fourth One-Way ANCOVA, with socioeconomic/hearing group as the independent variable and functional communication as the dependent variable. After adjusting for craniospinal irradiation and age, there was not a significant difference between FC scores for different groups, $F(3, 84) = 1.634$, $p = .188$, partial eta squared = .055.

**Tests of Between-Subjects Effects**

Dependent Variable: FC

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 1142.801[a] | 5 | 228.560 | 1.970 | .091 | .105 |
| Intercept | 69221.428 | 1 | 69221.428 | 596.717 | <.001 | .877 |
| CSI | 326.795 | 1 | 326.795 | 2.817 | .097 | .032 |
| Dx.Age | 68.654 | 1 | 68.654 | .592 | .444 | .007 |
| HLInsGrp | 568.717 | 3 | 189.572 | 1.634 | .188 | .055 |
| Error | 9744.321 | 84 | 116.004 | | | |
| Total | 194309.000 | 90 | | | | |
| Corrected Total | 10887.122 | 89 | | | | |

a. R Squared = .105 (Adjusted R Squared = .052)

**Figure 4: One-Way ANCOVA results showing that socioeconomic/hearing group had a non-significant effect on functional communication (*p* = .188)**

II. Two-Way ANCOVAs

**Figure 5** shows the results of the first Two-Way ANCOVA, with insurance type and hearing loss as independent variables, and crystalized verbal intelligence as the dependent variable. After adjusting for craniospinal irradiation and age, there was a non-significant interaction effect, $F(1, 73) = .848$, $p = .360$, partial eta squared = .011. There also was no significant difference between CVI scores for participants with and without hearing loss, $F(1, 73) = .633$, $p = .429$, partial eta squared = .009. However, there was a significant difference between CVI scores for participants with public and private insurance, $F(1, 73) = 12.086$, $p < .001$, partial eta squared = .142.

**Tests of Between-Subjects Effects**

Dependent Variable: CVI

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 1821.747[a] | 5 | 364.349 | 3.454 | .007 | .191 |
| Intercept | 38614.239 | 1 | 38614.239 | 366.064 | <.001 | .834 |
| CSI | 48.575 | 1 | 48.575 | .460 | .500 | .006 |
| Dx.Age | 511.482 | 1 | 511.482 | 4.849 | .031 | .062 |
| Insurance | 1274.874 | 1 | 1274.874 | 12.086 | <.001 | .142 |
| HARec | 66.722 | 1 | 66.722 | .633 | .429 | .009 |
| Insurance * HARec | 89.400 | 1 | 89.400 | .848 | .360 | .011 |
| Error | 7700.405 | 73 | 105.485 | | | |
| Total | 170850.000 | 79 | | | | |
| Corrected Total | 9522.152 | 78 | | | | |

a. R Squared = .191 (Adjusted R Squared = .136)

**Figure 5: Two-Way ANCOVA results showing that there was a non-significant interaction effect between insurance type and hearing loss on crystalized verbal intelligence (*p* = .360), a non-significant effect of**

**hearing loss on crystalized verbal intelligence (*p* = .429), and a significant effect of insurance type on crystalized verbal intelligence (*p* < .001)**

**Figure 6** shows the results of the second Two-Way ANCOVA, with insurance type and hearing loss as independent variables, and functional communication as the dependent variable. After adjusting for craniospinal irradiation and age, there was a non-significant interaction effect, $F(1, 82) = .030$, $p = .864$, partial eta squared = .000. There also was no significant difference between FC scores for participants with and without hearing loss, $F(1, 82) = 1.067$, $p = .305$, partial eta squared = .013, or between FC scores for participants with public and private insurance, $F(1, 82) = 2.540$, $p = .115$, partial eta squared = .030.

**Tests of Between-Subjects Effects**

**Dependent Variable: FC**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 1150.108[a] | 5 | 230.022 | 2.009 | .086 | .109 |
| Intercept | 66710.712 | 1 | 66710.712 | 582.589 | <.001 | .877 |
| CSI | 395.350 | 1 | 395.350 | 3.453 | .067 | .040 |
| Dx.Age | 27.283 | 1 | 27.283 | .238 | .627 | .003 |
| Insurance | 290.797 | 1 | 290.797 | 2.540 | .115 | .030 |
| HARec | 122.124 | 1 | 122.124 | 1.067 | .305 | .013 |
| Insurance * HARec | 3.385 | 1 | 3.385 | .030 | .864 | .000 |
| Error | 9389.608 | 82 | 114.507 | | | |
| Total | 190273.000 | 88 | | | | |
| Corrected Total | 10539.716 | 87 | | | | |

a. R Squared = .109 (Adjusted R Squared = .055)

**Figure 6: Two-Way ANCOVA results showing that there was a non-significant interaction effect between insurance type and hearing loss on functional communication (*p* = .864), a non-significant effect of hearing loss on functional communication (*p* = .305), and a non-significant effect of insurance type on functional communication (*p* = .115)**

III. <u>Chi-Square Test for Independence</u>

**Figures 7 and 8** show the results of a Chi-Square Test for Independence with Yates' Continuity Correction. The results indicated no significant association between insurance type and hearing loss, as well as a small effect size, $X^2$ (1, $n = 105$) = 1.913, $p = .167$, *phi* = .156.

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---|---|---|---|---|---|
| Pearson Chi-Square | 2.542[a] | 1 | .111 | | |
| Continuity Correction[b] | 1.913 | 1 | .167 | | |
| Likelihood Ratio | 2.583 | 1 | .108 | | |
| Fisher's Exact Test | | | | .140 | .083 |
| Linear-by-Linear Association | 2.518 | 1 | .113 | | |
| N of Valid Cases | 105 | | | | |

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.77.

b. Computed only for a 2x2 table

**Figure 7: Chi-Square Test for Independence results showing there was a non-significant relationship between insurance type and hearing loss (*p* = .167)**

**Symmetric Measures**

| | | Value | Approximate Significance |
|---|---|---|---|
| Nominal by Nominal | Phi | .156 | .111 |
| | Cramer's V | .156 | .111 |
| N of Valid Cases | | 105 | |

**Figure 8: Symmetric Measures from a Chi-Square Test for Independence showing there was a small effect size according to Cohen's (1988) criteria (*phi* = .156)**

IV. Box Plots

**Figures 9 and 10** are box plots illustrating the spread of crystalized verbal intelligence and functional communication t-scores for each socioeconomic/hearing group. **Figure 9** indicates that there was a significant difference in CVI between the group with private insurance without hearing loss and the group with public insurance without hearing loss (*p* = .012). There was also a significant difference in CVI between the group with private insurance without hearing loss and the group with public insurance with hearing loss (p = .028). **Figure 10** indicates there was a significant difference in FC between the group with private insurance without hearing loss and the group with public insurance with hearing loss (p = .035).

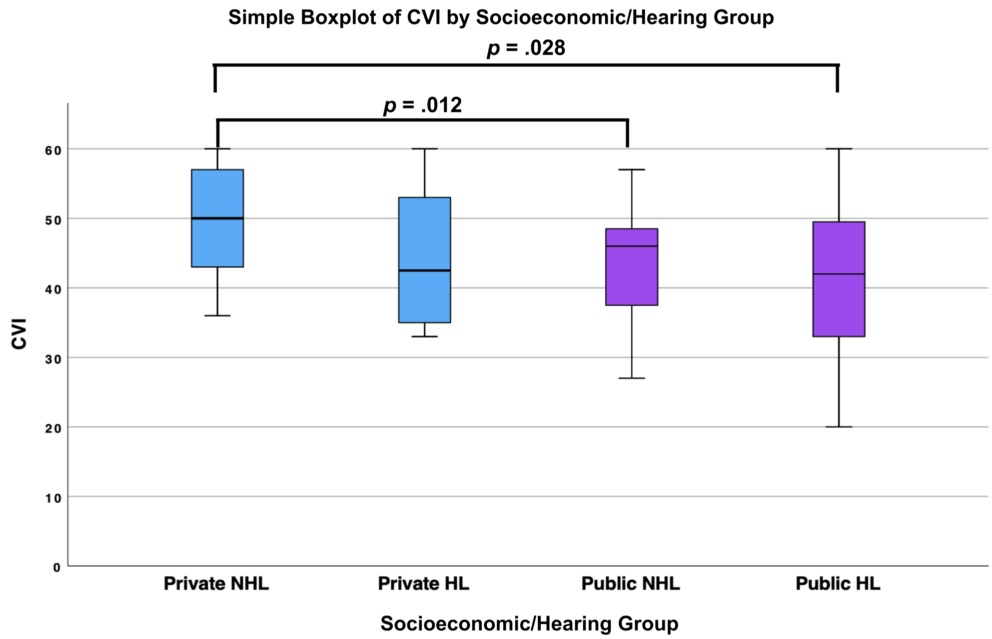


**Figure 9: Box plot illustrating the spread of crystalized verbal intelligence for each socioeconomic/hearing group. Significant difference between Group 1 and Group 3 (*p* = .012), and between Group 1 and Group 4 (*p* = .028)**

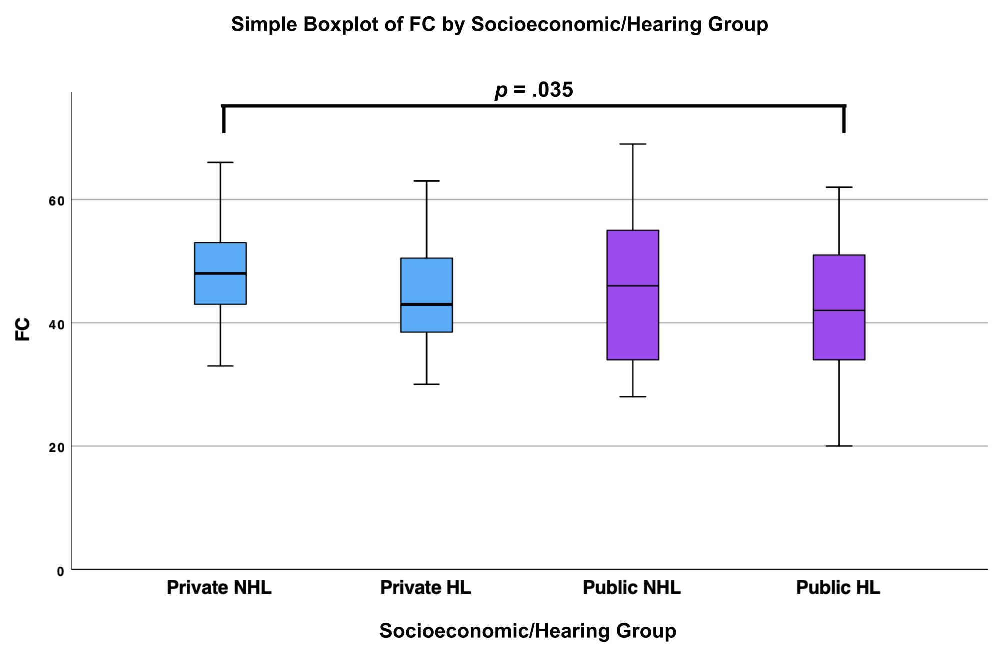


**Figure 10: Box plot illustrating the spread of functional communication for each socioeconomic/hearing group. Significant difference between Group 1 and Group 4 (*p* = .035)**

## DISCUSSION

### *Analysis of Study*

The results from the study supported the hypothesis that high socioeconomic status, represented by private insurance, statistically corresponded with higher crystalized verbal intelligence t-scores. Additionally, the relationship between socioeconomic status and functional communication t-scores approached significance with a *p*-value .003 away from being considered statistically significant, though this null hypothesis was unable to be rejected by the study.

However, when hearing loss was added as an independent variable during the third and fourth One-Way ANCOVA tests and both of the Two-Way ANCOVA tests, there was no longer a statistically significant effect on either CVI or FC. The box plots suggest that there were significant differences between some of the socioeconomic/hearing groups, but not all. These results indicate that there were not greater deficits to neurocognition when SES was compounded with hearing loss, and that insurance type was a stronger predictor of neurocognition in pediatric cancer survivors than hearing loss. This agrees with the results from a previous study which found that socioeconomic status, represented by income, had a significant relationship with CVI ($p < .001$) (Blackman, 2024).

Furthermore, there was a non-significant association between insurance type and hearing loss, demonstrated by the Chi-Square Test for Independence. Thus, socioeconomic status impacts some aspects of a patient's health more than others. The likelihood of a participant to be recommended a hearing aid by their audiologist did not change based on their insurance type, but their neurocognition, especially CVI, was significantly impacted by their socioeconomic status. This agrees with a study that found sustained economic hardship led to poorer physical, psychological, and cognitive functioning (Lynch et al., 1997).

### *Evaluation*

This study was the first of its kind to use an interdisciplinary approach to examine the relationship between socioeconomics, audiology, neuropsychology, and oncology. The conclusions drawn from this research can have large-scale impacts on the future of cancer survivorship. A push can be made toward equity in healthcare, ultimately enhancing the wellbeing of pediatric cancer survivors.

On the other hand, this study may have been limited by the sample size, the context of the participants, and the narrow definition of socioeconomic status. For instance, a sample size larger than 105 could increase the accuracy of the research by restricting the impact that outliers have on the results. Additionally, all participants received care through the same pediatric hospital. Although this served as a constant for the study, it also made the results specific to a single hospital. The results might not be mirrored in cancer survivors throughout the country who have different medical providers. A third limitation was using insurance type as the only predictor of the patient's socioeconomic status, since there are many factors that may impact SES. These include, but are not limited to: education, parental education, nutrition, living conditions, access to prenatal care, and parental occupation. These factors may all have diverse effects on neurocognition and hearing loss, but they were not investigated since this study only focused on health insurance.

### *Future Research*

Future research could repeat this study on a larger scale, examining the interplay between SES, hearing loss, and neurocognition in hospitals across the United States. Cancer survivors with the same socioeconomic status might have different experiences based on the medical facility providing their care, leading to unique impacts on neurocognition and hearing loss. The results from this future study might also be stronger than the current results due to a larger sample size.

Another future study could utilize a broader definition of SES. By including more factors, a clearer idea could be developed on SES's role in pediatric neurodevelopment. This could also lead to a more accurate representation of the effect SES has on the healthcare field, as well as the inequities faced by patients.

Lastly, further research could explore the effects of SES and hearing loss on neurocognitive variables beyond CVI and FC. These neuropsychological tests were selected due to a suspected relationship with ototoxicity. However, it has been found that memory, processing speed, attention, and executive functions are some of the most impaired cognitive domains post-chemotherapy (Lange et al., 2019). Therefore, there are many other neurocognitive variables that may impact a cancer survivor's quality of life through academic, professional, and social pathways.

### *Conclusion*

This study revealed the upsetting impact that health insurance type had on the neurocognition of pediatric cancer survivors, as well as the lack of impact that hearing loss had on neurocognition. Evidently, neurocognitive disparities in cancer survivors may result from low socioeconomic status. This study used health insurance as a proxy for the patients' socioeconomic status, but there are countless factors that can impact an individual's general access to resources, including education quality, parent availability, and nutritious food options. Awareness of this issue can hopefully lead to increased advocacy for patients, and eventually greater equity in the neuropsychological and oncological fields for individuals with low socioeconomic status. The study can also inspire future research regarding the relationships between SES, hearing loss, and neurocognition.

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