Using Conceptual Modeling to Plan and Execute Quasi-Experimental Studies - An Example from Hearing Loss

Annie N. Simpson and Kit N. Simpson
Department of Healthcare Leadership and Management
Department of Otolaryngology-Head and Neck Surgery
Medical University of South Carolina
Charleston, South Carolina

Work supported by
NIH/NIDCD (US)
A Statistical Model - A Mathematical Formulaic Model

Linear regression of plant height by Soil water content

The Classical Medical Model - A Theoretical Framework

Source: Taxi Driver Training -- Democracy, Disability and Society Group, UK
An Alternative Framework

THE SOCIAL MODEL OF DISABILITY

Source: Taxi Driver Training -- Democracy, Disability and Society Group, UK
Model: The International Classification of Functioning, Disability and Health (ICF)

Differences between Theoretical Framework/Models and Conceptual Models?
Conceptual Framework/Model

- This consists of concepts that are placed within a logical and sequential design
- Represents less formal structure and used for studies in which existing theory is inapplicable or insufficient
- Based on specific concepts and propositions, derived from empirical observation and intuition
- May deduce theories from a conceptual framework

Purposes of Conceptual Framework
- To clarify concepts and propose relationships among the concepts in a study
- To provide a context for interpreting the study findings
- To explain observations
- To encourage theory development that is useful to practice

Donabedian’s Quality Improvement Model

Structure
- Physical and organisational characteristics where health care occurs

Process
- Focus on the care delivered to patients (e.g. services or treatments)

Outcome
- Effect of health care on the status of patients and populations

Adapted Conceptual Model Based on the EPIS Framework of Implementation and Dissemination

**Figure 2: EPIS Model adapted to ICU Innovations**

- **Outer Context**
  - **ICU innovations’ collaborative engagement**
  - Professional guidelines
  - Strategic health system affiliations
  - Leverage MUSC expertise and resources
  - Publicly reported hospital-acquired infections
  - Quality related financial impact

- **Implementation outcomes: Aim 2**
  - Fidelity
  - Uptake
  - Sustainability capacity

- **Effectiveness outcomes: Aim 1**
  - ↓Duration of mechanical ventilation
  - ↑LPV
  - ↑Combined SAT/SBT

- **Value outcomes: Aim 3**
  - ↓Cost
  - ↓VDRF complications

- **Inner Context**
  - Hospital Characteristics
    - **Communication**
    - **IP teamwork**
    - **Site champion leadership**
    - Innovations/EBP fit
    - ICU structure
    - ICU QI goals
    - Change receptivity
    - ICU culture
    - Leadership
    - Resources
    - Technology
  - ICU Staff
    - Adaptability
    - Attitudes toward EBP
    - QI self-efficacy


### Most Common Chronic Conditions, by Age and Gender

<table>
<thead>
<tr>
<th></th>
<th>MALE</th>
<th>FEMALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL AGES</td>
<td>• Orthopedic impairments</td>
<td>• Sinusitis</td>
</tr>
<tr>
<td></td>
<td>• Sinusitis</td>
<td>• Arthritis</td>
</tr>
<tr>
<td></td>
<td>• Hearing impairments</td>
<td>• Orthopedic impairments</td>
</tr>
<tr>
<td></td>
<td>• Hypertension</td>
<td>• Hypertension</td>
</tr>
<tr>
<td></td>
<td>• Hay Fever</td>
<td>• Hay Fever</td>
</tr>
<tr>
<td>0–17</td>
<td>• Asthma</td>
<td>• Sinusitis</td>
</tr>
<tr>
<td></td>
<td>• Hay Fever</td>
<td>• Asthma</td>
</tr>
<tr>
<td></td>
<td>• Sinusitis</td>
<td>• Hay Fever</td>
</tr>
<tr>
<td></td>
<td>• Bronchitis</td>
<td>• Bronchitis</td>
</tr>
<tr>
<td></td>
<td>• Dermatitis</td>
<td>• Dermatitis</td>
</tr>
<tr>
<td>18–44</td>
<td>• Orthopedic impairments</td>
<td>• Sinusitis</td>
</tr>
<tr>
<td></td>
<td>• Sinusitis</td>
<td>• Orthopedic impairments</td>
</tr>
<tr>
<td></td>
<td>• Hay Fever</td>
<td>• Hypertension</td>
</tr>
<tr>
<td></td>
<td>• Hearing impairments</td>
<td>• Hay Fever</td>
</tr>
<tr>
<td></td>
<td>• Hypertension</td>
<td>• Migraine</td>
</tr>
<tr>
<td></td>
<td>• Hay Fever</td>
<td>• Asthma</td>
</tr>
<tr>
<td>45–74</td>
<td>• Hypertension</td>
<td>• Arthritis</td>
</tr>
<tr>
<td></td>
<td>• Arthritis</td>
<td>• Hypertension</td>
</tr>
<tr>
<td></td>
<td>• Hearing impairments</td>
<td>• Sinusitis</td>
</tr>
<tr>
<td></td>
<td>• Orthopedic impairments</td>
<td>• Orthopedic impairments</td>
</tr>
<tr>
<td></td>
<td>• Heart Disease</td>
<td>• Hay Fever</td>
</tr>
<tr>
<td>75+</td>
<td>• Hearing impairments</td>
<td>• Arthritis</td>
</tr>
<tr>
<td></td>
<td>• Arthritis</td>
<td>• Hypertension</td>
</tr>
<tr>
<td></td>
<td>• Hearing impairments</td>
<td>• Hearing impairments</td>
</tr>
<tr>
<td></td>
<td>• Heart Disease</td>
<td>• Heart Disease</td>
</tr>
<tr>
<td></td>
<td>• Hypertension</td>
<td>• Cataracts</td>
</tr>
<tr>
<td></td>
<td>• Cataracts</td>
<td></td>
</tr>
</tbody>
</table>

**SOURCE:** National Academy on an Aging Society analysis of National Health Interview Survey data.

- Hearing loss is one of the most common chronic health conditions, especially among older adults
- Affects ~360 million people worldwide
- Affects >60% of US adults over age 70
- Associated with decreased quality of life, and increased risk of hospitalization and functional and cognitive declines.
- Little is known about the impact of HL on healthcare use and cost
Study Design

- 2 cohorts of patients over age 65
- ICD-9 code of HL (V41.2, V72.1x, 388.00, 388.01, 388.40, 388.43, 388.44, 388.5, 389.1x, 389.2x)
- Baseline Matching based on 6 months of bills prior to index date
- Included only individuals
  - with at least 18 months of continuous insurance coverage
  - > 65 years of age
- Excluded individuals with diagnoses of late effects of stroke, coma or paralysis
Defining “Cost” and Comparison Groups

- Healthcare bills (provider plus any out-of-pocket) up to 18-months post index were summed by patient to calculate total payments for:
  - *inpatient*  
  - *prescription medication*
  - *Outpatient*  
  - *cost of hearing services (HS)*

- Three Comparison Groups
  - Individuals with no hearing loss diagnosis
  - Individuals with hearing loss:
    - With Hearing Services were defined for bills with ICD-9 procedure codes 9548, 69710, 69711, V532, V5014, V5267, V5298, V5010, V5011, or V5275.
    - Without Hearing Services
2 Cohorts plus 1 Subgroup

- First cohort: Medicare plus Supplemental privately insured individuals (MS) was extracted using the 2009-2013 Market Scan® data base.
- Second cohort: Medicare (M5%) extracted from the 2012-2013 Medicare Limited Data Set standard analytic files (SAF) National 5% sample, Medicare as primary insurance.
- Subgroup: Dually eligible (DE) Medicare/Medicaid. A subgroup of the Medicare group who were dually eligible for Medicaid.
Table 1. Patient Descriptive Characteristics

<table>
<thead>
<tr>
<th>Chronic Conditions</th>
<th>MS Hearing Loss (n= 391,108)</th>
<th>M5% Hearing Loss (n = 75,148)</th>
<th>DE Hearing Loss (n = 8,729)</th>
<th>DE No Hearing Loss (n = 8,509)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, m(sd)</td>
<td>75.9 (7.8)</td>
<td>75.9 (7.8)</td>
<td>77.1 (8.0)</td>
<td>77.0 (7.9)</td>
</tr>
<tr>
<td>Charlson Score, m(sd)</td>
<td>0.1 (0.4)</td>
<td>0.1 (0.4)</td>
<td>0.2 (0.7)</td>
<td>0.1 (0.7)</td>
</tr>
<tr>
<td>Follow Up Days, m(sd)</td>
<td>540.0 (29.3)</td>
<td>537.5 (33.2)</td>
<td>191.1 (59.1)</td>
<td>195.2 (67.0)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>192,038 (49.1)</td>
<td>194,133 (49.6)</td>
<td>29,221 (38.9)</td>
<td>29,265 (38.9)</td>
</tr>
<tr>
<td>Female</td>
<td>199,070 (50.9)</td>
<td>196,975 (50.4)</td>
<td>45,927 (61.1)</td>
<td>45,883 (61.1)</td>
</tr>
<tr>
<td>White Race</td>
<td>NA</td>
<td>NA</td>
<td>66,669 (88.7)</td>
<td>66,958 (89.1)</td>
</tr>
<tr>
<td>Hearing Services</td>
<td>109,968 (28.1)</td>
<td>0 (0.0)</td>
<td>2,873 (3.8)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Chronic Conditions:
- Hypertension
- Diabetes
- CHF
- COPD
- Heart Valve
- CondHF
- RA
- Asthma
- Diverticulitis
- CRF
- Parkinson’s
- Epilepsy
- SLE
- Hepatitis
- MS
- Schizophrenia
- HIV
- CF
- SCA
### Table 2. Adjusted 18-month Total Healthcare Payments by Hearing Loss†

<table>
<thead>
<tr>
<th></th>
<th>Hearing Loss</th>
<th>Hearing Loss with Hearing Services</th>
<th>No Hearing Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS</strong>*</td>
<td>20,304</td>
<td>18,873</td>
<td>16,717</td>
</tr>
<tr>
<td>(20,211-20,398)</td>
<td>(18,735-19,012)</td>
<td></td>
<td>(16,652-16,782)</td>
</tr>
<tr>
<td><strong>M5%</strong></td>
<td>11,957</td>
<td>10,309</td>
<td>8,178</td>
</tr>
<tr>
<td>(11,815-12,101)</td>
<td>(9,713-10,942)</td>
<td></td>
<td>(8,083-8,275)</td>
</tr>
<tr>
<td><strong>DE</strong></td>
<td>16,281</td>
<td>12,850</td>
<td>11,624</td>
</tr>
<tr>
<td>(15,737-16,843)</td>
<td>(10,599-15,579)</td>
<td></td>
<td>(11,237-12,024)</td>
</tr>
</tbody>
</table>

*Includes prescription payments; **Payments do not include prescription medication.
†Estimates are adjusted for age, sex, race (when available), Charlson Score, HS use, time in study and 22 chronic conditions.
All p-values <0.001 within cohort.
Figure 1. Adjusted 18-month Total Healthcare Payments by Hearing Loss

- No Hearing Loss
- Hearing Loss with Hearing Services
- Hearing Loss without Hearing Services
Principal Findings

- Study Goal: Compare the average healthcare costs in US older adults with and without hearing loss
- Multiple data sources enables us to examine health care cost for Medicare patients who have substantially different levels of financial resources
- After propensity score matching and covariate adjustment, we observed >20% higher payments over a 1.5-year time period for a group of insured patients with HL
Figure 1: Conceptual Model of the Effects of HL

Quality of Life
(Association found in pilot data)

Individual Patient Characteristics:
Charlson Comorbidity Index, 22 Chronic Conditions, Follow up days, Age, Sex, Race

Intervening Factors:
(Unmeasured in current study)
Health Literacy
Care Satisfaction
Delayed or Missing Primary Care

Hearing Loss Dx

AIM 3:
Cost of Care

Community Characteristics:
Rural/Urban, US Region

Unmeasured Confounders?
1. Treatment Seeking Behavior
2. Frailty
3. Disease Severity
Limitations

- This study is limited by:
  - The lack of audiometry confirmation of HL
  - Inability to differentiate between successful HL interventions and failed interventions
- Residual selection bias may remain due to unmeasured variables
- Billing data contain coding errors and variation
- Billing data contain limited clinical information
Acknowledgements

This work was supported by grant R21 DC014031-01 from NIH/NIDCD and by the South Carolina Clinical and Translational Research (SCTR) Institute, with an academic home at the Medical University of South Carolina, through NIH Grant Numbers UL1 RR029882. This investigation was conducted in a facility constructed with support from NIH Research Facilities Improvement Program Grant Number C06 RR14516.

Medical University of South Carolina
Departments of Healthcare Leadership and Management and Otolaryngology-Head and Neck Surgery
For more information contact Annie Simpson:

simpsona@musc.edu
Conclusions

• All three data sets defined by patients’ insurance type;
  • patient with untreated HL had the highest cost, followed by patients with treated HL, with patients without HL have lowest cost
• MS cohort had the highest means cost (Drug Costs)
• M5% cohort had the lowest cost
• DE group (poorest patients), had consistently ↑ costs across the HL categories, and marginal cost difference between the treated and the untreated HL group
  • Economic effect of untreated HL may be exacerbated by poverty
Discussion and Policy Implications

- Findings consistent with earlier cost study in Adults 55-64 years of age (Simpson).
- Supported by study finding increased hospitalization risk in people with hearing loss (Genther).
- No Medicare coverage for hearing aids, nor for most hearing services
- Private insurance and Medicaid has limited hearing coverage
- Medicaid coverage varies widely by state
Procedure Codes for Hearing Services

- 9548 - Fitting of Hearing Aid
- 69710 - Surgical Procedures on the Middle Ear
- 69711 - Other Procedures on the Middle Ear
- V532 - Adjustment Hearing Aid
- V5014 - Repair/Modification Hearing Aid
- V5267 - Hearing aid or assistive listening device/supplies/accessories
- V5298 - Hearing Aid not otherwise classified
- V5010 - Assessment for Hearing Aid
- V5011 - Fitting/orientation/checking of hearing aid
- V5275 - Ear impression
Diagnosis Codes for Hearing Loss

- V41.2 - Problems with hearing
- V72.1x - Examination of Ears and Hearing

388 Other Disorders of the Ear
- 388.00 - Degenerative and vascular disorders
- 388.01 - Presbyacusis
- 388.40 - Abnormal Auditory Perception
- 388.43 - Impairment of Auditory Discrimination
- 388.44 - Auditory Recruitment
- 388.5 - Disorders of Acoustic Nerve

389 Hearing Loss
- 389.1x - Sensorineural Hearing Loss
- 389.2x - Mixed conductive and sensorineural hearing loss