

Visualization Techniques for Nursing Research

Visualizing Data Patterns of Interest to Nursing

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SCHOOL OF NURSING

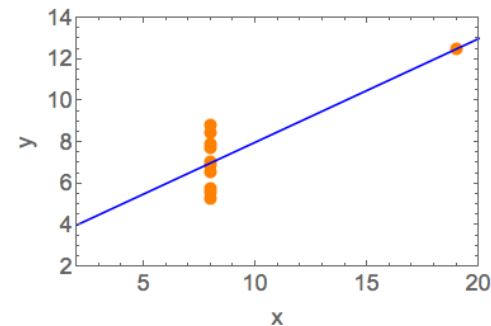
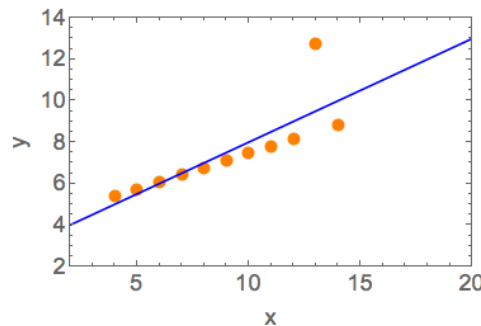
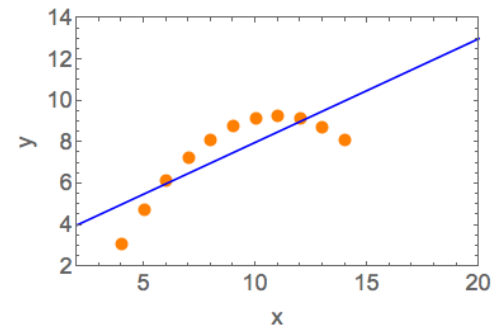
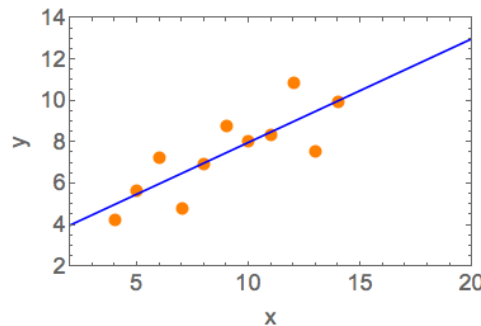
UNIVERSITY OF MINNESOTA

Acknowledgments

- University of Minnesota Center for Nursing Informatics
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- All research teams and co-authors

Visualization Better Science: Anscombe's Quartet

- Four sets of data that have the same means, variances, correlation, and linear fit.



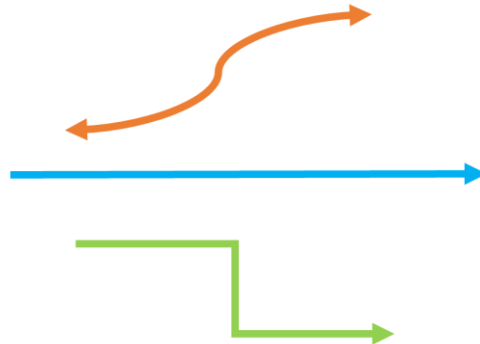
Visualize Nursing Data to:

- Make data interpretable in real time
- Or make data interpretable for research
- Uncover new associations
- Generate hypotheses for further testing
- Depict findings



Data for Visualization

- Standardized, structured data are essential
 - May be categorical (boxes) or continuous (lines)
 - Other data types must be pre-processed to create either categorical or continuous data
 - Relationships among variables should be known and specified



Nursing Data

Nursing Minimum Data Set

http://www.nursing.umn.edu/prod/groups/nurs/@pub/@nurs/documents/asset/nurs_71413.pdf

a **minimum set** of elements of information with uniform **definitions** and categories concerning the specific dimensions of **nursing**, which meets the information needs of multiple **data** users in the health care system.

- Client characteristics & outcomes
- Nursing assessments & interventions

Werley HH. Nursing minimum data: abstract tool for standardized comparable, essential data. Am J Public Health. 1991;81(4):421-6. doi:10.2105/AJPH.81.4.421.

Nursing Context Data

Nursing Management Minimum Data Set

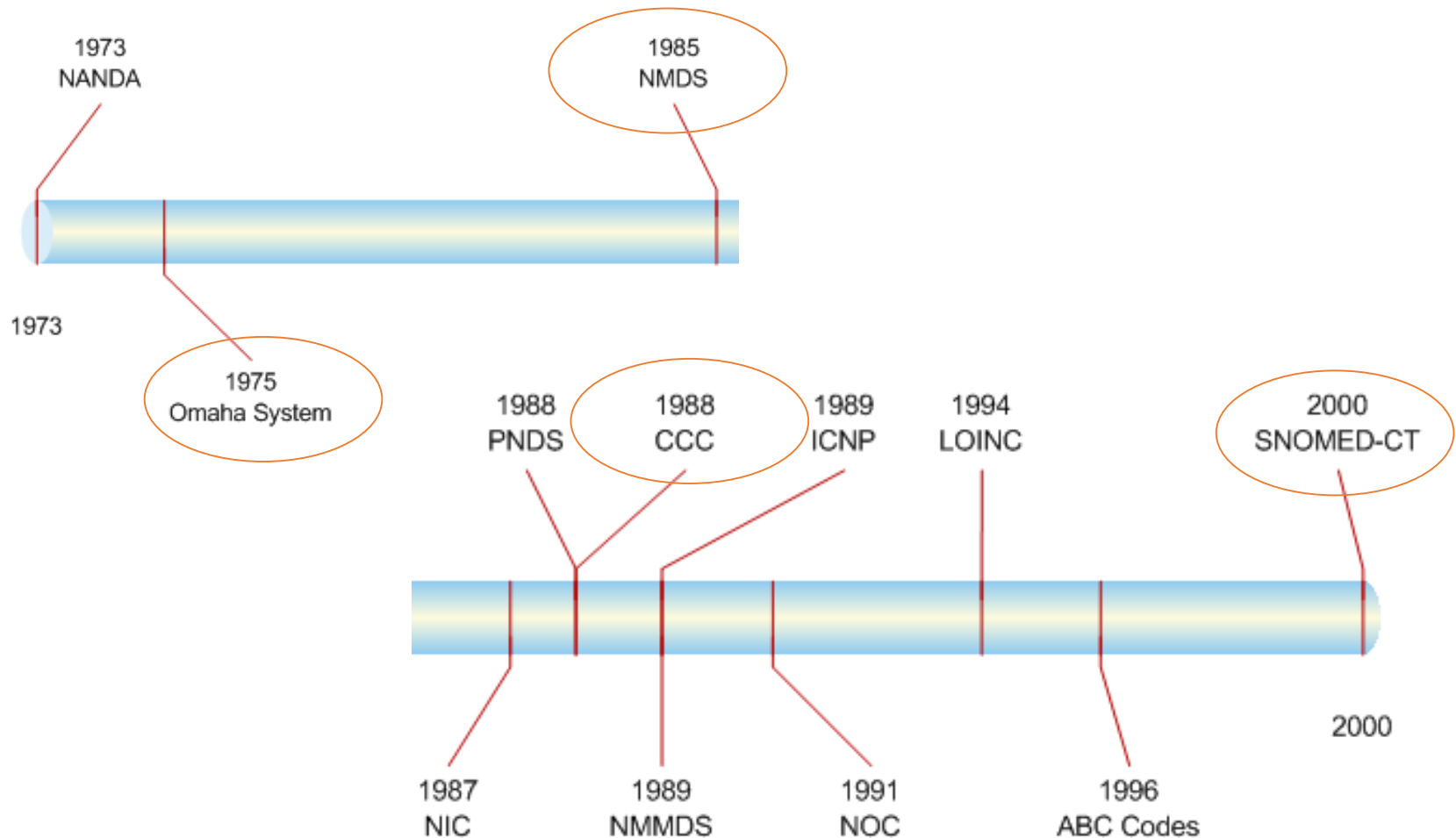
<http://www.nursing.umn.edu/icnp/usa-nmmds/>

core essential data needed to support the administrative and management information needs for the provision of nursing care. The standardized format allows for comparable nursing data collection within and across organizations.

- Nurse and health system characteristics
- Nurse and health system credentials

Huber D, Delaney C. The American Organization of Nurse Executives (AONE) research column. the Nursing Management Minimum Data Set. Appl Nurs Res. 1997;10:164-165.

Development of Nursing and other Clinical Terminologies



Sewell, J. P. & Thede, L. Q. (2012). Nursing and Informatics: Opportunities and Challenges. Nursing Documentation in the Age of the EHR. Available at: <http://dlthede.net/informatics/Chap16Documentation/anarecterm.html>

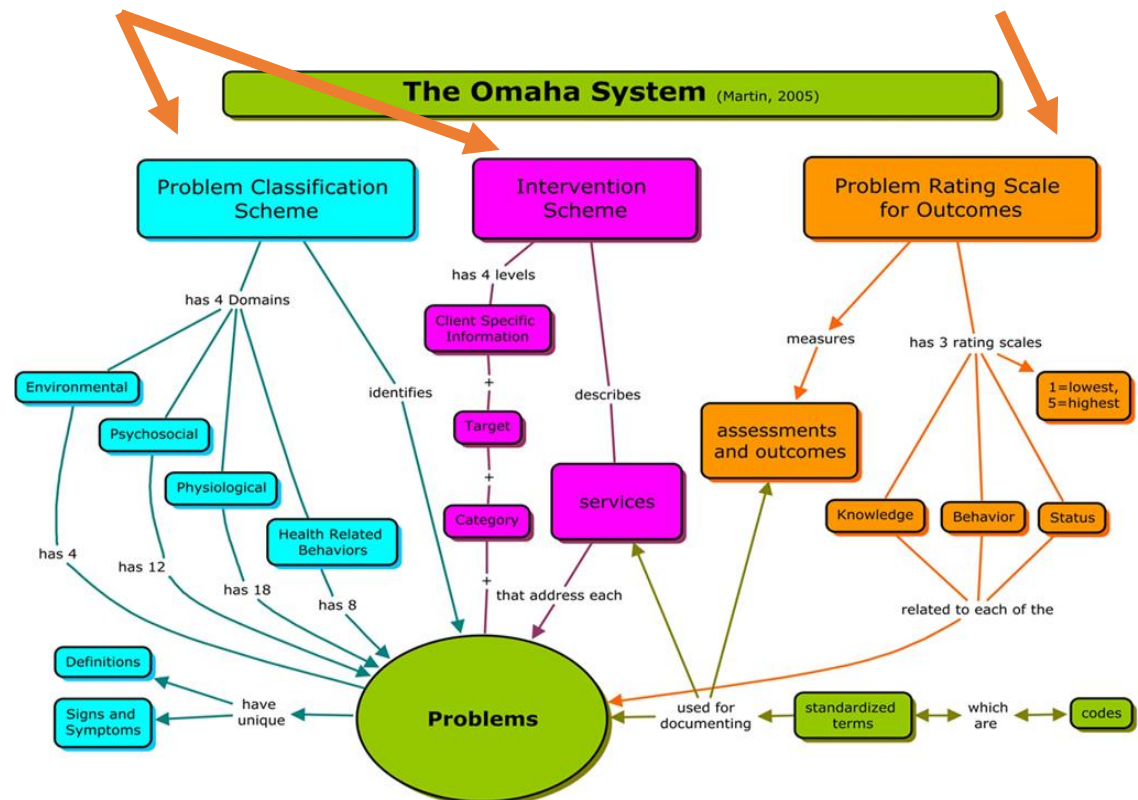
Westra, B.L., Delaney, C.W., Konicek, D., & Keenan, G. (2008). Nursing Standards to Support the Electronic Health Record. Nursing Outlook, 56, 258-266.e1

Magic of the Omaha System

Classification & Measurement (Categorical) (Continuous)

- Classification creates the palate for painting meaningful pictures

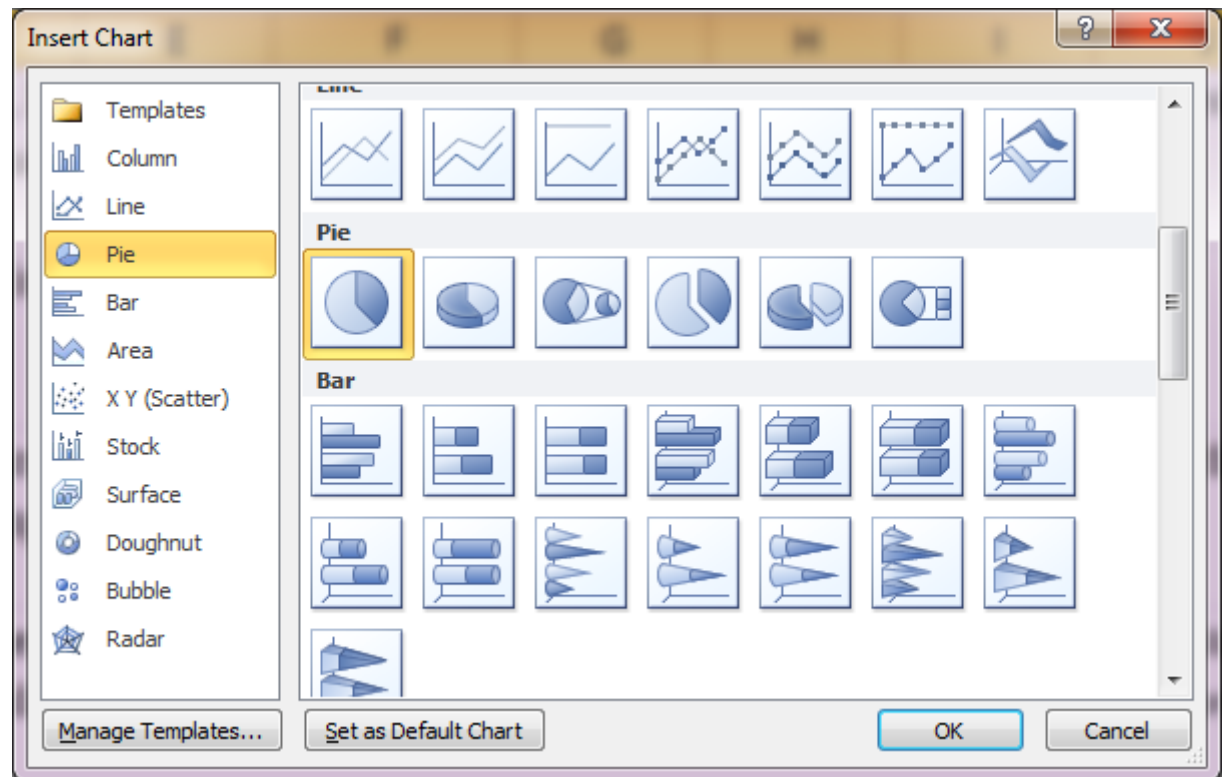
- simple, taxonomic structure
- pre-defined relationships



Created by Karen Monsen in cmaptools

Visualization Easy: Quick Accessible Software

- Tableau
- Excel
- D3
- SPSS
- R
- SAS
- ArcGIS
- Python



Microsoft Excel Insert Chart Menu

This figure created in Excel shows how heat maps (A), pie charts (B), bar charts (C), bubble charts (D), and Venn diagrams (E) can be used to display **categorical data**.

Males

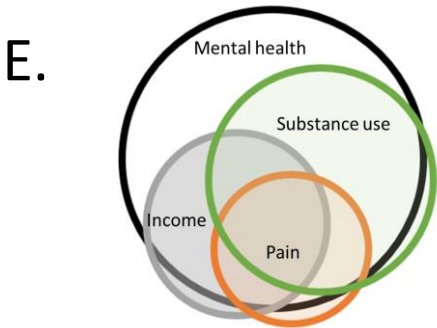
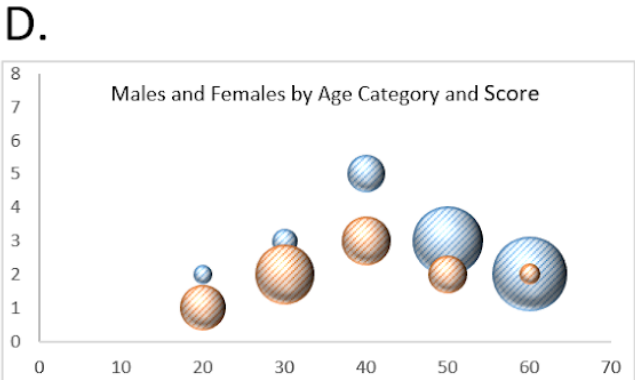
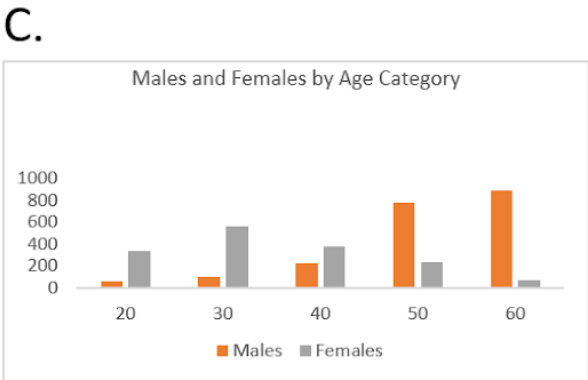
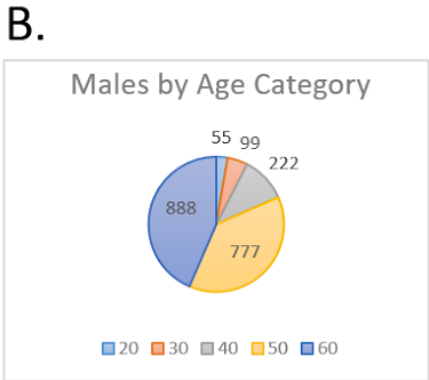
| Age Category | Score | N |
|--------------|-------|-----|
| 20 | 2 | 55 |
| 30 | 3 | 99 |
| 40 | 4 | 222 |
| 50 | 3 | 777 |
| 60 | 2 | 888 |

Females

| Age Category | Score | N |
|--------------|-------|-----|
| 20 | 1 | 333 |
| 30 | 2 | 555 |
| 40 | 3 | 377 |
| 50 | 2 | 233 |
| 60 | 2 | 66 |

A.

| Age Category | Males | Females |
|--------------|-------|---------|
| 20 | 55 | 333 |
| 30 | 99 | 555 |
| 40 | 222 | 377 |
| 50 | 777 | 233 |
| 60 | 888 | 66 |

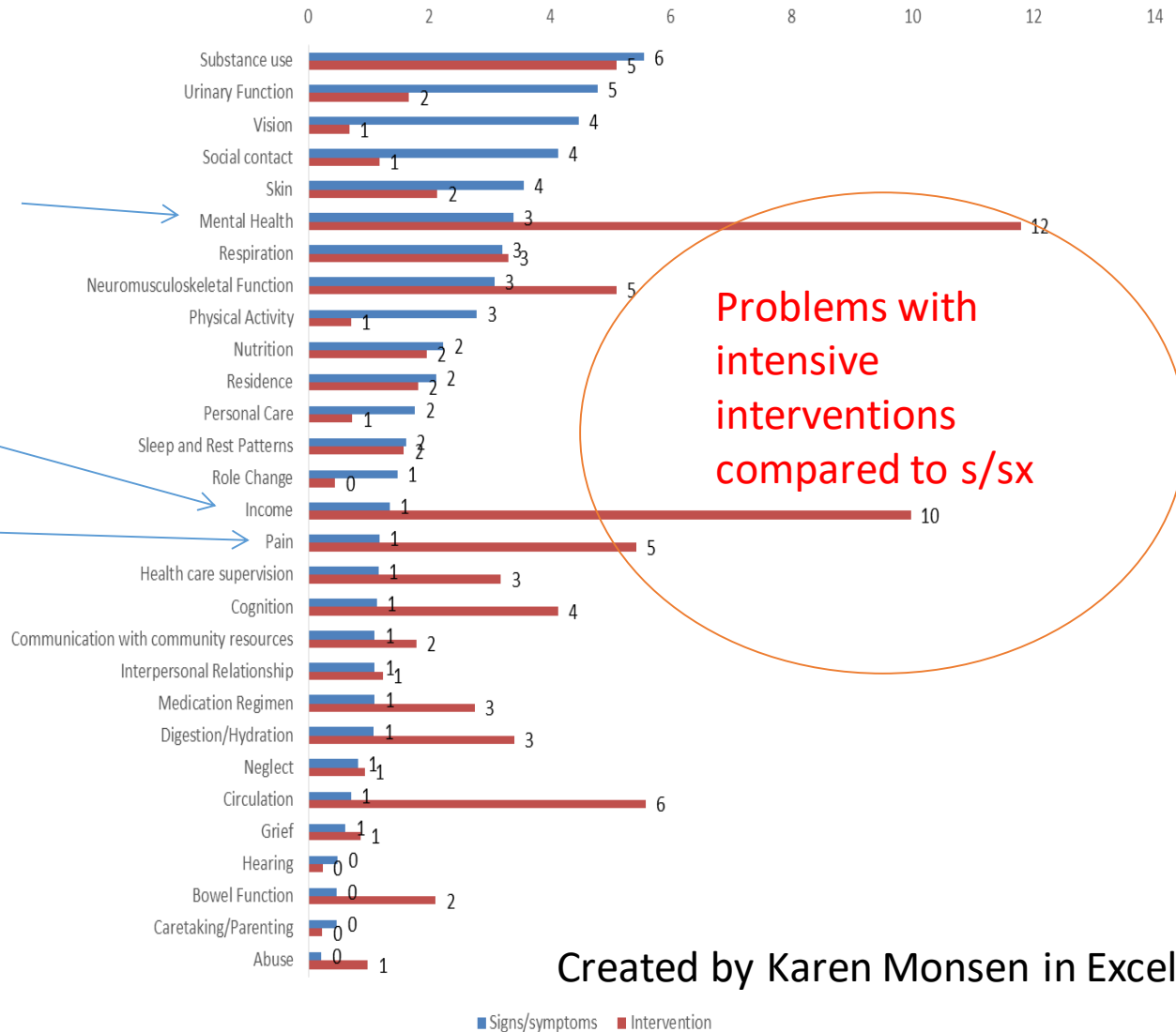


Interventions and S/sx by Problem

- Mental health

- Income

- Pain



Which do you prefer?

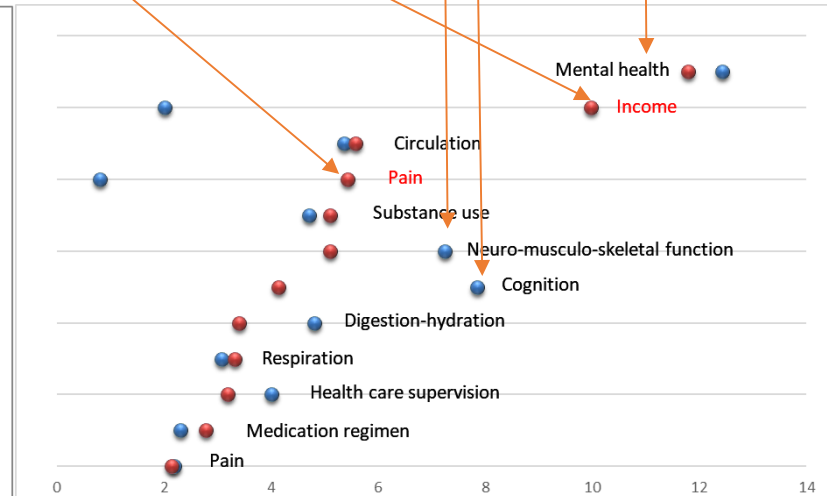
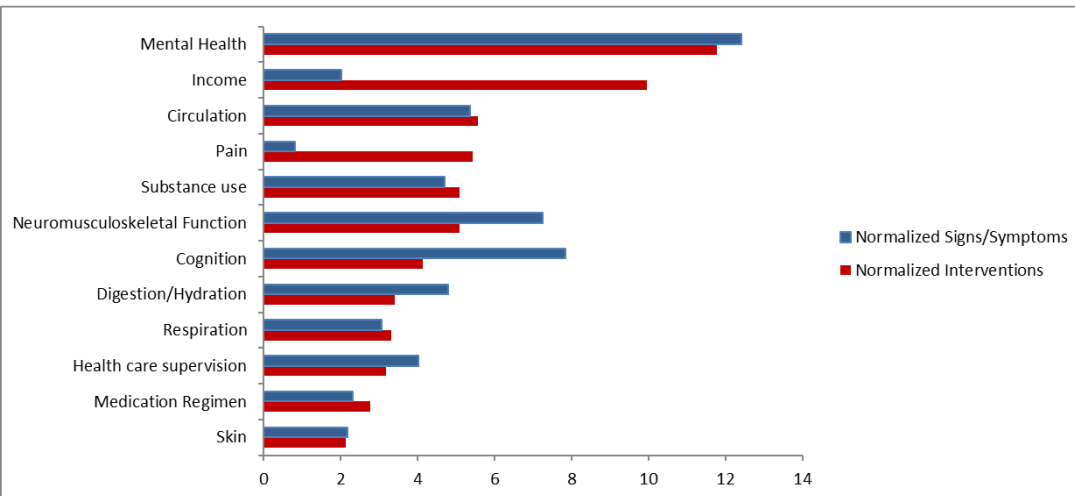
Most s/sx and interventions

More s/sx than interventions

More interventions than s/sx

Bar chart

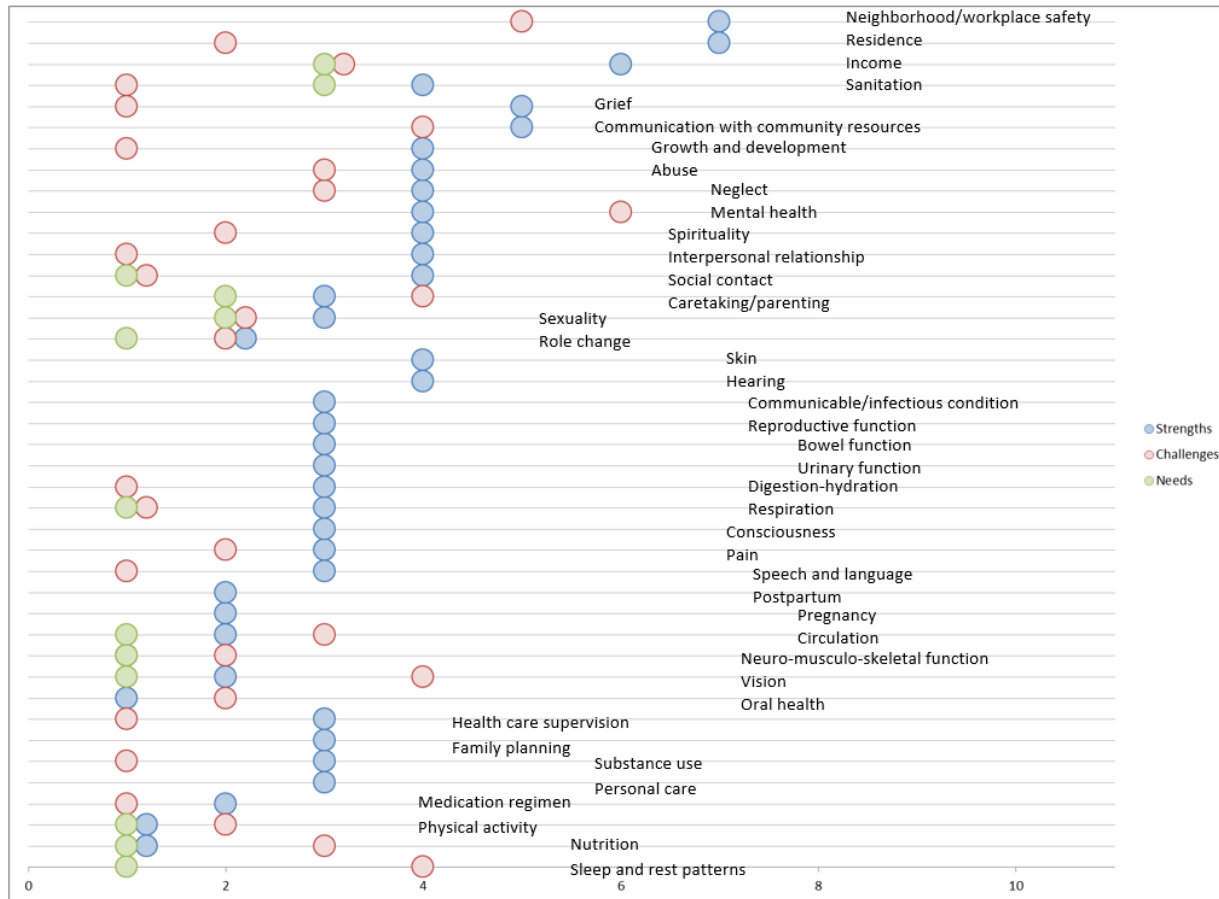
Dot plot



Dot Plot

Blue = strengths – Most common
 Red = challenges – Less common
 Green = needs – Fewest

Most challenges = Mental health, Vision, Nutrition, and Sleep
 Most needs = Income



Created by Karen Monsen in Excel - <http://stephanieevergreen.com/easy-dot-plots-in-excel/>

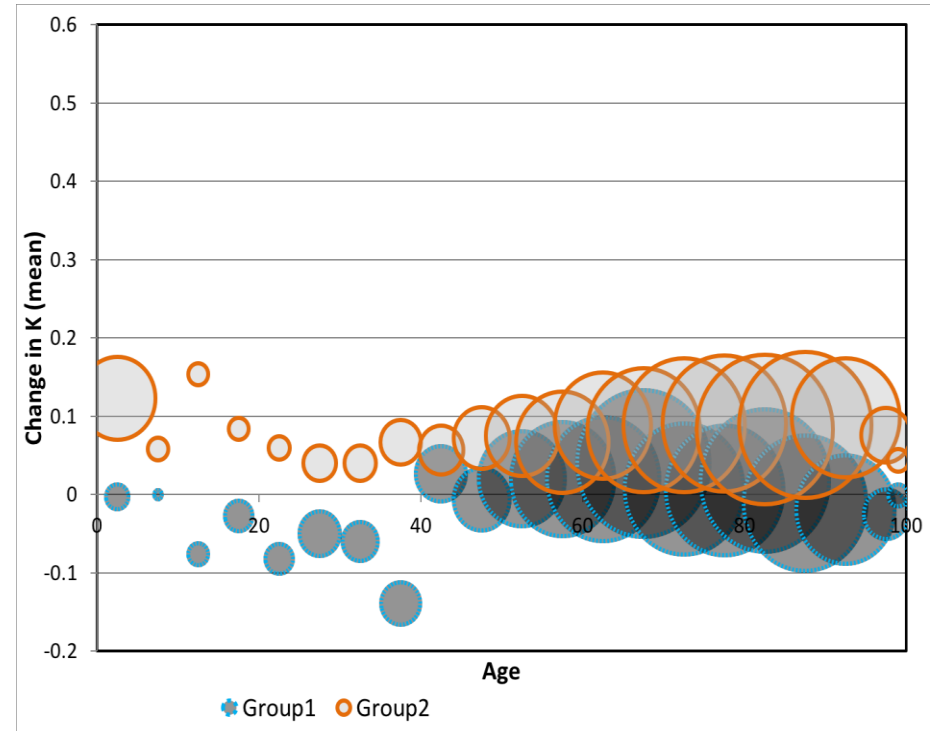
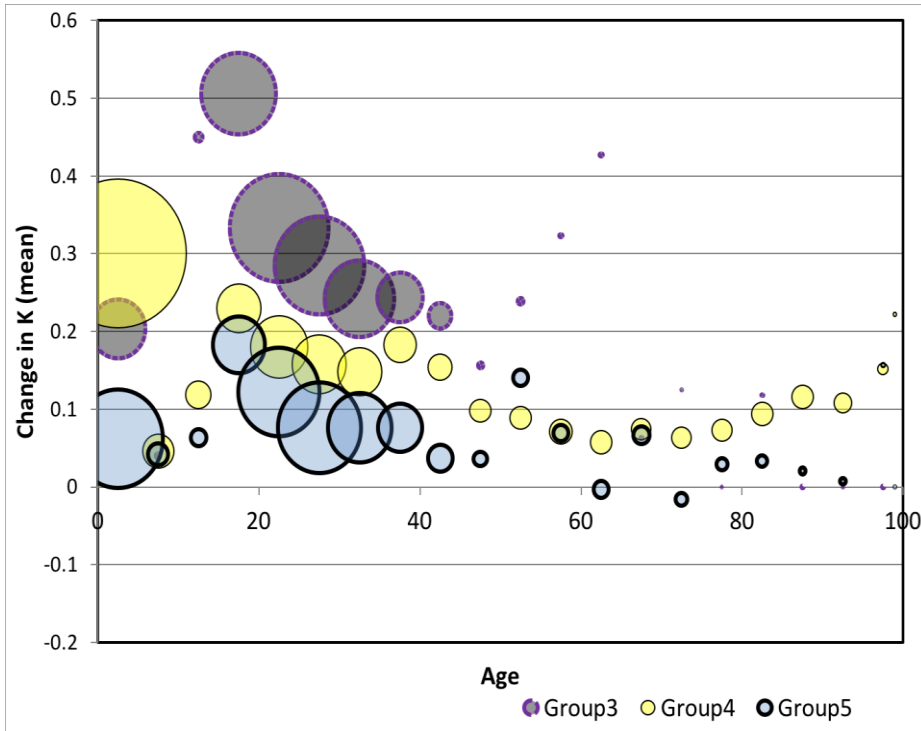
Weighted Mean Knowledge Gain for MCH & Elders

MCH show greater gains in health literacy vs. elders

Both MCH and Elders show gains in health literacy after intervention

Unique groups exist within MCH and Elders

Created by Michelle A. Mathiason in Excel

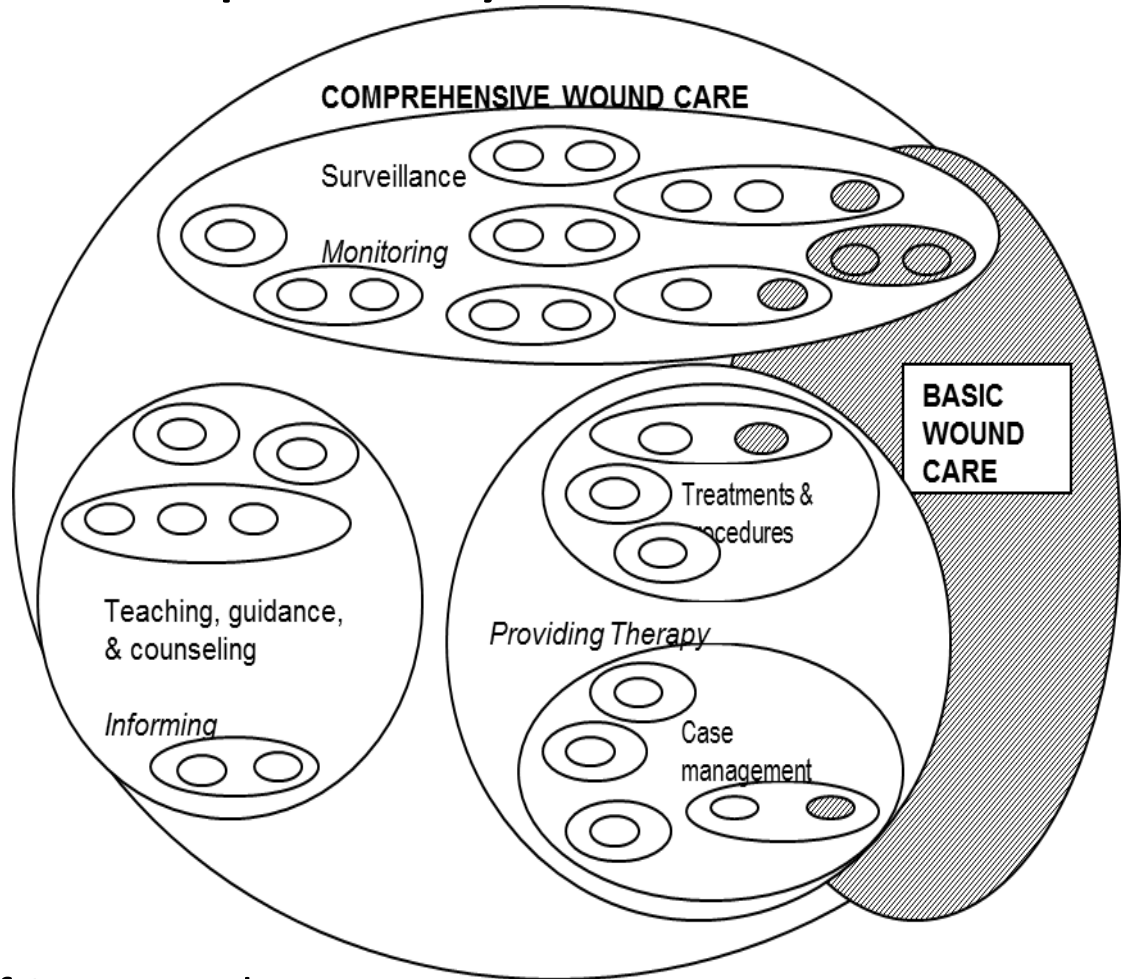


Visualizing Complexity of Care

- Data-Driven Intervention Clusters for Care

Nurses provide care differently depending on policy and/or client needs

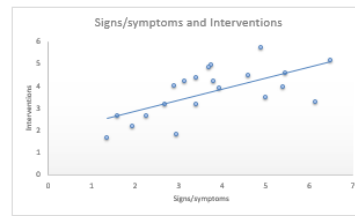
- Compared to Basic, Wound Care
 - Includes TGC
 - Greater numbers of S, CM, and TP



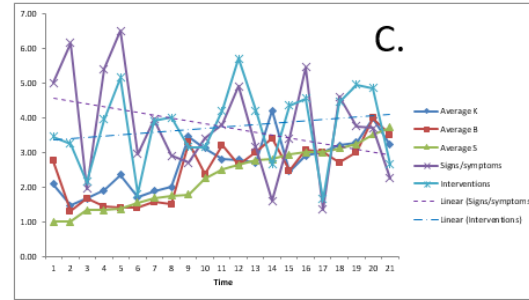
This figure created in Excel shows how heat maps (A), Scatterplot (B), Line graphs (C), Control Chart (D), Boxplot (E), and Histograms (F) can be used to display **continuous data**.

| Time | Average K | Average B | Average S | Signs/symptoms | Interventions |
|------|-----------|-----------|-----------|----------------|---------------|
| 1 | 2.09 | 2.75 | 1.00 | 5 | 3.45 |
| 2 | 1.47 | 1.30 | 1.00 | 6.15 | 3.25 |
| 3 | 1.67 | 1.33 | 1.33 | 1.95 | 2.15 |
| 4 | 1.90 | 1.43 | 1.33 | 5.4 | 3.95 |
| 5 | 2.36 | 1.40 | 1.37 | 6.5 | 6.15 |
| 6 | 1.70 | 1.40 | 1.55 | 2.95 | 1.8 |
| 7 | 1.88 | 1.56 | 1.69 | 3.95 | 3.3 |
| 8 | 2.00 | 1.50 | 1.75 | 2.3 | 4 |
| 9 | 3.44 | 3.28 | 1.78 | 2.7 | 3.15 |
| 10 | 3.12 | 2.38 | 2.25 | 3.4 | 3.15 |
| 11 | 2.80 | 3.20 | 2.50 | 3.8 | 4.2 |
| 12 | 2.78 | 2.65 | 2.64 | 4.9 | 5.7 |
| 13 | 2.71 | 3.00 | 2.78 | 3.15 | 4.2 |
| 14 | 4.20 | 3.40 | 2.90 | 1.6 | 2.65 |
| 15 | 2.45 | 2.46 | 2.93 | 3.4 | 4.35 |
| 16 | 2.89 | 3.06 | 3.00 | 5.45 | 4.55 |
| 17 | 3.00 | 3.00 | 3.00 | 1.05 | 1.65 |
| 18 | 3.20 | 2.70 | 3.12 | 4.6 | 4.45 |
| 19 | 3.29 | 3.00 | 3.24 | 3.75 | 4.95 |
| 20 | 3.98 | 3.98 | 3.52 | 3.7 | 4.85 |
| 21 | 3.22 | 3.50 | 3.72 | 2.25 | 2.65 |

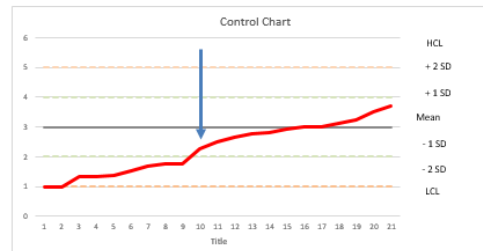
A.



B.

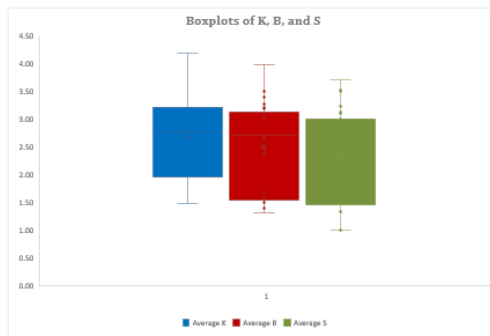


D.

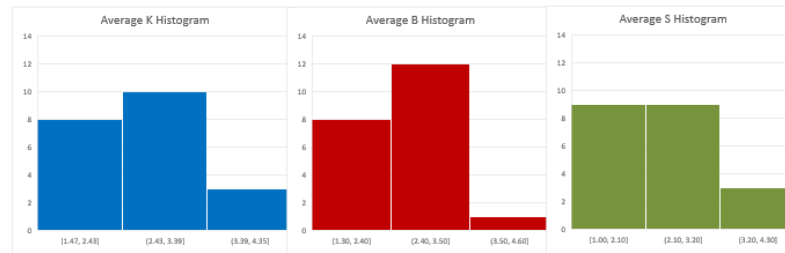


| Lowest | Min | Ave | Average S | Goal | Highest |
|--------|-----|-----|-----------|------|---------|
| 1 | 2 | 3 | 1.00 | 4 | 5 |
| 1 | 2 | 3 | 1.00 | 4 | 5 |
| 1 | 2 | 3 | 1.33 | 4 | 5 |
| 1 | 2 | 3 | 1.33 | 4 | 5 |
| 1 | 2 | 3 | 1.37 | 4 | 5 |
| 1 | 2 | 3 | 1.55 | 4 | 5 |
| 1 | 2 | 3 | 1.69 | 4 | 5 |
| 1 | 2 | 3 | 1.75 | 4 | 5 |
| 1 | 2 | 3 | 1.78 | 4 | 5 |
| 1 | 2 | 3 | 2.25 | 4 | 5 |
| 1 | 2 | 3 | 2.50 | 4 | 5 |
| 1 | 2 | 3 | 2.64 | 4 | 5 |
| 1 | 2 | 3 | 2.78 | 4 | 5 |
| 1 | 2 | 3 | 2.80 | 4 | 5 |
| 1 | 2 | 3 | 2.93 | 4 | 5 |
| 1 | 2 | 3 | 3.00 | 4 | 5 |
| 1 | 2 | 3 | 3.00 | 4 | 5 |
| 1 | 2 | 3 | 3.12 | 4 | 5 |
| 1 | 2 | 3 | 3.24 | 4 | 5 |
| 1 | 2 | 3 | 3.52 | 4 | 5 |
| 1 | 2 | 3 | 3.72 | 4 | 5 |

E.

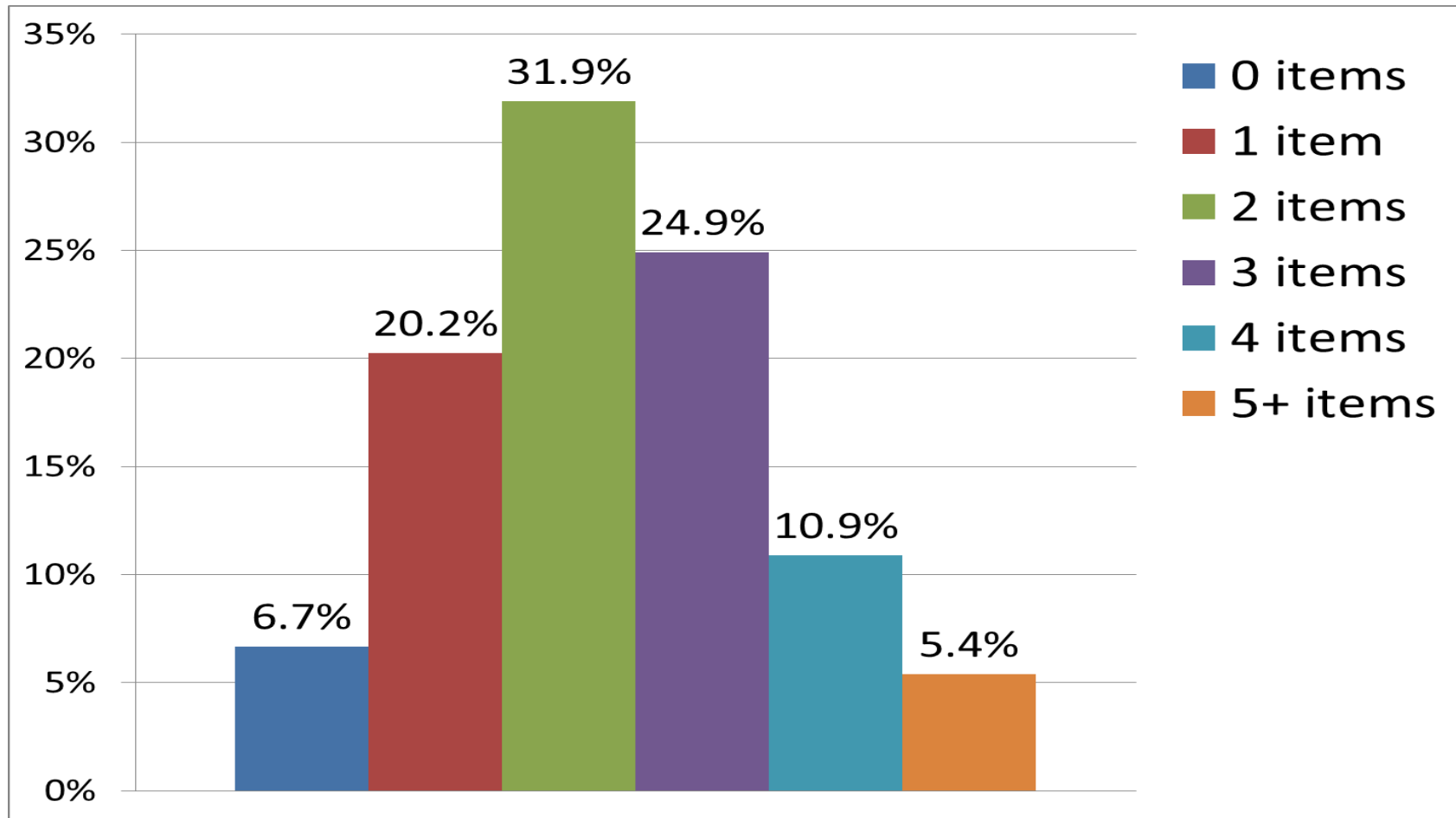


F.



Column Chart (Histogram) SBDH Groups (N=4,263)

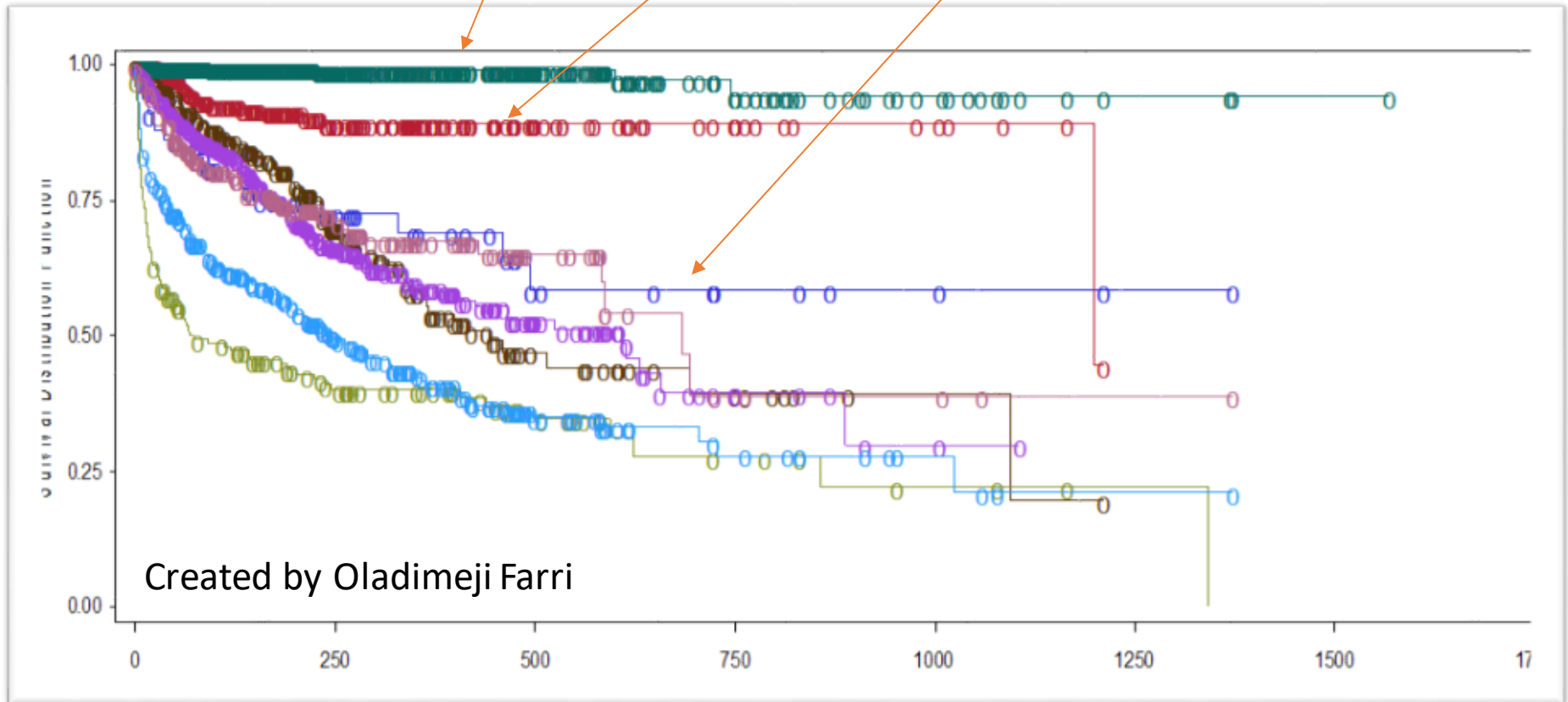
Few mothers had SBDH scores of 0 – most had 1 or more. Minorities cannot have SBDH scores of 0.



Created by Michelle A. Mathiason in Excel

Using Kaplan-Meier Curves to Depict Problem Stabilization

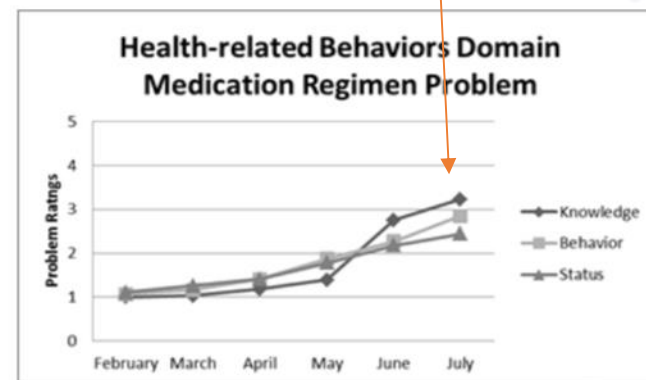
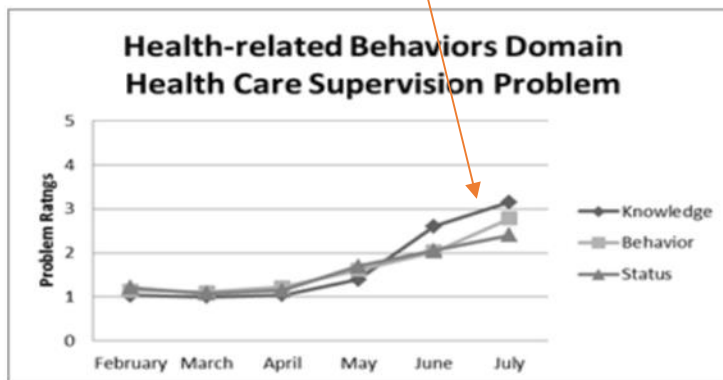
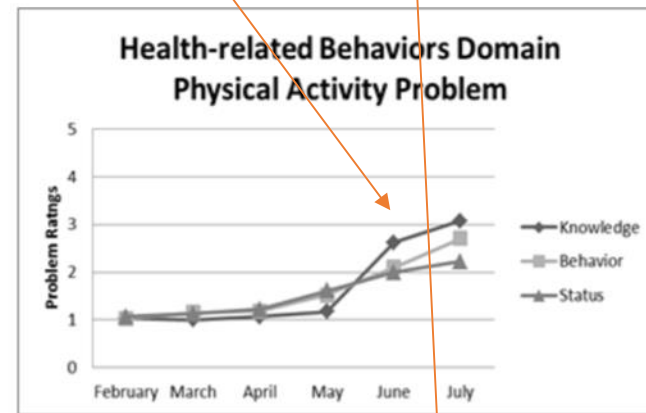
Problems stabilize differentially after intervention – Caretaking/parenting and Pregnancy do not stabilize because of continuous need for developmental teaching, guidance, and counseling. Other problems (Mental health, Income, Family planning, Abuse, Substance use) stabilize more rapidly after intervention.



Multi-series Line Graphs

Improvement in KBS over time for individuals with diabetes in rural Mexico after regular visits in important problems: Physical activity, Medication regimen, and Health care supervision

- ▶ Outcome evaluation demonstrated that knowledge, behavior, and status ratings improved significantly ($p < .001$).
- ▶ Examples of problem-specific changes over time are shown for Health care supervision, Physical activity and Medication regimen problems.

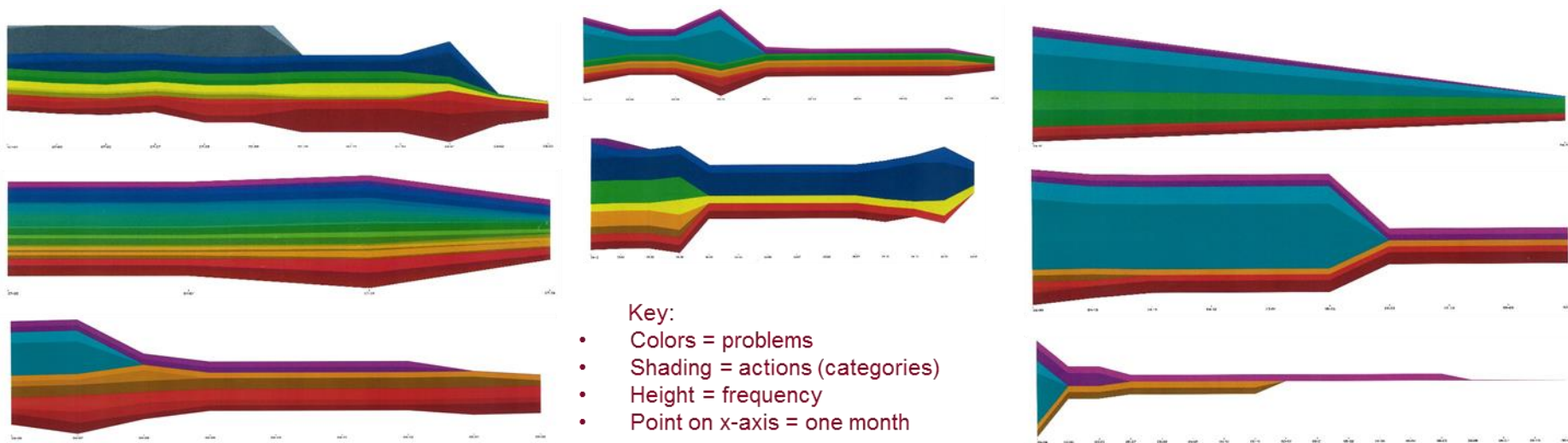


Erika Lozada-Perezmitre, María Magdalena Soriano-Sotomayor MSN, CCRN; María de la Luz Bonilla-Luis MSN, RN; Beatriz García-Solano DRN, NR; Lisiane Pruinelli, MSN, RN; Karen A. Monsen, PhD, RN, FAAN. (2014). Improving Outcomes of Diabetes Mellitus Type 2 Patients in Rural Mexico through *Educational Home Care Services*. H3IT, Washington DC

Streamgraphs

Intervention patterns show numbers of interventions by problem over time.
Patterns differ by nurse and patient needs.
Tailoring interventions shows quality care.

- Using Data Visualization to Detect Nursing Intervention Patterns



Created by Era Kim in d3

Monsen, K. A., Peterson, J. J., Mathiason, M. A., Kim, E., Votava, B., & Pieczkiewicz, D. S. (2017). Discovering public health nurse-specific family home visiting intervention patterns using visualization techniques. *Western Journal of Nursing Research*, 39, 127-146. doi:10.1177/0193945916679663

Sometimes categorical data may be displayed using methods usually used with continuous data

Excel offers these recommended charts when selecting bar chart option to show differences in distribution of males and females in the sample.
Which charts show this best?

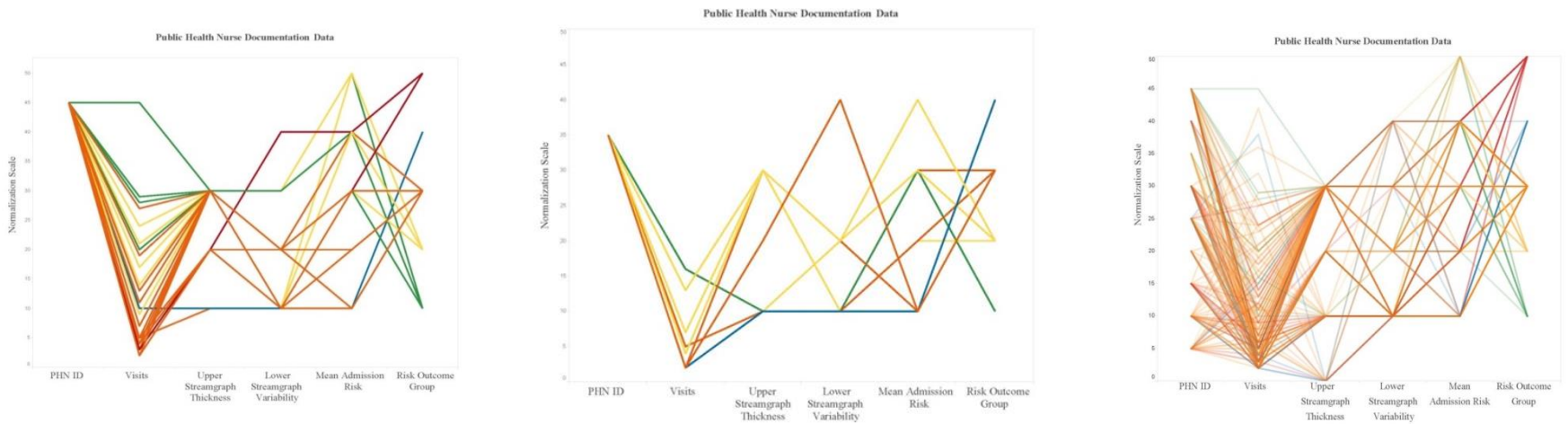
The screenshot shows the 'Insert Chart' dialog box in Excel. The 'Recommended Charts' tab is active, displaying several chart thumbnails. The 'Clustered Column' chart is selected and shown in a larger preview window. The preview window includes a legend with 'Age Category Males' (blue) and 'Age Category Females' (orange). Below the chart, a text box explains: 'A clustered column chart is used to compare values across a few categories. Use it when the order of categories is not important.'

OK Cancel

Parallel Coordinates: Relating Nurses, Risk, Problems, Interventions, and Outcomes

Parallel coordinates allows comparison of numerous variables on multiple y-axes across the x-axis. Line graphs are connecting the variables and do not show patterns over time.

This was instrumental in discovering the 'nurse effect' in relationship to client outcomes.



Created by Jessica Peterson in R

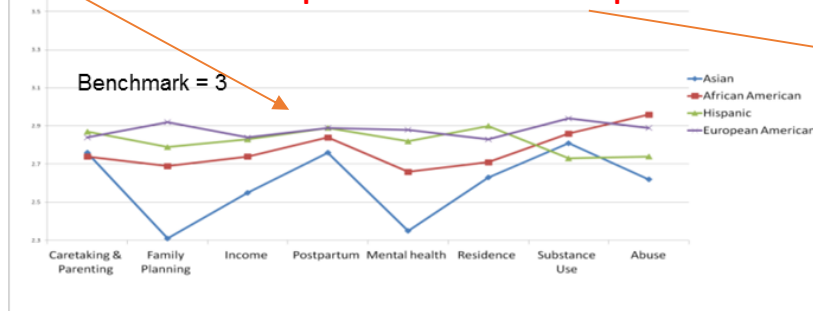
Seeing is Believing!

A version of parallel coordinates looking at patterns in outcomes by problem and race/ethnicity. After intervention we see improvement in health literacy and change in patterns outcomes by race – nursing intervention takes away health disparities

- Shows the complexity of the problem
- Provides convincing evidence of the outcome
- Demonstrates value of care
- Knowledge scores across problems over time
- Pre-intervention, patterns by race/ethnicity - Post-intervention, patterns by problem

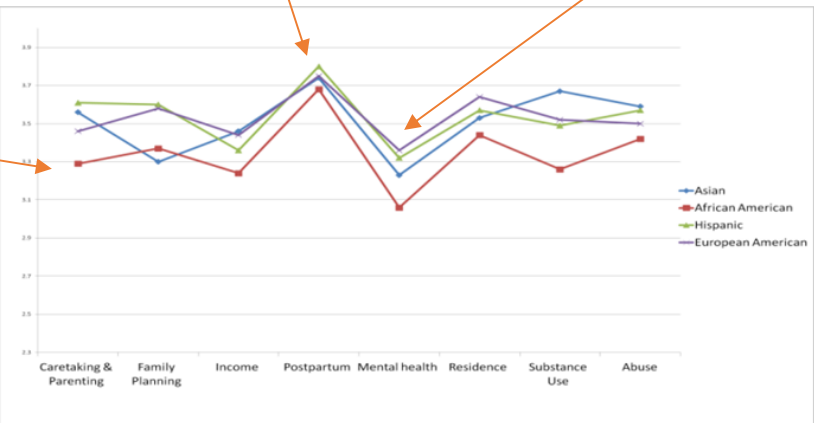
Stratified by race/ethnicity

Lines cross – pattern reflects problem



Best outcome – Postpartum

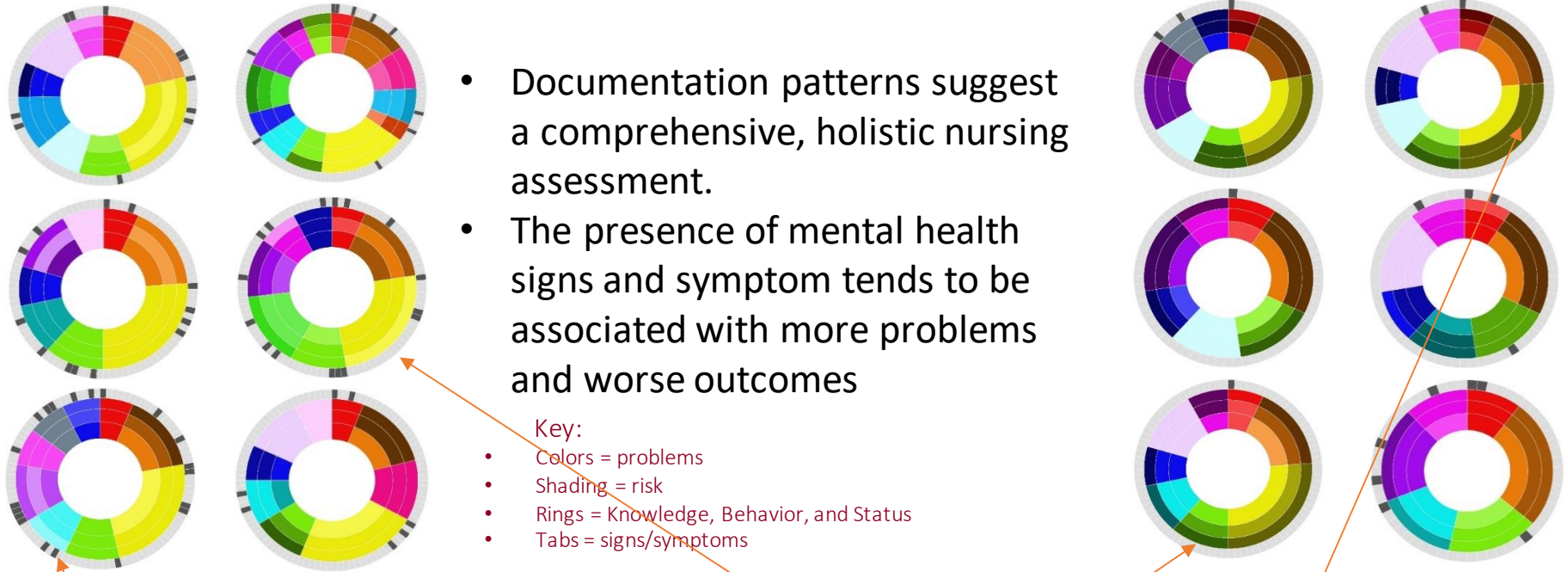
Most challenging – Mental health



Monsen, K. A., Areba, E. M., Radosevich, D. M., Brandt, J. K., Lytton, A. B., Kerr, M. J., Johnson, K. E., Farri, O, & Martin, K. S. (2012). Evaluating effects of public health nurse home visiting on health literacy for immigrants and refugees using standardized nursing terminology data. 11th International Congress on Nursing Informatics, Montreal.

Created by Karen Monsen in Excel

Sunbursts combine categorical and continuous data

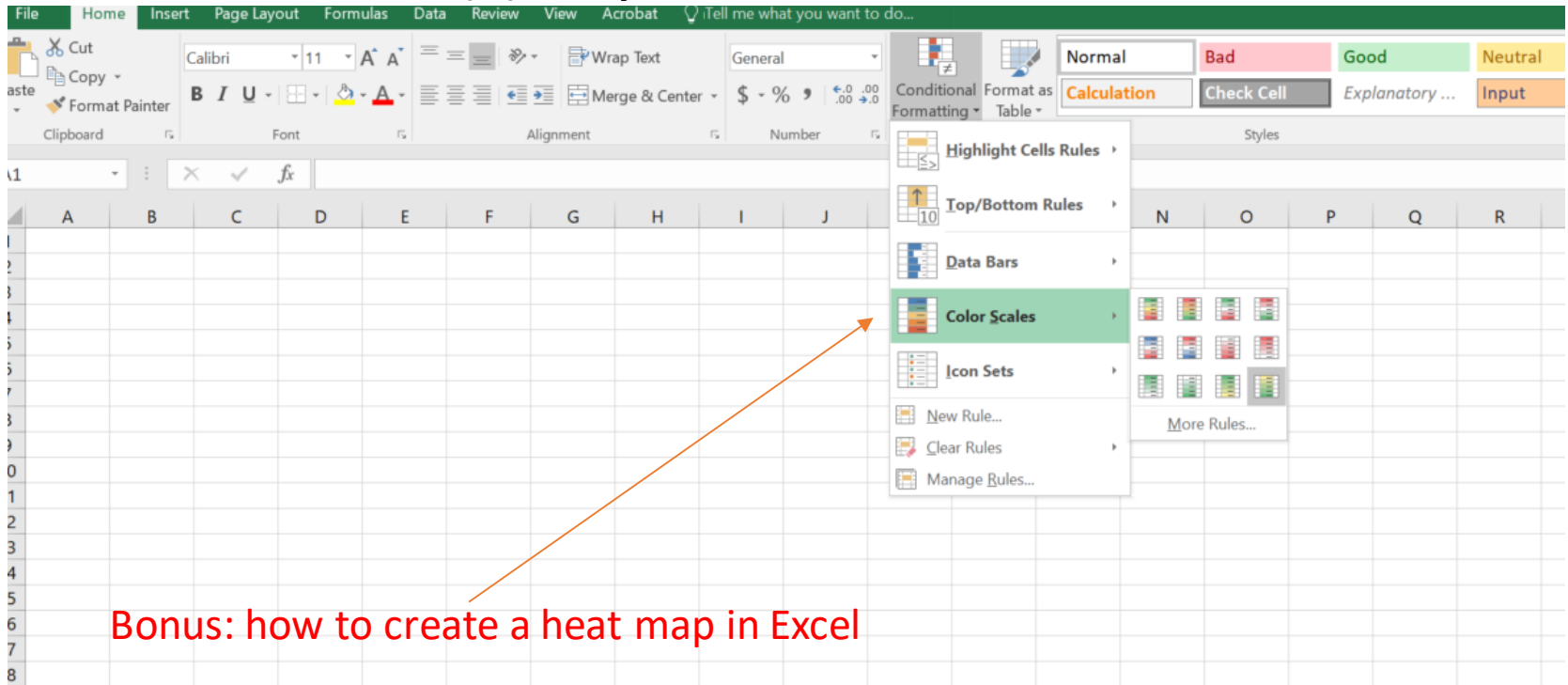


Created by Era Kim in d3

A version of pie charts that combine categories (problems = colored sections) and (signs/symptoms = tabs) and measures (KBS = shading, 1=brighter to 5=darker)
Patterns identified a hidden group with higher needs.

Heat Map DIY: Excel Conditional Formatting Functions

- Highlight data, Select conditional formatting – color scales – color(s) of your choice



Bonus: how to create a heat map in Excel

Heat Map - Patterns

Distribution of the sample is shown in first column

Other columns reveal different patterns from which we generated hypotheses

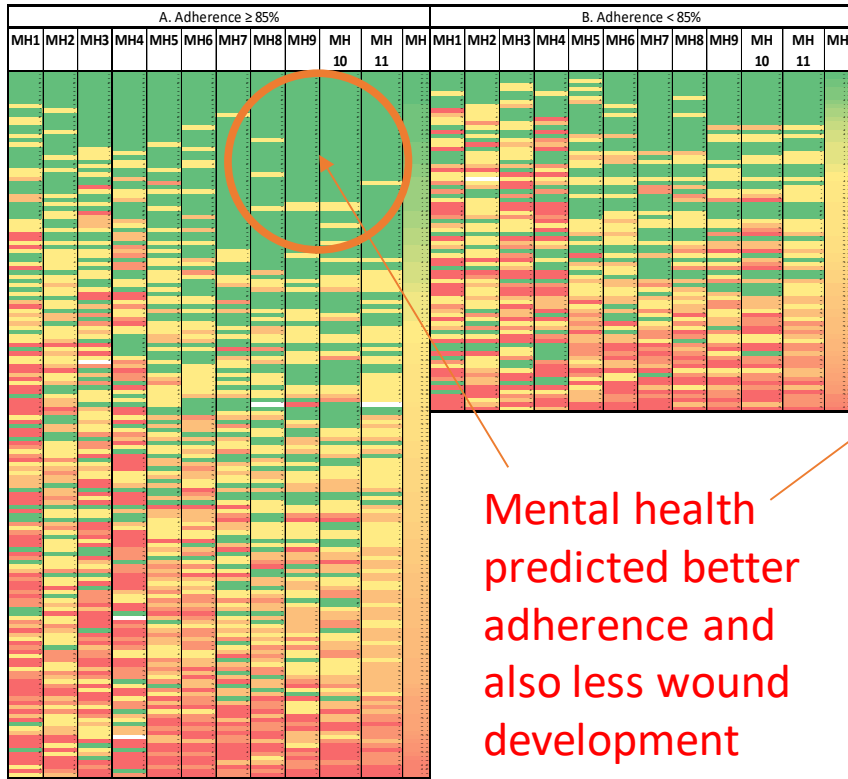
| SBDH Item Subgroups | Income | | | Mental health | | | Abuse | | | | | Substance use | | | | |
|---------------------|-----------------------------------|-----------------|-------------------|------------------------|--------------------------------------|---------------------------------------|--|--|-----------------------------------|---------------------------|---------------------------------------|-------------------------------------|---------------------------|---|-----------------------|-------------------------------------|
| | Proportion of the sample (N=4263) | married (n=914) | minority (n=2435) | low/no income (n=2812) | able to buy only necessities (n=340) | difficulty buying necessities (n=374) | sadness/hopelessness/decreased self-esteem (n=669) | loss of interest/involvement in activities/self-care (n=194) | difficulty managing stress (n=51) | attacked verbally (n=129) | fearful/hypervigilant behavior (n=38) | consistent negative messages (n=80) | assaulted sexually (n=68) | welts/bruises/burns/other injuries (n=34) | abuses alcohol (n=90) | smokes/uses tobacco products (n=48) |
| 0 | 0.07 | 0.17 | | | | | | | | | | | | | | |
| 1 | 0.20 | 0.32 | 0.13 | 0.09 | 0.03 | 0.01 | 0.02 | 0.03 | | | | | | | 0.01 | 0.03 |
| 2 | 0.32 | 0.36 | 0.31 | 0.35 | 0.11 | 0.09 | 0.14 | 0.07 | 0.06 | 0.07 | 0.03 | 0.03 | 0.03 | 0.01 | 0.17 | 0.01 |
| 3 | 0.25 | 0.10 | 0.34 | 0.34 | 0.33 | 0.16 | 0.29 | 0.23 | 0.10 | 0.14 | 0.13 | 0.15 | 0.29 | 0.03 | 0.24 | 0.01 |
| 4 | 0.10 | 0.03 | 0.15 | 0.15 | 0.35 | 0.35 | 0.03 | 0.29 | 0.35 | 0.29 | 0.16 | 0.24 | 0.23 | 0.21 | 0.23 | 0.31 |
| 5 to 10 | 0.05 | 0.02 | 0.08 | 0.08 | 0.13 | 0.29 | 0.25 | 0.39 | 0.49 | 0.48 | 0.68 | 0.59 | 0.46 | 0.44 | 0.34 | 0.46 |

Monsen, K. A., Brandt, J. K., Brueshoff, B., Chi, C. L., Mathiason, M. A., Swenson, S. M., & Thorson, D. R. (2017). Social determinants and health disparities associated with outcomes of women of childbearing age receiving public health nurse home visiting services. *JOGNN*, 46 (2), 292-303. doi: 10.1016/j.jogn.2016.11.014.

Created by Karen Monsen in Excel

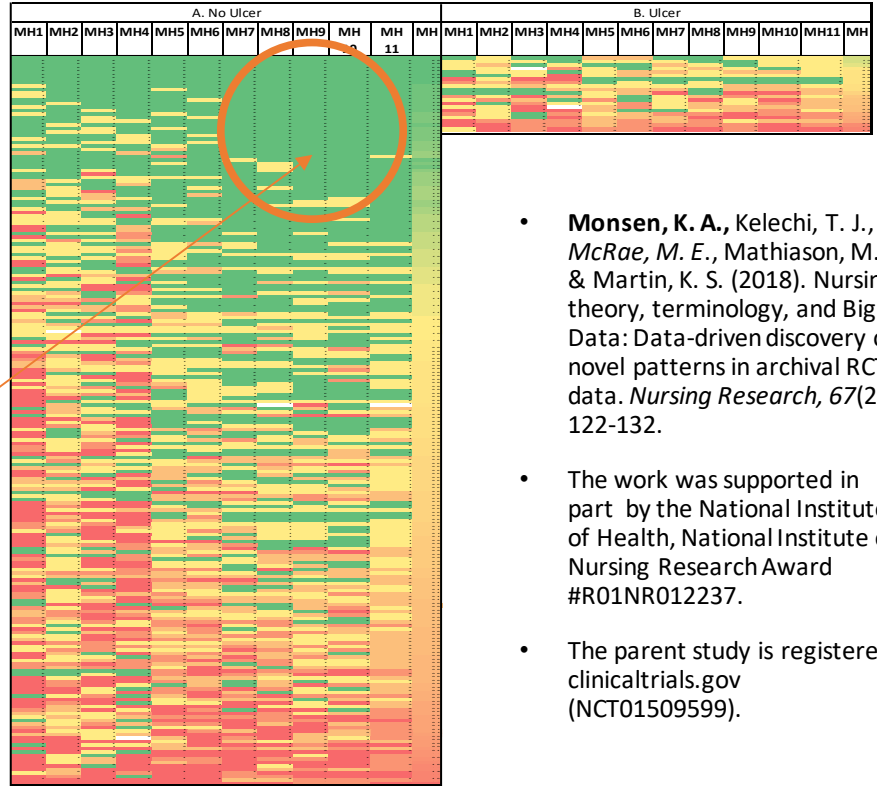
Heat Maps: Mental Health

Adherence Outcome (N=247, 167 with higher and 80 with lower)

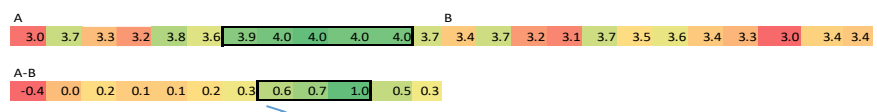
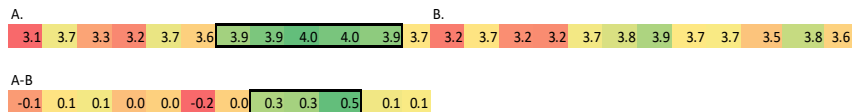


Mental health predicted better adherence and also less wound development

Ulcer Development Outcome (N=233; 210 without ulcers, 23 with ulcers)



- **Monsen, K. A.,** Kelechi, T. J., **McRae, M. E.,** Mathiason, M. A., & Martin, K. S. (2018). Nursing theory, terminology, and Big Data: Data-driven discovery of novel patterns in archival RCT data. *Nursing Research*, 67(2), 122-132.
- The work was supported in part by the National Institutes of Health, National Institute of Nursing Research Award #R01NR012237.
- The parent study is registered at clinicaltrials.gov (NCT01509599).



Created by Michelle A. Mathiason in Excel

Three variables appeared to be related to both adherence and wound development outcomes: MH 8, MH 9, MH 10

Heat Map: Intervention Analysis

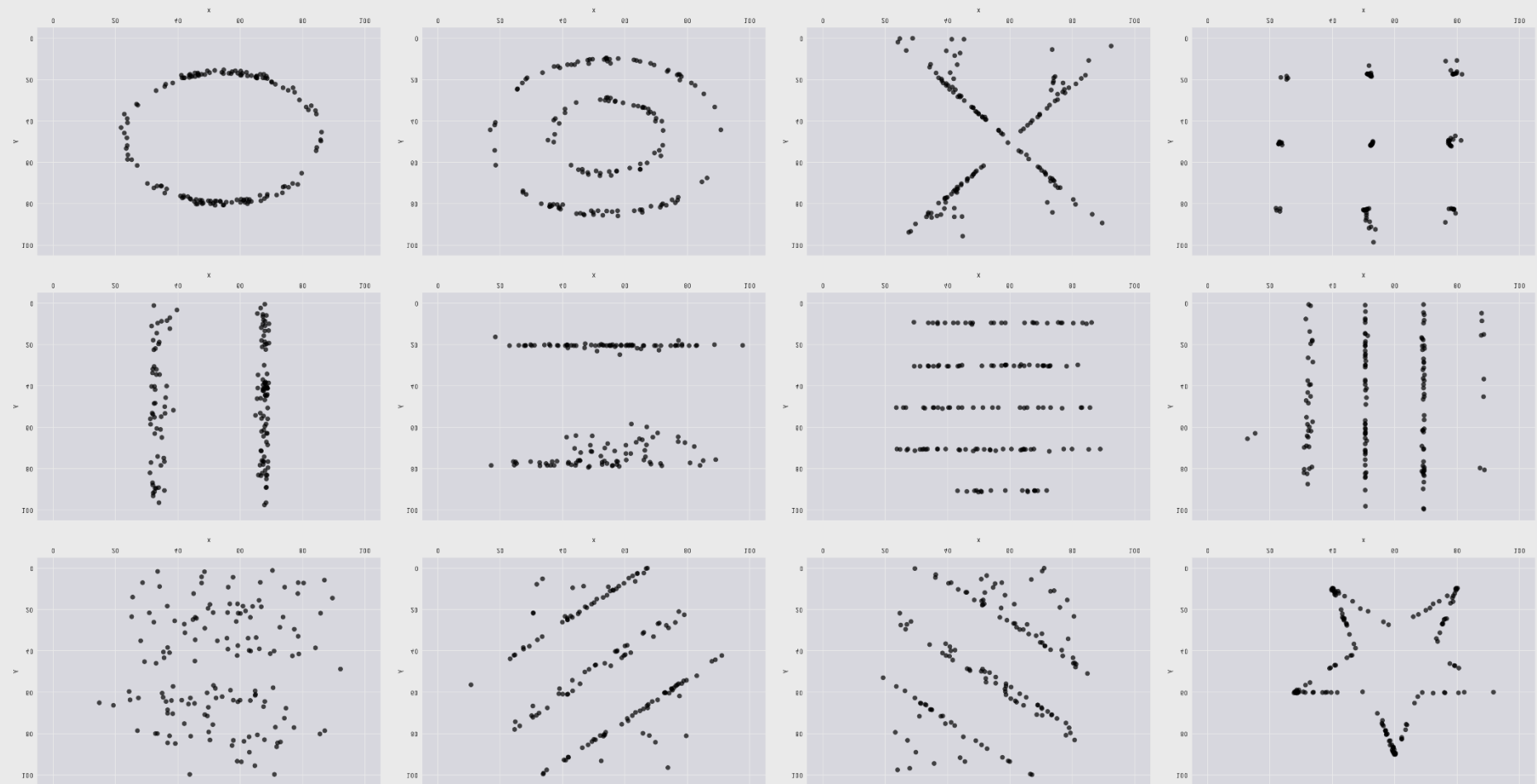
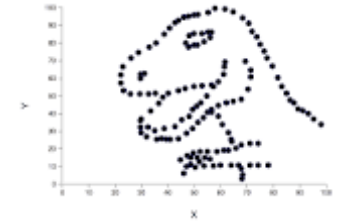
Nurses' scope of practice reflects the total intervention scope

Mental health interventions predominate across the continuum of care

- Patterns of evidence-based EOLC care

| Term | All | Nurse | Provider | Social worker | Psychologist | Chaplain | Music therapist | Massage therapist | Pharmacist | Patient | Surrogate | Admission to nursing home | Admission to hospital | Admission to hospice | Patient health deteriorating | End of life care | Discharge planning | Hospice standing orders | Published guidelines | |
|--|-----|-------|----------|---------------|--------------|----------|-----------------|-------------------|------------|---------|-----------|---------------------------|-----------------------|----------------------|------------------------------|------------------|--------------------|-------------------------|----------------------|----|
| Health care supervision | 33 | 28 | 25 | 13 | 7 | 5 | | | | 5 | 5 | | | | 16 | 16 | | | 16 | |
| Respiration | 24 | 24 | | | | | | | | | | 1 | 1 | 1 | 1 | | 1 | | | 1 |
| Bowel function | 16 | 16 | | | | | | | | | | | | | | | | | | 1 |
| Pain | 14 | 14 | 1 | | | | | | | | 1 | 1 | 1 | 1 | | | | | | 1 |
| Digestion-hydration | 12 | 12 | 1 | | | | | | | | | | | | 12 | 12 | | | | 12 |
| Skin | 11 | 11 | 1 | | | | | | | | | | | | | | | | | 1 |
| Mental health | 9 | 8 | 1 | 1 | 2 | 2 | 3 | 1 | | 1 | | 14 | 11 | 11 | 23 | 21 | 14 | | 5 | 28 |
| Urinary function | 7 | 7 | | | | | | | | | | 1 | 1 | 1 | 5 | 5 | 1 | | 2 | 3 |
| Interpersonal relationship | 5 | 4 | 2 | 2 | 3 | 3 | 1 | | | 1 | 2 | | | | 3 | 3 | | | 1 | 2 |
| Oral health | 5 | 5 | | | | | | | | | | | | | 9 | 9 | | | | 9 |
| Sleep and rest patterns | 4 | 4 | | | | | | | | | | | | | 1 | 1 | | | | 1 |
| Medication regimen | 3 | 2 | 2 | | | | | 1 | 1 | | | | | | 1 | 1 | | | | 1 |
| Cognition | 1 | 1 | 1 | | 1 | | | | | | | | | | 3 | 3 | | | | 5 |
| Communicable/infectious condition | 1 | 1 | | | | | | | | | | 1 | 1 | 1 | 14 | 14 | 1 | | | 13 |
| Communication with community resources | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | 1 | 1 | | | | 1 |
| Grief | 1 | 1 | | 1 | 1 | 1 | | | | | | | | | | | | | | 1 |
| Neuro-musculo-skeletal function | 1 | 1 | | | | | | 1 | | | | | | | 24 | 24 | | | | 24 |
| Nutrition | 1 | | | | | | | | | 1 | | | | | 9 | 9 | | | | 11 |
| Physical activity | 1 | | | | | | | | | 1 | | | | | 4 | 4 | | | | 4 |
| Reproductive function | 1 | 1 | | | | | | | | | | 1 | 1 | 1 | 1 | 1 | | | | 1 |
| Spirituality | 1 | 1 | 1 | | 1 | 1 | | | | | | | | | 7 | 7 | | | | 7 |
| Vision | 1 | 1 | | | | | | | | | | | | | 1 | 1 | | | | 1 |

Scatterplot Matrix: Datasaurus Dozen



"never trust summary statistics alone; always visualize your data" – Alberto Cairo <https://www.autodeskresearch.com/publications/samestats>

Visualization for Nursing Data

- Put your data to work
 - Make pictures
 - Identify patterns
 - Generate hypotheses
 - Test them to see if they are true
- Try it – your research will be better if you do!

Thank you! Questions?

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