Collaborative Visual Analytics for Public Health: Facilitating Problem Solving and Supporting Decision-Making

by

Samar H. Al-Hajj

M.Sc. (Telecommunications Management), Golden Gate University, 2004
B.Sc. (Computer Information Systems), Golden Gate University, 2002

Dissertation Submitted in Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy

in the
School of Interactive Arts and Technology
Faculty of Communication, Art and Technology

SIMON FRASER UNIVERSITY

Spring 2014

Approval

Name: **Samar Al-Hajj**

Degree: **Doctor of Philosophy**

Title of Dissertation: ***Collaborative Visual Analytics for Public Health: Facilitating Problem Solving and Supporting Decision-Making***

Examining Committee: **Chair:** Tom Calvert,
Professor Emeritus

Brian Fisher
Senior Supervisor
Associate Professor

Ian Pike
Co-Supervisor
Associate Professor
Department of Paediatrics,
Faculty of Medicine,
University of British Columbia

Ron Wakkary
Supervisor
Professor

Carman Neustaedter
Internal Examiner
Assistant Professor

Colin Macarthur
External Examiner
Professor
Department of Paediatrics and
Department of Health Policy
Management and Evaluation
University of Toronto

Date Defended/Approved: April 23, 2014

Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics,

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University;

or has conducted the research

c. as a co-investigator, collaborator or research assistant in a research project approved in advance,

or

d. as a member of a course approved in advance for minimal risk human research, by the Office of Research Ethics.

A copy of the approval letter has been filed at the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Burnaby, British Columbia, Canada

Abstract

With advancement in information technology, health data are collected at an unprecedented rate. Accurate understanding, analysis and interpretation of complex, multidimensional data is critical to understand wicked health problems to make timely decisions and interventions. Injury problems are classified as wicked health problems, they are associated with numerous individual, social, environmental and policy related factors. Wicked injury problems are multidimensional and require a multidisciplinary approach for effective solutions.

We studied the integration of Visual Analytics (VA) methods to solve wicked injury problems. The science of VA leverages information visualization techniques and computational analysis methods to facilitate understanding of heterogeneous data and support decisions about dynamic injury situations. We designed a proof-of-concept prototype - *interactive* Analytical Injury Dashboard (*i*AID) and demonstrated its application with injury stakeholders, using Canadian CHIRPP injury data. We adopted the Paired Analytics (PA) methodology to assess the interface design, layout and functionality of the *i*AID. Inspired by the Delphi method, the study adapted (PA) methodology and introduced a novel methodology - Group Analytics (GA), which was pilot tested and refined for the final research study design. GA was used to evaluate the impact of collaborative VA on facilitating problem solving and supporting decision-making within the injury sector.

We conducted seven PA sessions and two GA sessions. Data included stakeholders observations, audio and video recordings, questionnaires and follow up interviews, and were analyzed to gain in-depth understanding of the collaborative VA process and its impact on problem solving and decision-making. Results demonstrated that *i*AID helped injury stakeholders to convert data into useful information, facilitate task completion, and support problem solving and decision-making. Based on the Joint Activity Theory and distributed cognition framework, analysis revealed that GA triggered the emergence of *Common Ground* among stakeholders, which evolved throughout the GA sessions to enhance their interactions, communication, coordination of joint activities and ultimately their collaboration on problem solving and decision-making. These findings will help inform the design of innovative VA tools that assist health professionals in analyzing and interpreting complex health data, and will introduce new metrics to enhance group collaboration to support timely decisions and actions.

Keywords: Collaborative Visual Analytics; Public Health; Paired Analytics; Group Analytics; Delphi Method; Interactive Dashboard

Dedication

To my children,

Batoul, Mohammad and Hawraa

With love and compassion

Acknowledgements

First, I would like to express my acknowledgment and sincere thanks to my supervisor Dr. Brian Fisher for giving me the opportunity for join his lab and unravel my intellectual potential. His expertise, flexibility and friendliness helped me in my research study.

My gratitude and appreciation are extended to my co-supervisor from UBC, Dr. Ian Pike. I am grateful for his continuous guidance and encouragement that gave me the strengths needed during my PhD journey. His inspiration, compassion and mentorship provided me with personal and professional growth and gave me the confidence to be who I am today.

I would like to extend my thanks to the members of my dissertation committee: Dr. Tom Calvert, for serving as my Committee Chair, Dr. Ron Wakkary, Dr. Carman Neustaedter as my Internal Examiner, and a special thanks for Dr. Collin Macarthur from the University of Toronto for serving as my External Examiner.

Special thanks to Dr. Linda Kastraa for reviewing and providing insightful comments and invaluable feedback on sections of this thesis. Thanks also to my fellow graduate students at SFU SCIENCE Lab for their help and support, especially Nadya Calderon. Special thanks to researchers and the team at the British Columbia Injury Research and Prevention Unit (BCIRPU), BC Children's Hospital, who assisted me and supported me during my research work at the unit, in particular, Shannon Piedt and Fahra Rajabali.

Many thanks to all the health professionals, policy makers, injury researchers, epidemiologists and medical practitioners who participated in the '*Dashboard Project'* pilot study and the *'Child and Youth Injury Dashboard using BC CHIRPP data'* study. Your cooperation made this research possible.

Lastly, I would like to extend my special thanks to my husband for his encouragement and selfless love during this period of time. My heartfelt gratitude and thanks to my children for their patience and cooperation. Sincere thanks to my mother, siblings and close friends for their moral support, advices, and prayers.

Quotation

"Computers are incredibly fast, accurate and stupid. Human beings are incredibly slow, inaccurate and brilliant. Together they are powerful beyond imagination."

Albert Einstein (1879 - 1955)

Table of Contents

List of Tables

List of Figures

List of Acronyms

BCIRPU	British Columbia Research and Prevention Unit
CDA	Confirmatory Data Analysis
CG	Common Ground
CHIRPP	Canadian Hospitals Injury Reporting and Prevention Program
D-Cog	Distributed Cognition
EDA	Exploratory Data Analysis
EHR	Electronic Health Records
ESSENCE	Electronic Surveillance System for the Early Notification of Community based Epidemics
GA	Group Analytics
GUI	Graphical User Interface
GUI	Graphical User Interface
HCI	Human Computer Interaction
*i*AID	*Interactive* Analytical Injury Dashboard
IBIS	Issue Based Information Systems
*i*DOT	*Interactive* Data Online Tool
InfoVis	Information Visualization
JAT	Joint Activity Theory
PA	Paired Analytics
PHAC	Public Health Agency of Canada
RODs	Real-Time Outbreak Detection Systems
SA	Situation Awareness
SME	Subject Matter Expert
UBC	University of British Columbia
VA	Visual Analytics
VAE	Visual Analytics Expert
VisQL	Visual Query Language

Glossary

Artefact	Using the *i*AID dashboard, artefacts refer to all created, manipulated, refined and interpreted visualizations.
Camtasia	Screen recording and video editing software used to record on-screen injury stakeholders' interactions with the *i*AID dashboard when manipulating the data and creating the visualizations.
Chronoviz	Visualization tool used to visualize and analyze time-coded multimodal data.
Injury Prevention	Strategies and programs adopted to reduce injury burden.
SME	Stakeholders knowledgeable of the subject matter. In this study, public health and in particular, injury prevention.
Tableau	Visual Analytics software used to create visualizations and build interactive dashboards.
VAE	Visual Analytics Expert in various types of visualization tools and techniques.

Chapter 1. Introduction

1.1. Research Approach

With the advancement in information technologies, complex and multidimensional data are generated at an unprecedented rate. In this data rich world, whether it is intelligence, finance or healthcare, complex and massive data hinder the ability of analysts and decision makers to make sense, understand, and reason about dynamic situations to make informed and timely decisions.

Within the healthcare sector, substantial amounts of multidimensional health data are produced everyday and housed in hospitals and clinics' health information systems. As a result, health professionals and policy makers are often faced with information overload and the inability to process and analyze multi-sourced and multifaceted health data. Public health data are 'data for action'; they are vital for the planning, implementation, and evaluation of public health programs, trainings and policies [Teutsch & Churchill, 2000]. To address emerging public health threats and problems, health professionals need to understand complex and massive data in order to assess health issues, implement strategies and programs, and monitor the outcome of health interventions, in a timely and effective manner. Being able to understand and make sense of massive generated health data is critical to building knowledge and making informed decisions about dynamic health events. The need arises for the integration of advanced tools and techniques that amplify health professionals' cognitive capabilities and complement their reasoning process to analyze health events characterized by heterogeneous and complex datasets. Health professionals and policy makers need interactive decision-support technology solution that can help them to visually explore, comprehend and interpret complex health data.

We adopted Visual Analytics technology and methods to leverage health professionals' perceptual and cognitive capabilities to comprehend and analyze complex and dynamic datasets in order to facilitate problem solving and support decision-making process. Visual Analytics (VA) is defined as the 'Science of analytical reasoning facilitated by interactive visual interfaces' [Cook and Thomas, 2005]. Visual Analytics is an interdisciplinary science that synthesizes methods and techniques from multiple disciplines including information visualization, Human Computer Interaction (HCI), data mining, data management, decision science, mathematical and computational science, statistics, cognitive psychology, and perceptual science [Keim et al, 2006; Boulos et al, 2011]. The adoption of Visual Analytics tools and techniques can support health professionals and policy makers' with reasoning process and assist with the synthesis of salient information from multidimensional and dynamic health data in order to build fundamental knowledge and make informed and timely decisions [Shrinivasan et al. 2008].

This thesis offers a novel approach to address multidimensional public health problems. The study's research design adopts theories and methods from Visual Analytics and cognitive science to explore the effect of collaborative Visual Analytics on problem solving and decision-making when dealing with public health problems related to child and youth injury and injury prevention programming. Furthermore, this thesis proposes a methodology termed 'Group Analytics' for capturing and understanding collaborative Visual Analytics among multiple stakeholders and how it influences group problem solving and decision-making process. This thesis begins by examining the complex nature of public problems in general, and the injury prevention problem in particular. It further discusses how Visual Analytics tools and techniques represent a unique approach to address these types of problems. Furthermore, this thesis describes the theoretical framework adopted to design the Group Analytics method and to evaluate and analyze the captured data during the analytics sessions.

The underlying goal of this research is to provide in-depth understanding of the use of collaborative Visual Analytics as a tool for public health injury prevention problems. Additionally, the study assesses and evaluates the application of the Group Analytics method to capture the impact of collaborative Visual Analytics on facilitating group problem solving and supporting decision-making within the public health sector.

1.2. Public Health Problems are Wicked Problems

Dynamic problems, such as those experienced in public health in general, and injury prevention in particular, combine multidimensional elements and constitute what Horst-Rittel called the ‘Wicked Problem’ [Rittel & Webber, 1973]. Horst-Rittel coined the term ‘wicked problems’, which he defines as a ‘class of social system problems which are ill-formulated where the information is confusing where there are many clients and decision-makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing.’ [Buchanan,1992]. Consistent with this description, Kirschner et al explain in their book, ‘*Visualizing Argumentation*’, that ‘wicked problems’ are ill-structured and dynamic problems that combine multidimensional elements and don’t follow the conventional problem solving approach [Kirschner, Shum & Carr, 2003]. We therefore synthesized these well-known definitions of ‘wicked problem’ to reflect the context of this study.

According to Rittel and Webber (1973), there are ten unique characteristics of wicked problems [Rittel & Webber, 1973] that we explore and explain as follows:

1. **Wicked problems don't have a well-known definition or formulation:** Wicked problems lack an agreed upon definition. They cannot be represented in a precise and defined form. To describe a wicked problem, analysts need to state the proposed solutions that can be conceived to address the wicked problem.
2. **Wicked problems have ‘no stopping’ Rule:** there is no definite solution for the wicked problem. Hence, resolving a wicked problem is an evolving process of approaching towards a better solution.
3. **Solutions to wicked problems are ‘good or bad’ and not ‘true or false’:** analysts judge the solutions to wicked problems based on their personal assessment, background, expertise, and perspectives.
4. **Solutions to wicked problems cannot be compiled in a list of operations:** therefore, analysts cannot evaluate and determine solutions to wicked problems within a limited timeframe.
5. **Solutions to wicked problems are ‘one-shot’ solution:** proposed solutions to wicked problems are ‘consequential’ and ‘irreversible’. Therefore, every attempt to resolve the wicked problem is considered to be significantly important.
6. **Solutions to wicked problems have no ‘immediate or ultimate’ check:** There is no explicit set of principles, procedure or prescribed methods for resolving wicked problems.

7. **Wicked problems are not common problems:** they are distinct and unique problems therefore they cannot be solved by conventional problem solving techniques
8. **Wicked problems are 'symptom' of other wicked problems:** wicked problems are interconnected problems. Each problem is derived from a 'higher level' wicked problem.
9. **Wicked problems have no 'correct explanation':** wicked problems are multidimensional problems that should be resolved by combining multiple approaches that address the various aspects involved.
10. **Planners are liable for the action they generate:** 'planners have no right to be wrong'. The generated outcome of wicked problems affect many people, therefore analysts are responsible for their decisions.

Likewise, Adler and Ziglio [1996] in their book, "Gazing into the Oracle", explored the argumentative and societal nature of public health problems to give us insights into its three main characteristics, including:

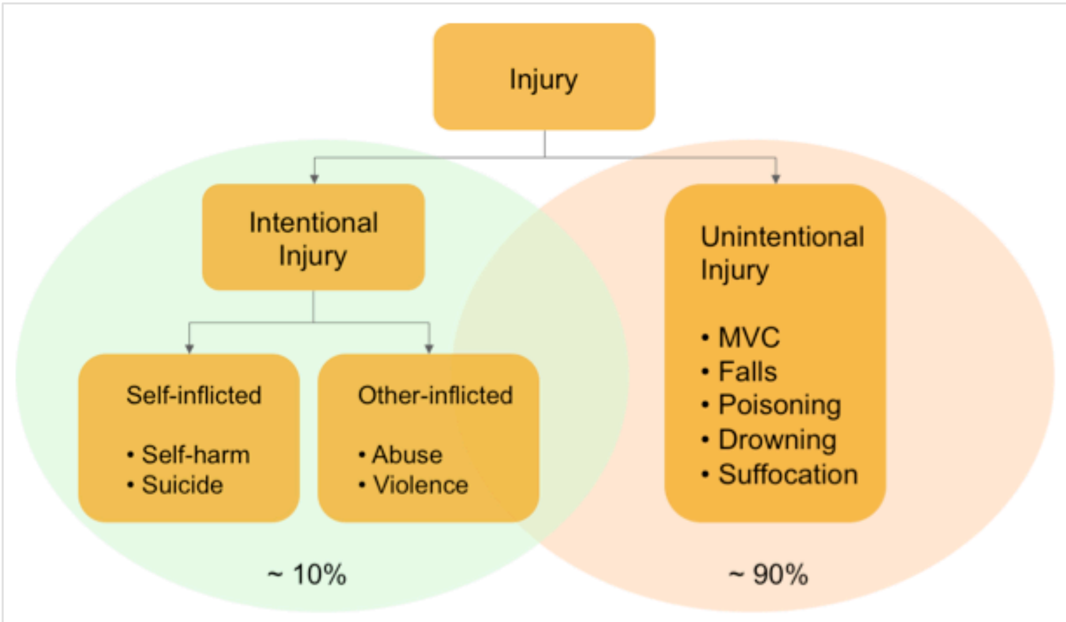
- **Public health problems are multifaceted and interconnected problems.** They are complex multilayered problems that combine numerous health elements and features. Health problems are largely associated with multiple social, environmental and policy related factors. Therefore they constitute multidimensional problems that require the exploration and discussion of many aspects and elements of the problem in order to propose a solution.
- **Public health problems are unstructured problems.** They have unknown patterns and they follow undefined trends. Therefore, it's challenging for health professionals to anticipate the potential impact of health problems on individuals and societies. Consequently, there aren't any specific analytical techniques or pre-built logic models that can be applied to solve these types of problems. Contrary to problems that follow well-known and structured patterns, these types of problems don't have a definite solution, they require creative and judgmental approaches to find a solution.
- **Public health problem deal with incomplete and uncertain data.** The public health data are characterized by complexity and uncertainty [Skulmoski et al, 2007]. However, despite the uncertainty and information insufficiency of public health problems, they require fast and appropriate actions to be taken to address timely health issues. Health professionals are faced with the challenge to address health issues with the inherited uncertainty of the dynamic health situation. Therefore, it's fundamental for health professionals to understand and gain insights into a timely solution that can be adopted as an optimal solution under unknown and uncertain conditions.

We argued that the nature of public health and injury prevention problems reflects the definition and characteristics of "wicked problem" provided by Horst-Rittel and Kirschner et al. [Rittel & Webber, 1973; Kirschner, Shum & Carr, 2003]. Within the context of this study, we qualify public health and injury prevention problems as ‘wicked problems’ as they clearly manifest several of Rittel & Webber presented characteristics of wicked problems enlisted above, mainly characteristics 2, 3, 5,6, 8 and 10. Injury problems are societal problems, they are multidimensional and unstructured problems characterized by uncertain and incomplete data. Injury problems are inherently complex and wicked problems that cannot be address using well-known problem solving techniques. Proposed solutions to wicked problems should be judged and assessed based on analysts’ perspectives, assessments and judgments. Public health and injury prevention problems are ill-structured data driven problems that are challenging to resolve using conventional problem solving approaches.

1.3. The Injury Burden

Injury is defined as the physical damage that results when a human body is suddenly or briefly subjected to intolerable levels of energy, including thermal, mechanical, electrical, or chemical energy; or the absence of essential energy, including thermal energy or oxygen [Langley & Brenner, 2004]. The time between exposure to the energy and appearance of physical damage is short. Injury is typically classified, firstly according to whether the physical damage resulted as result of an intentional (approximately 10% of injury cases) or unintentional (approximately 90% of injury cases) application of energy; and, secondly, according to any one of the numerous external causes of the application of the energy causing the physical damage, such as motor vehicle crashes, drowning, poisoning, falls or violence (Figure 1.1).

Figure 1.1. Injury Classification



Injury is a multifaceted health problem. Within the context of this dissertation, we addressed the 'Injury problem' as a specific wicked public health problem. Injury problems are societal health problems as they impose the biggest impact upon individuals, families and society in general. They are considered wicked health problems due to the complexity and multidimensional aspects of these problems. According to Health Canada, injury problems represent the leading cause of death among North Americans age 1-44 and result in the greatest number of potential years of life lost, compared to other causes of death [Health Canada, 1999]. Among children, injuries result in more deaths than all other causes combined. The causes of injury are numerous, including motor vehicle crashes, poisoning, drowning, falls and violence, among others [Pike et al., 2010]. Furthermore, injuries constitute a major public health concern and an overwhelming financial burden to the Canadian health care system due to the high number of injuries requiring treatment as well as the high costs of hospitalization, rehabilitation services and home health care. According to a 2009 SMARTRISK Report, the annual economic burden of injuries totalled $19.8 billion in Canada, representing the third leading cost of disease on the health system [SMARTRISK, 2009]. In Canada, the human burden of injury is expressed using a variety of data sources, including vital statistics, hospital separations data, emergency department surveillance systems, trauma registries, and some specialized local injury registries. With the exception of some of registry data and the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP), these data sets were established for administrative purposes rather than specifically for injury prevention. As such, specific information related to the circumstances of injury is often lacking. However, similar to endemic disease data, injury data are complex and dynamic and therefore need to be carefully examined in order to inform decisions and initiate actions regarding where to devote resources in order to reduce and prevent injury occurrences.

Preventing injury is a multifaceted health problem, considered to be a wicked health problem due to the complexity and multidimensional aspects involved. Wicked injury problems are especially challenging to solve because the causes of injury are not only complex but also unclear and uncertain [Adler & Ziglio, 1996]. Injury problems incorporate individual, social, cultural and economic factors that are hard to tackle. Injuries result from interconnected and interdependent problems that combine various health elements causing them to be difficult to unravel and resolve. Haddon, in his seminal work on injury prevention and safety emphasized the multiple underpinning attributes of injuries. He presented the Haddon Matrix (1970) as a model for analyzing the numerous environmental and personal factors contributing to various types of injuries in order to design and develop injury preventive measures. Based on Haddon's Matrix, Baker (1972) presented a practical classification of approaches to injury prevention and control based on the, *three E's* : *Education* (e.g. public awareness campaigns, media campaigns, personal advocacy for safety), *Ergonomics* (e.g. engineering and design related to environment, equipment, homes, toys, clothes and the natural world) and *Enforcement* (e.g. safety legislation, laws and policies). Understanding these three categorizations to injury prevention gives us insights into the complex and multidimensional approaches that need to be addressed when dealing with injury problems in order to more effectively address the problem, reduce injuries and promote healthier, safer communities [McClure, Stevenson & McEvoy, 2004].

As a result, wicked injury problems don't follow a conventional problem solving approach. They require a careful study of related health issues in order to make the best decisions. Wicked health problems that are characterized by uncertain data, and which follow unknown trends and patterns, are difficult to model using traditional computational and mathematical analytics and logic modeling. In a traditional analytics problem solving process, a well-structured problem follows a well-defined analytics model approach. Structured problems follow well-known patterns grounded in defined methods and conform to clear procedures that lead to anticipated answers and predictive outcomes. Well-structured problems incorporate known elements and follow a logic process to conduct rational reasoning in an attempt to solve the problem and reach a solution that is true (e.g. solving an algebraic equation). Conversely, ill-structured Public health problems, including injuries, are emergent problems that have less predictable outcomes. Most injury problems have no definitive solution or optimal resolution, because of the diverse nature of these problems [Rittel & Webber, 1973]. The lack of a definite solution classifies injury problems as 'wicked problems' that would benefit from a multidisciplinary problem solving approach to better inform decisions. According to Kirschner et al., solving ill-structured problem is an 'argumentation process requiring informal and not logical or mathematical reasoning (alone)' [Kirschner et al. 2002]. Hence, wicked problems require a rhetoric or argumentation approach in addition to the rational approach to solve the problem and reach a consensus. Within the context of this study, most injury problems have no definite solution that can be adopted as the optimal resolution, due to the diverse nature of these problems [Rittel & Webber, 1973]. Involving multiple injury stakeholders with diverse backgrounds, expertise and different interests leads to broader analysis of the wicked problem, improved judgment of the underpinning contributing factors and better assessment of the proposed solutions. The outcome is more often a multidimensional solution that incorporates a mixture of resolutions including the integration of public health services, the provision of training to health professionals, improved research, as well as the development and implementation of new or improved policies.

1.4. Visual Analytics: A Novel Approach

Effective analysis of wicked health problem is critical to the successful development of prevention strategies. Understanding the multi-layered aspects of injury data is crucial to the deployment of injury intervention policies and the allocation of trained personal and monetary resources to individuals and communities at risk [Teutsch

& Churchill, 2000]. In the case of the child and youth injury problem, understanding and analyzing injury data includes the identification of trends and patterns in injuries – who is being injured, where they are being injured, how they are being injured, and an understanding of the leading causes and associated factors of injury - in order to monitor and improve the health and well being of children and youth in Canada [Pike et al., 2010].

To effectively approach 'wicked' problems in injury, we adopted Visual Analytics methods and techniques to expand the shortcoming of analytical and computational approaches [Keim et al., 2010]. The nature of the public health data entails the use of a Visual Analytics approach to deal with the multi-sources and multi-dimensional health data retrieved from various sources. Visual Analytics constitutes a novel approach to address complex public health and injury problems and assist health professionals and policy makers in resolving wicked problems and making informed decisions. The emerging science of Visual Analytics integrates advanced visualization techniques and interactive graphical interfaces with mathematical and computational analytics to support analysts' reasoning process [Thomas and Cook, 2006; Keim et al., 2008]. As postulated in *Illuminating the path*, the main goal of Visual Analytics is to "facilitate the analytical reasoning process through the creation of software that maximizes human capacity to perceive, understand and reason about complex and dynamic data and situations." [Cook et al. 2005].

Visual Analytics plays a pivotal role in the data analysis process as it offers analysts two key functionalities: Visualization and Interactivity. On one hand, data visualization is important to amplify analyst's cognitive capabilities as well as to facilitate problem solving by making the solution to the problem prominent or salient. On the other hand, interactivity is essential to establish a dialogue between the analyst and the data in order to support data analysis by asking the data questions, seeking answers, generating hypotheses and testing scenarios.

Visual Analytics tools are integrated into the analytical process to amplify analyst's limited cognitive and perceptual capabilities. According to Miller, humans' memory suffers from inherent limitations that constrain the brain's capacity from retaining and processing massive and complex information. Miller demonstrates that the number of items that can be retained in humans' working memory at one time is limited to seven, plus or minus two [Miller, 1956]. Cognitive scientists Stenning and Lambalgen support Miller's earlier work and explain that 'human brain capacity to perceive and understand massive and complex data is limited due to the visual memory' restricted amount of information that can be processed at one time [Stenning & Lambalgen, 2008]. To relieve the memory from information overload problem, Visual Analytics represents external visual aids that help analysts to overcome the inherent limitations and weaknesses of the short term-memory. Likewise, Card et al. in "Readings in information Visualization: Using Vision to Think", states that information visualization is the "use of computer-supported, interactive, visual representations of abstract data to amplify cognition" [Card et al, 1999]. Visualization tools expand the inherent limited human's cognitive and perceptual capabilities and help to reason and conduct fast and efficient analysis. Visual Analytics' main objective is to facilitate human's visual query and support the cognitive and analytical process, enabling analysts to explore the complex data, identify trends and patterns, spot outliers and compare data. In his book, "*Visual Thinking for Design*", Ware underlines this notion of cognitive overload and explains that effective visual representations of large datasets trigger humans' eyes and exploit their visual pattern detector capabilities to amplify cognition and facilitate data exploration (i.e. compare datasets, reveal hidden trends and patterns in data, spot outliers) [Ware, 2008]. Heuer on the other hand, highlights in his book '*Psychology of intelligence Analysis'* the importance of adopting external aids to cope with the limited functioning of the human's cognitive process caused by the inborn weaknesses of the human's brain. Heuer emphasized the need for auxiliary aids to support and enhance analyst's cognitive capabilities. He explained that there is a need to introduce 'techniques and tools for coping with the inherent limitations on analysts' mental machinery" [Heuer, 1999]. Integrating auxiliary tools and techniques into the analysis process can assist analysts in overcoming these inherent limitations and obstacles and help to boost analysts' cognitive and perceptual capabilities to improve the analytical work.

Within the public health sector, we adopted Visual Analytics techniques to supplement health professionals' analytical cognitive process and to offer them rapid synthesis and interpretation of complex and multidimensional injury data. According to Kirschner et al, visualization tools are tools to "think with" [Kirschner et al., 2003]. The authors demonstrated that effective visual representations of analytical problems dramatically amplify individuals' cognitive and perceptual skills and facilitate their analytics work while reducing memory's workload. From the distributed cognition perspective, Hutchins further emphasizes the need for external graphical representations as cognitive tools to amplify analysts' cognition and expand their abilities to perceive and reason about complex cognitive tasks [Hutchins, 1996]. Data visualization tools and techniques provide analysts with external visual aids to reduce multidimensional data into manageable chunks of data that can be easily processed to derive meaning and make sense of complex health situations. Hence, Visual Analytics exploits graphical representations and interactive visual interfaces to support humans' analytical reasoning process in order to gain insights into massive and complex data and ultimately generate knowledge [Cook and Thomas, 2005].

With regard to 'wicked problems', the effective visual representation of the wicked problem is substantial to the problem solving process. By making the solution explicit, health professionals expedite and enhance the problem solving and decision-making process. Social scientist Herbert Simon notes that, 'solving a problem simply means representing it so as to make the solution transparent' [Simon, 1996]. The way data is presented can significantly influence analyst's ability to observe and compare data elements and variables, see the problem from various perspectives and ultimately be able to solve it accurately. Likewise, Few (2007) explained that representing complex data visually empowers analysts with the ability to convert slow reasoning tasks into fast perception tasks by making them visually salient [Few, 2007]. Data visualizations are graphical representations of data that are meant to convey the main concepts and ideas behind the data in a way that make the data easy to explore and the solution easy to see. Edward Tufte, in his book *Visual Explanations*, expanded this concept and rationalized that clear visual structuring and arrangement of data result in a clear reasoning about the data. He stated that "clarity and excellence in thinking is very much like clarity and excellence in the display of data. When principles of design replicate principles of thought, the act of arranging information becomes an act of insight' [Tufte, 1997]. Visual Analytics tools empower analysts with various visualization techniques including 2D Visualization, 3D Visualization, Geometrically-Transformed Displays, Dense Pixel Displays, Dynamic Projections, Temporal Visualization, Tree & Network

Data, Interactive Filtering, Zooming, and Linking & Brushing [Keim, 2002] in an attempt to make the solution more insightful and augment analysts' cognitive skills to support the problem solving and decision-making process.

In addition to data visualization, Visual Analytics offers analysts interactivity to support data analysis and scenario testing. Interactivity provides analysts with a platform to establish an *Analytic Discourse* [Thomas & Cook, 2005] between the analysts and the data. This computer-mediated communication empowers analysts with the ability to collect information from multifaceted data, test hypotheses and interactively explore alternatives in order to make judgements about an issue. Analysts can interact, understand, anticipate and forecast information based on the available data. Visual Analytics methods support analysts' reasoning process by clearly and concisely communicating ideas and information hidden in complex and heterogeneous datasets using a variety of interaction techniques that enhance the data visualization process. Shneiderman's seminal work (1996) on interactive graphical manipulation proposed interaction approaches to information exploration expressed as the Shneiderman Visual Information Seeking Mantra: Overview, Zoom and Filter, Details on Demand [Shneiderman, 1996]. These approaches had profound impact on the information visualization discipline and the design of advanced user interfaces in order to understand various information visualizations. Keim (2008) further expands Shneiderman's Mantra to include the analytical process. He proposed an extended Mantra that includes: Analyze first, Show the Important, Zoom, Filter and Analyze further, Details on Demand [Keim et al., 2008]. Integrating these different interactive approaches informed the design of advanced Visual Analytics tools and techniques that enable analysts to understand data visualizations and retrieve salient information in order to gain knowledge from complex datasets.

Within the context of this study, interactivity is fundamental to deal with wicked injury problems. Interactivity allows health professionals and policy makers to visually investigate chunks of data in a small space, giving them a comprehensive overview of dynamic injury situations while enabling them to interact with the injury data using filtering and zooming techniques for additional levels of granularity to gain further details-on-demand information about the complex injury data. Furthermore, interactivity enables injury stakeholders to manipulate the graphical display and tailor the visual interface to fit their goals and needs and adapt to their skills in order to ultimately support the decision-making process. Being able to see the wicked problem not just statically from a number of displays, but also interactively can facilitate injury stakeholders' informal discussion and give them the ability to question the data and to obtain a slightly new visualization about the data from a different angle and different lens. Interactivity provides health professionals with a flexible and interactive platform to test various scenarios and examine the underpinning claims of each suggested solution. Furthermore, interactivity enables injury stakeholders to experiment and examine various situations and collaboratively assess the pros and cons of the wicked problem.

The nature of these ill-structured injury health problems can potentially take advantage of Visual Analytics methods and techniques that combine visual and automatic approaches. With its visualization and interactivity elements, Visual Analytics represents an ideal and novel method that fosters the *Analytic Discourse* between injury stakeholder and complex injury data to facilitate problem solving and support decision-making.

1.5. Research Objective

Reducing injury occurrences represent a critical component in the success of public health injury prevention programs and the promotion of child and youth health. To enhance early detection of health issues and provide timely health interventions, health data should be accurately interpreted and analyzed. The objective of this thesis is to propose the adoption of collaborative Visual Analytics tools and techniques to efficiently and effectively address injury health problems. This adoption integrates the strengths of computational methods with human cognitive and perceptual capabilities to facilitate problem solving and support decision-making within the public health sector.

Interactive manipulation of Visual Analytics tools may facilitate the problem solving process, allowing health professionals to question the data, get details on demand information, drill down for further levels of granularities, spot data outliers, identify trends and patterns in the data, locate geographic distribution of injuries across locations as well as observe time trends of injury cases across time. In addition, a Visual

Analytics tool may support the decision-making process, enabling health professionals and policy makers to quickly explore and analyze complex and multidimensional injury data that requires substantial computational capabilities, to compare multi-sourced data to build a comprehensive picture of the injury situation in order to make informed and timely decisions and intervene with appropriate actions. To successfully integrate Visual Analytics tools and techniques into the healthcare, this thesis aims at achieving the following five key objectives:

1. To understand domain analytical tasks and the health (injury) problem that needs to be more efficiently solved using Visual Analytics.
2. To design and develop an evidence-based Visual Analytics tool as a proof-of-concept prototype that directly reflects injury stakeholders' needs and preferences.
3. To assess the integration of the Visual Analytics tool to assist injury stakeholders in analyzing the injury data as well as support accurate interpretation of the data to best target high risk populations for injury prevention efforts.
4. To empirically evaluate the application of collaborative Visual Analytics in order to facilitate injury problem solving and decision-making within the healthcare sector.
5. To gain in-depth understanding of how collaborative Visual Analytics influence the way in which analysts approach injury problem solving and, in turn, support injury prevention decision-making within the health care sector.

1.6. Research Contribution

This study will provide new information and add new knowledge to the field of Visual Analytics, social science and health science. The key contributions of this research study are summarized in the following points:

- A classification of injury problems as wicked problems. This classification is related to the nature of the injury problem that combines multidimensional elements and deals with complex and uncertain data.
- The conception of domain task taxonomy based on the information gathered from the 'Feel and Look' conferences carried out across Canada as well as the analysis of the compiled data generated from the analytics session.
- A comprehensive literature review integrating seminal research related to information visualization and its application to public health problems.

- Design and development of an *interactive* Analytical Injury Dashboard (*i*AID) as a proof-of-concept Visual Analytics tool based on the needs and preferences of injury stakeholders.
- Application of the *i*AID tool with real injury stakeholders and using real anonymous injury data retrieved from the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP).
- Documentation for a practical application of a Visual Analytics tool to explore and analyze multidimensional health data.
- Empirical evaluation of the use of the Paired Analytics methodology within the context of the public health community using qualitative and quantitative approaches.
- Design and introduction of the Group Analytics methodology based on the Paired Analytics methodology and inspired by the Delphi method. Conduct qualitative approaches to evaluate the application of the Group Analytics methodology within the public health sector.
- Examination and documentation for the impact of collaborative Visual Analytics on facilitating injury problem solving and supporting decision-making within the context of public health.
- Recommendations suggested informing the design of an innovative interactive injury dashboard to be integrated within the healthcare sector, as well as introduce new metrics to advance collaborative problem solving and decision-making process.

1.7. Thesis Outline

Chapter 1 and 2 constitute the Introductory Section of the thesis. These two chapters introduce the research topic, present its context and interdisciplinary nature as well as situate it in relation to previous research work in the area. Following the Introductory Section, this thesis presents the Theoretical Framework and Pilot Study Sections in chapters 3 and 4. Chapter 5 comprises the Design Section of this thesis, which describes the prototyped Visual Analytics tool. The Methodology Section is presented in chapter 6 to provide the conceptual structure and the methods used to conduct the study. Chapter 7 constitutes the Analysis and Discussion Section of this thesis and limitations to be addressed in future research. The final chapter summarizes the study contributions, lessons learned, and future research.

As shown in Fig 1.1, the remainder of the thesis is outlined as follows:

- **Chapter 1- Introduction:** This chapter introduces the research topic and provides the background, context and approach to the proposed research study. The chapter further discusses the characteristic of the wicked health problem and presents the study conceptual framework and its relevance in addressing these wicked problems.
- **Chapter 2- Related Literature:** A comprehensive overview of related literature is presented in this chapter. The literature review demonstrates knowledge of the field and presents a framework to situate the research study as well as highlights the gap in the knowledge that this study will address.
- **Chapter 3- Theoretical Framework:** This chapter presented the theoretical framework of this study, describing the modified Delphi Method used to structure the group sessions, as well as outlining the Joint Activity Theory and the Distributed cognition theory adopted as a framework to analyze the collected data.
- **Chapter 4- Interactive Dashboard Design:** A description of the Visual Analytics iAID dashboard is offered in this chapter. In addition, an outline of the early stages of designing, prototyping and evaluating the proposed *interactive* Analytical Injury Dashboard (*i*AID) is presented in this chapter.
- **Chapter 5- Pilot Study:** Results from the pilot study are discussed in this chapter. Lessons learned from the pilot study are presented, which caused us to refine the designed tool as well as to test the Paired Analytics and Group Analytics approaches and methods that we then adopted to design the final methods of the study.
- **Chapter 6- Methodology:** this chapter provides a detailed description of the qualitative and quantitative methods adopted to conduct the study. It also summarizes the Paired Analytics (PA) methodology and presents a full description of the designed Group Analytics methodology adopted to efficiently conduct the data collection process. A description of analytical tasks that were carried out during the study as well as the use of the CHIRPP data to populate the *i*AID dashboard are outlined in this chapter. The data transcription and data coding process are described in detail at the end of this chapter.
- **Chapter 7- Analysis and Discussion:** results of the study are presented in this chapter. Analysis, interpretation and evaluation of the qualitative and quantitative data are presented and discussed in detail. This chapter acknowledges the study delimitations and limitations, proposing areas for further research to address these delimitations and limitations and ultimately fill the research gaps.
- **Chapter 8- Conclusions and Future Work:** this chapter summarizes the findings of the study. Further, it provides design guidelines and recommendations for the development of effective dashboards with advanced visual analytical features and functionalities to support decision-making within the health care sector.

Figure 1.2. Thesis Outline

Chapter 1	INRODUCTION	This chapter introduces the thesis topic.
Chapter 2	RELATED LITERATURE	This chapter presents the conext of the dissertation problem and the approach to address it.
Chapter 3	THEORETICAL FRAMEWORK	This chapter elaborates on the Delphi Method and the Joint Action Theory and D-Cog paradigm to establish the thesis framework.
Chapter 4	PILOT STUDY	This chapter discusses the pilot study and lessons learned to inform the design of the actual study.
Chapter 5	INTERACTIVE DASHBOARD DESIGN	This chapter presents the design and prototype of the interactive Analytical Dashboard (iAID) .
Chapter 6	METHODOLOGY	This chapter discusses in details the two mehtodologies adopted: the Pair Analytics and the Group Analytics. I aslo discusses the data collection process of the two sessions, the choice of the analuytical task, the databases and the visualization tool.
Chapter 7	ANALYSIS AND DISCUSSION	This chapter presents the results of the audio and video recording as well as the screen capturing of the analytical session. Furthermore, the results from the analysis of the questionnaire data will be reported . The statistical analysis of the questionnnaire data will be presented and shown in this section as well as the analysis of the follow up interviews. This chapter acknowledges the study delimitations and limitations
Chapter 8	CONCLUSIONS AND FURTURE WORK	This chapter concludes and states the contribution of the current research work to the field of Visual Analytics and the Public Health sector.

Chapter 2. Related Literature

2.1. Visual Analytics

Analysis and interpretation of massive and heterogeneous health data is a complex and challenging task. Within the field of public health, health professionals and policy makers suffer from information overload and the inability to understand complex health data in order to make time-critical decisions. Information overload, resulting from massive amounts of data generated by advanced information technologies, consume health professionals time and drain their cognitive capabilities [Keim et al, 2008]. The emerging science of Visual Analytics leverages information visualization techniques and computational analysis methods to deal with information overload and solve complex and dynamic problems. In the Research and Development Agenda for Visual Analytics, Cook & Thomas (2005) defined the term Visual Analytics (VA) as the "Science of analytical reasoning facilitated by interactive visual interfaces". The authors further explained the related disciplines that intertwined to constitute the interdisciplinary science of Visual Analytics, including: 1. Analytical Reasoning. 2. Visual representations and interactions. 3. Data representations and transformation and 4. Results generation and dissemination.

Earlier studies examined how Visual Analytics addressed the issue of information overload and enabled analysts to '*detect the expected and discover the unexpected*' [Cook & Tomas 2005; Keim et al., 2006]. Subsequently, Keim et al. (2006) and (2008) wrote several papers on the application of Visual Analytics to facilitate the exploration of massive and complex data and to help analysts deal with information overload by transforming raw data into salient information and knowledge [Keim et al., 2006; Keim et al., 2008]. In a later study, Keim et al. (2010) thoroughly defined Visual Analytics, its scope and field of applications. The authors explained that Visual Analytics methodology combines 'Automatic Analysis' methodology and 'Visualization' methodology to overcome the shortening of one methodology as well as to empower analysts with the ability to enhance the data exploration process and ultimately to expedite the data analytical process [Keim et al., 2010].

Cook and Thomas outlined the main objective of Visual Analytics as ‘to facilitate the analytical reasoning process through the creation of software that maximizes human capacity to perceive, understand and reason about complex and dynamic data and situations’ [Cook & Thomas, 2005]. Numerous Visual Analytics software and tools have been designed to support the analytical reasoning process and help analysts to ‘*synthesize information and derive insight from massive, dynamic, ambiguous, and often conflicting data’* [Thomas & Cook, 2005]. These software were developed and implemented to deal with various types and forms of data, including numerical data using Tableau (www.Tableausoftware.com) and TIBCO spotfire (www.spotfire.tibco.com), textual data using IN-SPIRE (www.in-spire.pnnl.gov), and geospatial data using Geotime (www.geotime.com). These visualization tools adopt Visual Analytics methods and techniques to amplify analysts’ cognitive and perceptual capabilities to support the analytical reasoning process.

When dealing with complex and ill-structured problems, computers alone are not sufficient to reason and make sense of multidimensional health data and convert them into relevant information. Human analytical reasoning capabilities and background knowledge should be incorporated to support the analysis process [Keim et al., 2006]. Keim et al (2006) and (2008) emphasized the significance of including ‘human judgment’ into the analysis process through the use of Visual Analytics interactive interfaces. They argued that incorporating human factors like reasoning, judgment, cognition, perception, knowledge and creativity into the analytical process improve the outcome of the analysis and advance the decision-making process [Keim et al., 2006; Hanrahan et al., 2009]. Alongside the machine capacities, the integration of human cognitive and perceptual capabilities is fundamental to advance the analytical process and to improve decision-making [Keim et al., 2006; Keim at al, 2008]. Humans exploit the machine’s capabilities to sift through massive and complex data and interact with the visual interfaces in order to retrieve relevant information that helps to make sense of dynamic situations and inform timely decisions.

This thesis is motivated to adopt Visual Analytics methodologies and techniques not only to deal with information overload but also to help health professionals and policy makers to address wicked and ill-structured health problems. These wicked health problems cannot be solved by humans alone or by computers independently. Therefore, integrating Visual Analytics tool and techniques bridges this gap and synthesizes the strengths of both humans and computers to efficiently and effectively integrate domain knowledge to address wicked problems and inform timely decisions.

With the advantages offered by the emerging field of Visual Analytics, a growing number of organizational and academic studies surveyed and reported the successful use of Visual Analytics for exploring massive dynamic data and making informed decisions. From intelligence [Stasko, Görg, & Liu, 2008], to finance [Rudolph, Savikhin, & Ebert, 2009], to geospatial studies [Guo et al., 2007; Andrienko et al., 2010; Maciejewski et al., 2010], to economics [Savinkhin et al., 2008], to health [MacEachren et al., 2004; Boulos et al., 2011], and medical [Mane et al., 2011; Borkin et al., 2011], Visual Analytics has been extensively adopted in various scientific fields to help analysts to reason about complex and dynamic data to support timely real-life decisions.

Cook & Thomas (2005) along with other early research identified many challenges facing the application of Visual Analytics in real-world settings including dealing with unknown and uncertain data [Keim et al., 2008; Thomas & Kielman, 2009]. In this thesis, we focused on this challenge as we integrate Visual Analytics tools and techniques to understand and analyze dynamic health data characterized by insufficiency and uncertainty. While many researchers have applied Visual Analytics to various disciplines, our study focuses on the application of Visual Analytics to deal with complex public health issues and in particular, child and youth injury. One of this thesis' novel contributions is the application of Visual Analytics to solve public health injury problems with real injury stakeholders (Subject Matter Experts) and using real - anonymous - patient injury data retrieved from the database of the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP).

2.2. Information Visualization and Public Health

Gaining insights into the complex and multidimensional surveillance health data is fundamental to inform superior decisions and drive appropriate actions within the public health sector. Information visualization methods and techniques are essential to transform data into prominent information that can be used to make enhanced decisions and initiate applicable health interventions. A seminal work and an early example of information visualization of public health data was illustrated in Tufte & Moeller's book '*Visual Explanations*'. The authors presented historical examples of information visualization of epidemic health data designed and drawn by Dr. John Snow in 1854 [Tufte & Moeller, 1997]. Dr. Snow created a map overlaid with a plot of the death locations due to Cholera, widespread alongside street pumps in the Soho district of London. By pinpointing the deaths incidences on the map, Dr. Snow was able to visually see how the deaths were clustered around 'Broad Street' pump. Visualizing the cases of Cholera in proximity to the pump location enabled Dr. Snow to propose the possible existing relationship between the spread of infectious disease and the water pump. Dr. Snow was able to test his hypothesis as well as to discover and link the spread of Cholera to contaminated water. Consequently, a decision was reached to make the Broad Street pump inoperable by removing the pump handle in an attempt to stop the transmission of the water-born Cholera disease. This example illustrates how information visualization enabled epidemiologists like Dr. Snow to detect health incidence, investigate health outbreaks and ultimately support decision-making to prevent health problems and save lives.

Since the early example of information visualization of Cholera health data, a significant number of researches attended to the implication of exploiting information visualization methods and techniques to facilitate problem solving and support decision-making within the healthcare sector. As more health data is collected, the public healthcare community has realized the need to make sense of massive and complex health data in order to understand what is important and what to focus on. As the advancement in information technologies has grown considerably within the healthcare system, an increasing number of healthcare institutions are able to collect massive amounts of complex health data including temporal and spatial data [Georgiou, 2002].

With this trend, health professionals appreciate the advantage of integrating information visualization tools and techniques into the public health workflow to effectively facilitate data exploration, keep track of health issues, monitor health system functioning and support decision-making [Shneiderman et al, 2013; Moore et al., 2008].

Several studies reported the use of information visualization systems to enable health professionals to facilitate detection and investigation of health incidences [Moore et al., 2008; Cheng et al., 2011; Mazzella-Ebstein & Saddul, 2004, MacEachcren et al, 2004]. Moore et al. (2008) explored the integration of information visualization systems to empower epidemiologists with effective data exploration and understanding. The author argued that information visualization and GUI enabled health professionals to explore massive amount of syndromic surveillance health data, detect health anomalies, map their locations, and recognize their trends and changing patterns to make timely interventions. As surveillance data incorporate temporal and geospatial information, effective data representations can dramatically enhance epidemiologists' interpretation and understanding of syndromic surveillance data. In his research study, Moore et al. presented a comprehensive picture of existing syndromic surveillance systems that offer epidemiologists a simultaneous view of temporal and spatial visualizations of health outbreaks to facilitate interpretation of health surveillance data. The authors investigated existing syndromic systems that successfully integrated graphical user interface and advanced visualizations techniques to depict syndromic data and facilitate the detection and investigation of health incidences, including BioSense Systems, ESSENCE Systems and RODs Systems. Theses systems enable epidemiologists to identify high levels of syndromic data and detect possible outbreak, to drill down and investigate detailed syndromic data related to time/location/syndrome as well as to observe temporal and geospatial visualizations that depict the syndromic data [Moore et al, 2008]. Similarly, MacEachren et al. (2004) defined geovisualization and provided concrete examples of geovisualization application for public health geospatial datasets. The authors emphasized the role geovisualization plays in assisting health professionals in identifying and locating the geographic distribution of health incidences. The study adopted a variety of methods including information visualization, cartography and Exploratory Data Analysis (EDA) to develop geovisualization tool for collaborative data exploration. The authors used specific applications for geovisualization of datasets such as Multiple

Bivariate Matrix to visualize the distribution of cancer mortality and risk- factors, spacefill for public health data exploration, Concept VISTA for land cover data exploration, and Dialogue Assisted Visual Environment for Geo information (DAVE-G) to assess crisis information and support timely decision-making activities [MacEachren et al., 2004]. Comparably, Guo (2007) explored the use of a geovisualization tool to track the spread of pandemic disease across geographic space. The author reported evidence that the geovisualization tool helps to identify spatial patterns in individual's daily movement and interactions with others in order to support decisions that limit spread of the pandemic disease [Guo, 2007]. In more recent studies, Boulos (2011) examined the successful use of a geospatial visual analytics tool to map patients' mortality data and to effectively identify patterns and detect trends in mortality data [Boulos et al, 2011].

In addition to the public health application, information visual systems had been widely used in clinical and medical settings to boost work performance as well as to improve quality of services. In a study conducted by Plaisant & Shneiderman and their team at University of Maryland Institute for Advanced Computer Studies (1998), the authors designed the LifeLines visualization tool to improve the navigation, exploration and analysis of patient records and personal health histories. The authors conducted an experiment to test the new visualization tool. Based on the main results, the authors found evidence that information visualization led to a *"Quicker understanding of data, better comparison, and higher recall of patient information"* [Plaisant et al., 1998]. Later, the team designed and pilot tested LifeLines2, an information visualization system, to emphasize the temporal aspect of health data and its impact on understanding patient health history and identifying cause-effect patterns [Wang et al, 2008]. In a more recent work, Wang & Shneiderman along with their team (2011) provided relevant case studies to confirm initial findings and generalize early results from testing LifeLines2. The authors reported important findings regarding the use of visualization to support temporal analysis of health patient data. Analysis of the case studies' observations and users comments confirmed the authors' early findings and explained that the use of information visualization systems within healthcare, in particular EHR, resulted in making '*interesting discoveries*' and helping to '*improve patient care*' [Wang et al., 2011]. In line with this research work, Mane et al (2011) developed and implemented 'VisualDecisionLinc' a visualization system to facilitate fast and accurate interpretation of

Electronic Health Records (EHR). The study reported that the system succeeded in helping clinicians and medical staffs to evaluate massive amount of patients' records to understand the success and risk of various therapeutic options [Mane et al., 2011]. A recent paper was published by the Harvard School of Engineering & Applied Sciences in collaboration with the Vascular Profiling Lab at Brigham and Women's Hospital & Harvard Medical School (2011) about the effective use of visualization in helping cardiologists to detect, monitor and prevent heart diseases. The team designed an interactive visualization tool called 'HemoVis' for heart disease diagnosis showing 2D visualization of artery blood flow. To test the effectiveness of the visualization tool, the team conducted a user study with domain experts using patients' cardiovascular imaging data. The study presented statistically significant results confirming that the use of the visualization tool 'HemoVis' to visualize patient cardiovascular imaging data led to a reduction in *'diagnostic mistakes for heart diseases'* [Borkin et al, 2011].

More health professionals are integrating information visualization tools and techniques into their workflow. Despite their lack of technical background, an increasing number of health professionals are embracing the idea of integrating interactive visualization tools into their daily work to facilitate and expedite task performance. In a recent study conducted by Gesteland et al. (2012) to test the usability and usefulness of EpiCanvas, an interactive health surveillance weather map designed to explore and monitor temporal and spatial correlation of infectious diseases. The study reported that the vast majority of epidemiologist and health professionals agree that the tool is useful and applicable to support the investigation of disease outbreak and to facilitate collaboration with colleagues. However, one of the main contributions of this study is that it reports health professionals' positive attitude towards using technology and integrating interactive visualization tools within their daily work as they 'could make their work more interesting' [Gesteland et al., 2012].

2.3. Visual Dashboards in the Health Sector

To better address health problems, health professionals need to build a comprehensive picture of the dynamic health event and situation. Health data in the form of GIS and satellite map imaging are important to depict the geographic distribution of health data [Guo, 2007; Andrienko et al., 2007]. Other demographic information illustrated in quantitative histograms, bar charts or pie charts are additional resources needed to understand the distribution of health problems among genders and across various age groups. Each piece of health data is relevant to comprehensively tackle a health problem. Therefore, it is important to assemble various individual charts and maps to create visual dashboards that include coordinated views and represent the overall performance of the health system with regard to particular health issues. A Visual Dashboard is defined as a comprehensive visual representation of the most relevant information required for stakeholders to reach specific goals [Few, 2007]. Similar to a car dashboard, a health dashboard provides health professionals with a quick and easy access to collective information regarding different health indicators pertaining to a particular health problem, so as to build a comprehensive picture, allowing a more effective approach to the problem [Pike et al., 2010]. As a result, in addition to investigating the use of information visualization systems within the healthcare sector, we explored the particular literature related to the integration of visual dashboards into the public health sector and reported their impacts on workflow and task performance.

Health organizations and clinics house massive health data that in many cases, is not being efficiently used or taking advantage of. Recognizing the potential of this data to inform policy and practice decisions, there is an increasing trend and a growing number of dashboard uses within the public health sector to convert massive data into information and subsequently improve health services and quality of care [Georgiou, 2002]. Several studies reported the successful integration of digital dashboards as effective decision-support tools for quick data understanding and effective dissemination of surveillance data [Nagy et al., 2009; Cheng et al., 2011; Stone-Griffith et al., 2012]. These dashboards were used to empower epidemiologists and health professionals with advanced visualizations to facilitate detection and investigation of health incidences, which is a critical for making informed decisions and initiating timely actions.

A study conducted by Stone-Griffith et al. (2012) about the clinical use of dashboards reported that integrating visual dashboards into their workflow played a major role in improved quality of care and reduced emergency room waiting area by 54% over the course of three years [Stone-Griffith et al., 2012]. Another study conducted by Nagy et al (2009) demonstrated the advantages of a well-designed and developed graphical Radiology Dashboard for monitoring clinical operations and assessing work performance. The study showed that the integration of the dashboard into the radiology clinical system minimized effort and time, improved and enhanced work transparency and supported decision-making [Nagy et al., 2009]. Mazzella-Ebstein & Saddul (2004) reported a relevant case study about the implementation of a Nurse Executive Dashboard in patient care units. The executive dashboard provided interactive and multi-level reporting of performance indicators of various patient care units. The authors found evidence that the dashboard proved to be effective in advancing quality care practices [Mazzella-Ebstein & Saddul, 2004].

As reported in the literature, many research studies have successfully examined the effective use of visual dashboards in improving health professionals' data analytical process by offering them rapid synthesis and interpretation of complex health data. However, health professionals typically adopt pre-developed or pre-built Dashboard templates available from commercial vendors, which are typically designed for and driven by publically available health data. These tools allow health professionals to visualize overall health events and situations and do provide the information for enhanced organizational workflow and productivity. Relative to specific health issues, and based upon our current review of the literature, effective dashboards are those that are designed to uniquely fit the requirement of a group's analytical tasks in order to expedite their analytical process through the use of graphical display of aggregated data. Existing pre-built dashboards are not applicable in all instances and therefore, in this study we realized the need to develop an evidence-based visual dashboard that reflects injury stakeholders' needs and task requirements. This thesis is inspired to design a visual dashboard that can include various types of visualization techniques [Keim et al., 2002] to assist injury stakeholders in monitoring the injury occurrences across time and regions as well as support the accurate interpretations of injury data to best target populations at risks. Within the context of this study, our efforts were guided towards designing a decision-support tool based on injury stakeholders' goals and preferences. Our main goal was to build a simple and easy-to-use visual dashboard that can clearly indicate how the overall injury prevention system is functioning as well as to present important injury information in a readily accessible fashion.

2.4. Collaboration and Knowledge Building

To efficiently tackle a complex analytical problem, analysts need to collaborate in their work in order to reason and make sense of the analytical task. In the book, '*illuminating the Path*', Cook & Thomas (2005) emphasized the role of collaboration in improving and advancing the analytical reasoning process. The authors explained, *"The analytical reasoning must be a richly collaborative process"* [Cook & Thomas, 2005]. Collaboration among multiple analysts enhances the analytical reasoning process by combining analysts' background expertise and tacit knowledge in order to analyze all aspects of the problem, reason its underpinning elements and integrate the numerous proposed solutions into the final decision.

According to psychologists Hackman and Morris (1974), the two main reasons that necessitate group collaboration are: 1. The inability of an individual to solve a specific analytical task independently without seeking support from other group members. 2. The superior and enhanced quality of the analytical results generated by collaborating group members compared to the ones produced by a single individual [Hackman & Morris, 1974]. In the context of this thesis, injury stakeholders need to collaborate to accomplish two major tasks. Firstly, injury stakeholders need to initially collaborate to decide on the best metrics and indicators that summarize the injury system overall performance as well as to choose the most efficient visualizations that can be used to represent the multidimensional injury data. Collaboration is essential to combine and compile stakeholders' needs and goals to select the injury indicators that enable injury stakeholders to build a comprehensive picture of the preferred health situation. Furthermore, injury stakeholders' collaboration helps to inform the design and integration of visualization techniques and methods that efficiently depict the complex injury data and support domain's analytical task at hand.

Secondly, injury stakeholders need to collaborate in order to accurately interpret the dashboard visualizations and constructively suggest solutions to address wicked injury problems and support the decision making process. It is argued that when achieving a complex analytical task, the advantages of collaborative work substantially exceed individual work in terms of speed and accuracy of the analysis results [Mark et al., 2002]. As this study includes multiple stakeholders with diverse background knowledge and expertise, it is essential to foster a collaborative environment that encourages stakeholders to pool their expertise and knowledge and collaborate to solve the problem and make informed decisions. In the book '*Visualizing Argumentation'*, Horst-Rittel introduced the 'Issue Based Information Systems (IBIS)' methodology as an effective approach to solve ill-structured problems [Kirschner, Shum & Carr, 2003]. The IBIS methodology deals with inherently argumentative issues where multiple stakeholders establish issue-based communication and follow an informal argumentation approach to solve the problem. The IBIS methodology supports collaboration among multiple stakeholders with diverse background knowledge and expertise to discuss the numerous aspects of the problem, exchange perspectives and socially engage to reach a consensus and solve the problem. Other collaborative methods and techniques were introduced to address complex wicked problems and to support collaborative analytics such as the Delphi method that structure the collaboration of a group of experts to better address a complex problem [Linstone & Turoff, 2002]. The Delphi technique fosters a collaborative environment that enables experts to pool their knowledge and expertise to deal with the multidimensional aspects of wicked injury problems. Kirschner et al. introduced the 'Compendium' approach to support group communication and decision-making. Compendium is an argument-based approach that synthesizes the ISBIS methodology with a structured modeling technique to create a cognitive framework for collaborative analysis [Kirschner, Shum & Carr, 2003]. In a Compendium approach, a well-defined issue constitutes the foundation of a group argumentation process guided by a skilled facilitator who steers the group discussion and helps stakeholders to make sense of their situation and solve the problem at hand. The Compendium approach supports the distribution of cognition among multiple stakeholders to share their perspectives using external representations of their argumentation in order to facilitate data sense making and advance the problem-solving process.

Collaboration among group members is fundamental to retrieve analysts prior tacit knowledge related to the task at hand [Fischer, 2002]. In a relevant study conducted by Wang et al (2009), the authors emphasized the importance of combining prior domain knowledge with data exploration to enable users to build new understanding of the explored data. The authors argued that integrating domain knowledge into the data exploration process is essential to gain new insights into the data and ultimately improve analysis of complex analytical tasks [Wang et al., 2009]. Integrating stakeholders' prior knowledge into the data exploration and data analysis process is essential to assist stakeholders in understanding the investigated problem and ultimately to advance the analytical problem solving and decision-making process.

Exchanging prior domain knowledge and sharing information help group members to be more engaged in the analytical task achievement and ultimately contribute to drive enhanced decisions and customized actions. A collaborative environment provides the right platform for stakeholders with diverse domain knowledge and expertise to formulate and develop new ideas, exchange thoughts, discuss perspectives and build new understanding and knowledge about the phenomena under investigation. Stahl (2000) examined the collaborative knowledge building process to understand its implications on informing the design of effective Computer Supported Collaborative Learning (SCSL) software. The author discussed the various phases of collaborative knowledge building and argued that collaborative knowledge building is a 'product of social communication'. He emphasized the role of social interactions and communication in the collaborative knowledge building process, mediated by the use of language to communicate knowledge and shared with other group members [Stahl, 2000]. Consistent with this concept, Clark, in his book 'Using Language' emphasized the role of language use and verbal communication to collaborate and complete an intended task. Clark argued that the use of language plays a pivotal role in coordinating joint activities and shared beliefs between individuals to establish *Common Ground* and achieve intended goal [Clark, 1996]. He explained, '*when people take part in conversations, they bring with them certain prior knowledge, beliefs, assumptions and other information*' [Clark, p.38]. Collaboration through language use helps to establish a Common Ground among SMEs to align group members' goals, incentives and shared knowledge, which in turns can have positive implications on improving individuals coordination of joint activities and collaboration to solve analytical tasks. In an interesting study conducted by Webb (1982), the author combined results from different studies and interpreted them within the context of group interactions and their impact on the group task performance. The author reported important findings about the positive relationship between group interactions and higher task achievement [Webb, 1982].

This research extends previous studies and examines the impact of social collaboration on coordinating group activities through interactive communication and dialogue. The study further evaluates the role that this collaboration plays on building knowledge and understanding of the data that consequently support problem solving and decision-making when dealing with public health wicked problems.

2.5. Collaborative Visual Analytics: Problem Solving and Decision-Making

Several studies have reported encouraging findings about the effective integration of visualization tools into the collaborative process and its positive impact on enhancing collaboration among group members, improving analytical results and supporting decision-making [MacEachren et al., 2001; Brennan et al, 2006; Heer et al., 2008]. In an earlier study conducted by Fischer et al. (2002), the authors examined the integration of visualization tools and techniques into the collaborative group process and its effect on fostering collaborative knowledge construction. The study demonstrated that by providing a group of participants with a content-specific visualization tool, participants showed improvement in both the outcome as well as the process of the collaborative work [Fischer et al, 2002]. Visualization tools provide a display '*space*' or 'm*ediator*' that can be exploited by group members as a shared object to talk about, to think with as well as to coordinate perspectives and collaborate actions among them [MacEachren et al., 2004; Brennan et al., 2006].

As explained earlier, the integration of Visual Analytics tools and techniques is especially relevant to deal with wicked health problems. Visual Analytics extends information visualization to include analytical reasoning, human factors, data analysis and decision-making [Keim et al., 2008]. Visual Analytics helps analysts explore massive raw data and achieve insights into problem solving and decision-making, which is vital when dealing with complex wicked problems. Keim et al. (2008) emphasized the role Visual Analytics plays in making 'our way of processing data and information transparent for analytics decisions' [Keim et l, 2008]. Visual Analytics is especially needed to support the analysis process and efficiently handle complex analytical tasks as VA combines computational techniques with interactive visualizations to enhance problem solving and ultimately improve decision-making.

Collaborative Visual Analytics exploits the advantages of Visual Analytics to synthesize stakeholders' perceptual and cognitive capabilities in a social interactive setting to enhance the data exploration and analysis process. Collaborative Visual Analytics is referred by Heer & Agrawala as the *'process of peer production of information goods. Such goods may include the observations, questions, and hypotheses generated in the analysis process as well as tours or presentations of analysis results*' [Heer & Agrawala, 2008]. As collaborative Visual Analytics is perceived as an efficient way to solve complex analytical tasks [Brennan et al, 2006; Heer & Agrawala, 2008, Isenberg & Fischer, 2009], it's fundamental to integrate it into the problem solving and decision-making process.

An ample number of studies explored the social and cognitive aspects of collaborative Visual Analytics and its positive effect on addressing analytical tasks. For instance, Arias-Hernandez et al. (2011) adopted a structured approach called '*Paired Analytics'* to study collaborative Visual Analytics in a real-life setting between two analysts - a domain expert and a Visual Analytics expert working on an analytical problem and using a visualization tool. The authors found that collaborative Visual Analytics provides a framework that fostered cooperation and coordination between the two analysts through the use of language and flow of dialogue. The authors further explained that collaborative Paired Analytics worked as a dialogue channel through which analysts exchanged expertise, communicated knowledge and discussed the analytical task using shared visualizations to solve the problem at hand.

While Arias-Hernandez et al. (2011) studied collaborative Visual Analytics between two participants, other studies explored the collaboration of multiple participants engaged in social interactions to solve analytical problems using Visual Analytics tools. In a study conducted by Heer & Agrawala (2008), the authors explored asynchronous collaboration of multiple group members using a common Visual Analytics tool. The authors discussed the role of social interactions in the analytical sense-making process through the use of interactive visualization. The authors explained that social interactions and peer collaboration around interactive information visualization effectively impacted the outcome of the sense-making and analysis activity as well as advancing the Data Exploratory Analysis (DEA) process [Heer & Agrawala, 2008]. In a later study, Heer et al. (2009) proposed “sense.us”, an asynchronous collaborative analytics system with embedded interactive discussion forum that facilitated information externalization by enabling stakeholders to annotate the visualizations, comment, discuss and share their inputs and findings on the visualizations. The authors conducted two exploratory user studies: a laboratory user study (controlled) and a corporate user study (IBM sense.us live deployment) to observe participants’ asynchronous collaboration and to investigate the impact of social interactions and peer collaboration on the data visualization and data analysis process. The main finding identified the relevance of the social aspects of Visual Analytics (i.e. conversation, collaboration) and their implications on promoting and advancing the data exploratory and analysis process [Heer et al., 2009].

Findings from these previous researchers reveal the advantages offered by the collaboration of multiple participants using Visual Analytics tools to facilitate data exploration and analysis process. While Heer et al. explored asynchronous collaborative Visual Analytics and its impact on the data exploration and analysis process, we were interested in investigating the literature related to co-located synchronous collaboration. Several studies examined co-located collaboration among multiple participants using Visual Analytics tools and techniques to support the analysis and problem solving process [Kruger et al., 2003; Scott et al., 2004; Brennan et al., 2006; Tang et al., 2006; Isenberg et al, 2010]. Scott et al. (2004) studied the nature of the collaboration process among multiple stakeholders using tabletop visualization tools. Based on two observational studies, the authors identified various territories (i.e. personal, group and storage territories) that participants used to mediate social collaboration and coordinate their interactions. The study findings showed that group territories fostered less dominance and more verbal negotiation among participants while personal territories were ideal places for participants to customize their task before bringing it forward to the group. The study further demonstrated the importance of workspace awareness and the role it played in visibility and transparency of actions performed by other participants. Awareness of other group members’ actions and verbal communications are essential to understand the social collaboration among injury stakeholders during the problem solving process.

Providing multiple co-located stakeholders with the right visualization techniques is fundamental to mediate their communication and boost their collaboration during the decision-making process. A study carried out by Brennan et al., (2006) examined the effect of integrating different types of visualizations into the collaborative analytics process of multiple participants. The authors designed a collaborative visualization framework that integrated various visualization techniques to support multiple analysts' collaboration, information sharing, argumentation and decisions. The authors reported that by integrating various visualization types into the co-located collaborative process clearly supported analysts' collaboration as well as enabled multiple analysts to discuss solutions to existing analytical problems and propose claims to solve them [Brennan et al., 2006]. While the current prototyped framework suggested by Brennan et al. emphasized the use of various visualization types to support the needs of multiple analysts collaborating together, the framework doesn't address the collaboration of multiple participants with diverse background knowledge and expertise working together to solve a problem, which is the case in this thesis current study.

In a 2006 study, Tang et al. confirmed earlier findings from a study by Brennan et al. and extended them to explore how analysts use various visualization types to collaborate their work through various collaborative styles intended to achieve the assigned task using a co-located tabletop visual display. The authors reported the results of two observational studies. They described participants' collaborative styles and explained that different types of visualization tools and techniques affected the way in which participants collaborated their activities and coordinated the use of the shared visualization to actively engage to solve the analytical problem. An interesting observation reported in this study explained that participants tended to effectively collaborate on a particular task when they shared the responsibility for the generated outcome [Tang et al., 2006]. This study provides insights on the nature of collaborative activities among participants and its impact on the collaboration of multiple analysts working together in a collocated social setting. Another study conducted by Isenberg and her team further extends Tang's collaboration styles [Isenberg & Fisher, 2009; Isenberg et al., 2010]. The authors initially highlighted the importance of conducting co-located collaborative analysis to tackle complex analytical problems. Using an exploratory study, the authors argued that the use of a co-located visual analytics tool was linked with various types of collaborative style (e.g. active discussion, views engagement, views sharing) that significantly contributed to the advancement of the problem solving process. The authors claimed that the '*closeness of team's collaboration and communication*' using the visualization tool considerably impacted the way users performed on a given analytical task [Isenberg et al, 2010].

Examining the literature enables us to develop and build a comprehensive picture of collaborative Visual Analytics within the context of co-located collaborative problem solving. These comprehensive studies paved the way for further research work to examine and evaluate the impact of integrating collaborative Visual Analytics in a co-located setting in order to deal with wicked health problems. As we explored the wide use of visual dashboards within the medical and public health sector, we identified the existence of a knowledge gap regarding the effect of the use of analytical dashboards to facilitate collaborative analytical problem solving, and support decision making within a real domain application specific to injury prevention stakeholders. Furthermore, this research is needed to explore the effectiveness of collaborative VA to facilitate problem solving and support decision-making within the context of health data.

Chapter 3. Theoretical Framework

This study adopts a theoretical framework as a powerful approach to construct the study design and to support the analysis of the compiled data collected throughout the analytical sessions. This chapter provides in-depth discussion of the relevant aspects of three main theories adopted in this study: the Delphi method, the Joint Activity theory (JAT) and the Distributed Cognition (D-Cog) framework. Moreover, this chapter examines the significance of integrating these theories as a valid framework to inform the design of the analytical sessions as well as to structure the analysis of the collected data.

3.1. Delphi Method

The Delphi method is a consensus based decision-making technique. It was first introduced as a method for *"structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem*." [Linstone & Turoff, 2002]. The Delphi method originally developed by Dalkey and Helmer (1963) at the Rand Corporation [Hsu & Sandford, 2007] was introduced as a systematic method for interactively soliciting consensus of opinions from a structured group of experts regarding technological forecasting on warfare [Dalkey et al. 1969]. Ample research has expanded the application of the Delphi method from being a forecasting tool in the field of science and technology to being a 'collective intelligence' method exploited to assist with decisions on complex and multidimensional public issues [Adler & Ziglio, 1996; Linstone & Turoff, 2002; Okoli et al., 2004].

In the Delphi method, a panel of experts share and exchange observations and views about a complex problem under investigation. Participating experts pool their knowledge, expertise, and ideas into a group discussion focused on solving the problem and agreement on a solution. The generated solution synthesizes the opinions, perspectives and judgments of involved experts regarding the issue at hand. The Delphi method relies heavily on experts' background knowledge, expertise and judgmental information to decide on a problem. Therefore, choosing knowledgeable and cooperative experts is critical to ensure a sound Delphi approach to problem solving and decision-making [Okoli et al., 2004].

The Delphi technique incorporates an iterative process of soliciting and refining inputs from multiple experts to gain insights and reach a consensus about a given issue. A conventional Delphi process involves four different phases including, the *issue exploration* phase, the *problem approach* phase, the *discussion and argument* phase and finally the *analysis and evaluation* phase [Listone & Turoff, 2002]. These multiple phases of the Delphi process facilitate experts' brainstorming process and play substantial roles in advancing the problem solving and decision-making process. The main strength of the Delphi process is that it enables participating experts to explore the problem from various perspectives based on their professional knowledge and experience. Furthermore, it allows experts to identify the relevant elements of the issues and to discuss factors that can dramatically contribute to solving the problem and reaching an informed judgment.

As explained earlier, this study deals with public health injury problems. The debatable nature of this health problem and the multidimensional and diverse aspects of its forecasted solution require the adoption of an effective method to solicit multiple injury stakeholders' opinions and judgment. As such, the modified Delphi method is a valuable method to structure the design the Group analysis sessions and to explore the group performance on problem solving and decision-making process when dealing with complex health problems characterized by data uncertainty. Within the context of this study, multiple injury stakeholders need to decide on a particular injury problem. As explained earlier, public health injury problems are multidimensional ill-structured problems; therefore making an informed decision is a challenging and complex task. Injury is associated with numerous individual, social, environmental and policy related factors, and present multi-dimensional 'wicked' problems to public health professionals and researchers [Pike et al, 2010]. These ill-structured problems are interconnected and interdependent; they combine various health elements and require a careful study of related factors in order to make appropriate decisions. The characteristic and context of public health problem necessitate the effective integration of a Delphi method to structure the sessions and enable experts to solve these argumentative and societal problems, which require innovative solution and judgmental problem solving and decision-making approach. Delbecq (1975) argued that the Delphi method is a "judgmental decision-making" process. He explained that adopting the Delphi method is necessary when there is "lack of agreement or incomplete state of knowledge concerning either the nature of the problem or the components, which must be included in a successful solution. As a result, heterogeneous group members must pool their judgments to invent or discover a satisfactory course of action" [Delbecq et al., 1975]. We adopted the modified Delphi technique to foster a collaborative environment that promotes group interactions and stimulates effective communication that leads to innovative and comprehensive solutions [Alder & Ziglio, 1996]. The modified Delphi Method is an effective technique to deal with these types of dynamic and complex health problems characterized by unavailable or inaccurate information. It empowers experts with the right platform to discuss the various aspects of the problem and argue about the different approaches to problem solving.

We modified the conventional Delphi technique to synthesize experts' opinions and viewpoints about a particular analytical injury problem in a face-to-face collaborative setting. We termed this modified Delphi approach, the *Analytical Delphi* technique, which we employed to reach consensus about public health injury issues. In this *Analytical Delphi*, we included a skilled facilitator to manage the session and guide health professionals' discussions towards reaching a consensus within a specific time frame. We also extended the application of this *Analytical Delphi* to integrate the use of an interactive analytical dashboard technology that could be exploited to empower health professionals with the right tool to explore the injury data, retrieve needed information, exchange opinions and share perspectives about the analytical injury problem. The decision to conduct a collaborative face-to-face *Analytical Delphi* was to provide injury stakeholders with a co-located setting to explicitly discuss all potential solutions, to justify their different views, and to obtain prompt feedback from other experts about the implication of these suggested perspectives [Webler et al., 1991].

The modified Delphi method was used as a theoretical framework and a structured way to elicit and gather multiple views and various inputs regarding injury health issues. It enabled us to structure stakeholder discussions and to capture and collect data about experts' dialogue, argumentation and joint actions used to solicit their judgment in a group decision-making setting. Integrating the modified Delphi technique into the structured Group analysis session may have supported the decision-making process by limiting the influence and control of any one stakeholder on the eventual outcome of the session. As the modified Delphi technique ensures the equal participation and contribution of all group members, it enables members to collaborate and bring along their expertise, exchange opinions and share knowledge in order to agree on an optimal solution. This collaborative problem solving approach not only prevents dominance of ideas but also increases the chance for participating experts to convince each other and settle on a solution that is subjectively defined as a good solution to "wicked" public health problems.

3.2. Joint Activity Theory

The Joint Activity Theory (JAT) refers to Herbert H. Clark's theory of "using language" [Clark, 1996]. It is a psycholinguistic theory that adopts language use as a framework to structure time and space coordination of actions between individuals. Clark's JAT mainly focuses on individuals' verbal communication when coordinating their actions to attend to a common task. In his book "Using Language", Clark argues that "Language use is really a form of joint actions" [Clark, p. 3]. He explains that language plays a substantial role in coordinating individuals' joint actions in order to perform joint activities. Effective coordination of these joint actions depends upon individuals' communication and shared expectations with the intent to achieve joint activity.

We based our analysis on the Joint Activity Theory (JAT) [Clark, 1996]. Using JAT provides a powerful method to analyze and make sense of individuals' verbal communication in a collaborative face-to-face setting within the context of problem solving and decision-making. Joint Activity Theory is a practical theoretical framework to study collaboration among multiple stakeholders in a computer-mediated environment. We focused on specific aspects of JAT that are relevant to this study, including *Event Boundaries*, *Coordination of Actions, Common Ground*, *and Coordinated Devices.*

***Event Boundaries*:** Clark explains that each joint activity constitutes an independent event with its unique *entry, body and exit* [Clark, 1996]. Individuals coordinate the entry and exit of their joint actions when working on a joint project. Clack further indicates that a joint activity comprises a series of joint actions synchronized through verbal and non-verbal communications between individuals, and intended to perform a task or achieve a goal [Clark, 1996]. In our case, we adapted JAT and segmented joint activities into embedded communicative joint actions in order to better understand the explored phenomena within the boundaries of each defined activity. Given the dynamic of the interactive conversation and emerging dialogue among study participants, it was essential to specify and identify event boundaries in order to gain insights into how participants collaboratively interacted and engaged in each activity to solve the given analytical problem.

***Coordination of Actions*:** A joint action is established when individuals attending to a particular activity, coordinate their actions with specific intentions and expectations. In his book *'Using Language'*, Clark asserts that '*What makes an action a joint one, ultimately, is the coordination of individual actions by two or more people*' [Clark, p.59]. A joint action represents the basic unit of analysis of a joint activity. In order to engage in a joint activity, Clark argues that individuals need to coordinate the content and the process of their joint actions. Coordinating the content occurs when individuals coordinate what they are doing, and align their intentions and goals to achieve a joint activity. Coordinating the process occurs when individuals coordinate how they carry out their communication, including verbal and non-verbal cues, as well gestures in order to achieve the goal of their joint activity [Clark & Brennan, 1991]. Coordinating content and process of joint actions is essential to establish *Common Ground* between individuals and to collaborate on joint activities.

Common Ground (CG): *Common Ground* is defined by Clark as the aggregation of "mutual, common, or joint knowledge, beliefs and assumptions" of two individuals [Clark, 1996]. *Common Ground* represents joint beliefs and knowledge as the basic foundation upon which individuals' coordination of actions and collaboration rely. In his book "*Using Language"*, Clark presented the different types of *Common Ground* and discussed the relevance of establishing *Common Ground* between 2 individuals in order to coordinate their actions and advance their collaborative activities. Aspects of the *Common Ground* upon which this study focused include *Personal Common Ground and Communal Common Ground.*

The *Personal Common Ground* is established in a face-to-face interactive setting. The *Personal Common Ground* comprises two main bases: the *perceptual basis* and the *actions basis* [Clark, p 113, 114]. The *perceptual basis*, on the one hand, is developed by individuals perceptually sharing the same experience, either by attending to a joint salient event that garnered their awareness and attention, or by referring to perceptual co-present objects and events. The *action basis*, on the other hand, relies on the discourse and use of language to establish *Personal Common Ground* among individuals through interactions and verbal communication of personal knowledge and beliefs.

The ***Communal Common Ground*** is based on practice, expertise and knowledge shared by members of a specific community [Clark, p.117]. In this study, different types of Common Ground were expected to emerge throughout the collaborative session so as to provide the right platform for injury stakeholders to collaborate and coordinate their activities. For instance, injury stakeholders share and accumulate *Communal Common Ground* since they belong to the same public health community of injury prevention. This *Communal Common Ground* is essential in order to coordinate stakeholders' actions and to establish a *Common Ground* among them that advances their joint activities.

***Coordination Devices*:** Clark defined a *Coordination Device* as an explicit agreement that is observed throughout the conversation and dialogue to express participants' expectations, goals and intents so as to anticipate the joint actions and converge them toward a joint activity. Clark explains that participating individuals use the *Coordination Devices* as "*something to tell them which actions are expected"* [Clark, p.91]. The use of *Coordination Devices* constitutes an essential component in maintaining coordination and collaboration among individuals [Arias-Hernandez et al., 2011]. Individuals need to be on "the same page" so as to ensure effective communication and coordination of actions [Sebanz et al., 2006]. In a previous study, Clark et al. emphasized the relevance of establishing a "shared perceptual space" among participants performing a joint activity. The authors explained that participants working together on building a Lego model improved their task performance and reduced time to complete the task when they attended to a common object or workspace [Clark et al., 2004]. In this study, the use of an Injury Dashboard with the shared visual representation as the *Coordination Device*, is used to influence injury stakeholders' verbal communications and the coordination of their joint actions. We observed how this shared *Coordinated Device* served to align injury stakeholders' mutual conversation and joint actions, the coordination of their performance and the collaborative nature of their activities. The notion of *Coordination Devices* is interlinked with the emergence of *Common Ground,* as *Coordination Devices* act as another accumulated shared piece that can be added to the established *Common Ground* in order to enhance the coordination of joint actions and advance the joint activity.

This study adapts Joint Activity Theory as a valid conceptual framework to conduct the audio and video protocol analysis. As explained earlier, Joint Activity Theory underscores the role that language plays in the coordination of individuals' actions. It further emphasizes the importance of establishing dialogues and face-to-face interactions among individuals as communication channels to exchange thoughts and perspectives in order to coordinate actions and establish a *Common Ground* to advance the problem solving process. We grounded the data analysis of this study in Joint Activity Theory to better understand and document how injury stakeholders use language and dialogue to interact with each other and with the shared visual display, in order to solve the analytical problem and make an informed decision.

Furthermore, Joint Action Theory helps us to empirically investigate the social and cognitive aspects of collaborative Visual Analytics. In this study, we analyzed the data from two key perspectives or frameworks of Joint Action Theory that are most applicable to collaborative Visual Analytics: 1) social and 2) cognitive frameworks. On the one hand, the social framework helps us to examine and evaluate injury stakeholders' face-to-face interactions within their co-located social environments. This framework enables us to understand the impact of the different social aspects (i.e. social context, the environment, injury stakeholders' social relationships) on injury stakeholders' communication and joint actions and consequently on the advancement of the problem solving and decision-making process. The Joint Activity Theory offers us a framework to draw activity boundaries, *entry* and *exit* and observe the data from a joint activity perspective. It allows us to study injury stakeholders' coordinated actions and social interactions in a real world face-to-face social setting. On the other hand, the JAT cognitive framework emphasizes the establishment of a *Common Ground* and the use of *Coordinated Devices* (i.e. visualization tool, injury stakeholders' verbal and non-verbal interactions) as shared bases to enhance injury stakeholders' cognitive capabilities to solve the problem and make informed decisions. Clark argues that *Common Ground* accumulates with series of joint actions intended to advance the joint activity. As Clark explains, "the shared basis of *Common Ground* plays a crucial role in coordination with joint actions [Clark, p.98]. In this study, we observed how injury stakeholders' maintained and improved their *Common Ground,* as it is vital to support their coordinated actions and to ensure sustainability when advancing the collaborative activity. This study builds upon Clark's theory and enriches the scope to empirically study the establishment of a *Common Ground* among multiple stakeholders and its effect on the collaboration and coordination of their actions. We viewed and analyzed the data through the lenses of establishing and accumulating different types of *Common Ground* among injury stakeholders through their joint actions projected to advance the problem solving process. We identified and documented the different types of emerging *Common Ground* and examined how multiple stakeholders harmonized their actions and collaborated their cognitive process using external visualization tool to advance the problem solving and decision-making process.

3.3. The Distributed Cognition Framework

Along with the Joint Activity Theory, the Distributed Cognition (D-Cog) framework is a particularly relevant theoretical approach underpinning this study. The Distributed Cognition (D-Cog) theory, originally developed by Edwin Hutchins, lays the theoretical foundation for coordinating cognitive process among multiple entities including individuals, artefacts (i.e. created, manipulated and refined visualizations) and the environment [Hutchins, 1995].

In his book, '*Cognition in the Wild*', Hutchins (1995) introduced the concept of Distributed Cognition and underlines the significance of distributing the cognitive process among individuals and artefacts. He explained that the cognitive process should not be restricted to one individual; it should be extended to incorporate multiple individuals alongside physical artefacts to efficiently perform cognitive tasks. Hutchins highlighted the cognitive characteristic of a group compared to individual cognition. He stated that, ‘the cognitive properties of groups may differ from those of the individuals who constitute the group’ [Hutchins, p.239]. Hutchins demonstrated that successfully fulfilling the requirement of a cognitive task should not be achieved by one individual alone, but by the combination of cognitive efforts from multiple individuals and the contribution of various artefacts facilitated by the surrounding environment.

Hutchins examined, from a cognitive science perspective, the social and cultural properties of a cognitive system. He demonstrated that these properties influenced individuals’ cognition and shaped the way they interacted with artefacts in cognitive and computational systems. Hutchins emphasized the relevance of including the social and cultural environment within the cognitive system so as to empower individuals’ cognitive capabilities. He argued, “Humans create their cognitive powers by creating the environments in which they exercise those powers” [Hutchins, p. xvi]. Social and cultural environments play a pivotal role in providing individuals with the right context to promote distributed thinking and to develop new knowledge derived from interactions among components of this cognitive system. Including the social environment within the cognitive process empowers individuals with a resourceful platform that fosters a collaborative setting for individuals to exchange information and build knowledge through social interactions [Hutchins, 1995].

Within the context of Visual Analytics, the distributed cognition framework has primarily focused on the D-Cog “*external cognition*” approach [Arias-Hernandez et al, 2011]. This approach highlights the significance of using external graphical representations or visual aids to amplify analysts’ cognition and expand their abilities to perceive and reason about complex cognitive tasks.

In the case of this study, injury stakeholders are challenged to analyze complex and multidimensional injury data to solve a given analytical problem and make an informed decision. In this study, we presented injury stakeholders with a visualization tool that they exploited and interacted with in a group setting. We integrated the visualization tool as a key component of the injury stakeholders’ cognitive and computational system to support their analytical problem solving process. The purpose of integrating the visualization tool was to boost analysts' cognitive capabilities and to act as '*cognitive amplifiers*' [Lui et al, 2007] to facilitate data understanding and knowledge building, as well as to support the performance of their cognitive activities. Based on Hutchins' perspective, 'tools permit us to transform difficult tasks into ones that can be done by pattern matching, by the manipulation of simple physical systems' [Hutchins, p.170]. The integrated visualization tool was intended to serve as a display "space" or a "mediator" that multiple group members could exploit as a shared object to talk about, to think with, as well as to coordinate perspectives and collaborate actions among them [Mane et al., 2011; MacEachren et al., 2004]. Interaction with the visual display (i.e. zoom, filter) and visual manipulation of the abstracted information was intended to help injury stakeholders to understand the information in a way that augmented their cognitive capabilities and enhanced task performance. According to Hutchins, a person interacting with a tool constitutes part of a cognitive system and therefore develops superior cognitive capabilities compared to a person performing a task alone [Hutchins, 1995].

We applied the distributed cognition theoretical perspective to analyze the distribution of cognition among injury stakeholders, the visualization tool, and the social environment within the context of problem solving and decision-making. We examined the 'Collaborative Activity' as the unit of cognitive analysis and studied social interactions among SMEs as well as the use of the visualization tool in a collaborative environment to advance the cognitive process.

SMEs interactions with other group members constitute a major component of the distributed cognitive system. Previous studies in the human computer interaction field explored the collaboration of group activities through the lens of the distributed cognition perspective. Tomaszewski & MacEachren (2006), for example, applied the distributed cognition theoretical framework to examine group-distributed decision-making. They explained that the D-Cog approach enables researchers to efficiently understand how multiple group members collaborated and used visualization maps to coordinate their actions and synthesize their reasoning capabilities to make informed decisions [Tomaszewski & MacEachren; 2006].

Secondly, we adopted the D-Cog "external cognition" approach in order to understand SMEs experience interacting with the visualization tool to make sense of the complex injury data. The distributed cognition process synthesizes individuals' cognitive skills and the tool's computational capabilities to facilitate the cognitive process [Hutchins, 1995]. As explained earlier, we added the visual dashboard tool as a key component to the distributed cognition system in order to empower SMEs with a central reference point to explore the multidimensional data, extend their cognitive capabilities, enhance the coordination of their cognitive activities and support their collaboration. A human-computer interaction study, conducted by Scaife & Rogers, investigated the role that graphical representations play in facilitating learning and cognitive process. The authors explored the interplay between external representation and internal mental models and the way this interplay enhanced cognitive process. The authors explained the three critical aspects in which visual representations supported external cognition including: 1. *Computational Offload* (i.e. external visualization helped to off-load memory and minimized computational and cognitive effort needed to solve analytical problems), 2. *Re-Representation* (i.e. presentation of the information in a different visualization format to make the solution salient), and 3. *Graphical Constraining* (i.e. visual representation of the information in a way that restricted data interpretation and inferences) [Scaife & Rogers, 1996]. Within the context of this study, the visual dashboard presents an external visualization of the injury situation. These external representations can be manipulated by SMEs and may serve to support SMEs cognitive capabilities in a distributed cognitive process to build knowledge and make informed decisions [Giere, 2007]. Observing SMEs interactions with the tool from the distributed cognition perspective enables insights into the process of using external visualization to efficiently perform cognitive tasks within the context of problem solving and decision-making.

Lastly, the role of the social environment and its impact on SMEs performance of analytical cognitive tasks is an important consideration of this study. The distributed cognition framework provided the theoretical guideline to observe SMEs coordination of activities using the visualization tool as well as to study SMEs cognitive reasoning process in a social collaborative environment [Hutchins, 1995]. We explored the aspects of the collaborative analytics environment from the distributed cognition perspective and examined its impact on SMEs interactions with each other and with the visualization tool within this co-located social setting. A study carried out by Lui et al. (2007) examined the notion of distributed cognition from the Information Visualization (InfoVis) perspective. The authors highlighted the substantial role that a computer mediated environment plays in shaping the way individuals interacted with each other and with the artefacts [Lui et al, 2007]. The authors further demonstrated that within the context of information visualization environment, cognition is the product of '*visual representation*' of abstracted information and '*interactions*' among humans and artefacts [Lui et al, 2007]. Based on pervious studies, we adopted the socially distributed cognition framework to capture stakeholders' exchange of expertise through social interactions and the use of visual representations to amplify and distribute cognition among multiple SMEs in order to facilitate problem solving and support decision-making.

Chapter 4. Pilot Study

The objective of the pilot study was to ensure overall feasibility of the research project, test the prototype *i*AID dashboard with potential end users, and to test and refine the Paired Analytics (PA) and Group Analytics (GA) methodologies adopted in this study. Following the introduction to the healthcare and injury prevention domain work, this author accessed the health injury data and got familiar with the data in preparation for the pilot study. The pilot study was conducted mainly to test the research design and process before proceeding to the actual study.

A pilot study is defined as the 'small scale version, or trial run, done in preparation for the major study' [Polit, Beck, & Hungler, 2001]. Pilot studies refer to the initial study conducted prior to the actual study to test the methodology, procedures, tools and instruments that will be adopted in the planned study. Kezar (2000) explains that pilot study represents researchers' first-hand 'real world experience' that should be executed to better conceptualize, design and refine research studies [Kezar, 2000]. Conducting a pilot study prior to the actual study can provide researchers with insights and valuable information about the study methods, procedures in order to identify weaknesses in the proposed research study as well as prevent potential pitfalls and logistical problems. Social researchers Teijlingen & Hundley (2001) presented the various advantages for conducting a pilot study including: designing and evaluating research methods, procedures and analysis protocols, assessing study feasibility, testing study instruments and equipment, gathering initial data and refining the research question, as well as addressing potential issues and problems in an attempt to improve the full-scale study [Teijlingen & Hundley, 2002].

Along with literature reviews and previous studies of related phenomena, the theoretical and conceptual framework of the proposed study contributed to shape this pilot study. For instance, we reviewed a previous pilot study conducted by Arias-Hernandez et al., explored the use of Paired Analytics methodology to capture collaborative Visual Analytics when solving coordinated problems. The study reported interesting findings explaining how the collaborative setting of the pilot paired analysis sessions ensured the flow of communication and coordination between analysts when working on coordinated problems. The main focus of our pilot study is twofold. First, it aims to test the Paired Analytics (PA) and Group Analytics (GA) methodologies (please refer to chapter 6 for detailed description of these two methodologies) that we would adopt to design the main collaborative visual analytics study. Second, it serves to refine the designed Visual Analytics prototypes tool and finalize its interactive visual interface to reflect injury stakeholders' needs and preferences.

In order to conduct the pilot study, we organized a workshop on February 15, 2012, entitled '*The Dashboard Project'* (See Appendix F for Workshop Agenda). We invited injury stakeholders from across British Columbia and Canada to attend a demonstration of the prototype *i*AID dashboard in two collaborative Phases: Phase I - group analysis, and Phase II - paired analysis. We used Mortality and Morbidity injury indicators data in British Columbia, Canada to create the visualizations. The injury data are segmented into categories including patients' injury types, gender, socioeconomic status as well as geographic locations. The pilot Visual Analytics dashboard mock-up was built using Tableau Software. We mapped the injury mortality and morbidity data into Visual analytics animated visualizations using advanced visualization techniques to efficiently and effectively depict the injury indicators. As illustrated in Figure 4.1 and 4.2, the first annotated trend lines visualization on the left represents yearly trends of Mortality rates from 2001 to 2010. The second animated visualization shows hospitalization rates versus costs of hospitalization. We used various colors to refer to injury causes while bubbles sizes represent the cost of hospitalization pertaining to each injury cause.

Figure 4.1. Annotated Visualizations- Time Trend.

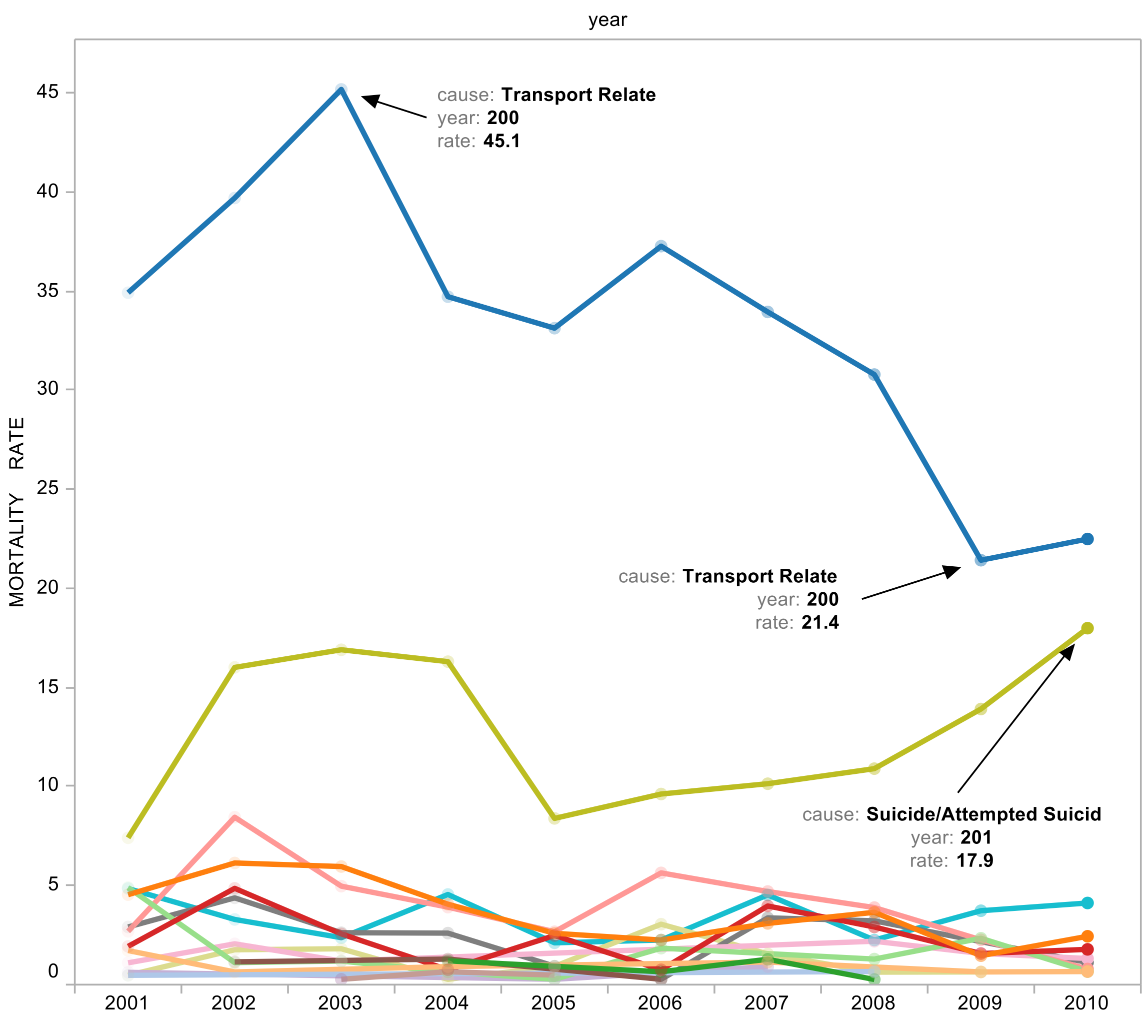
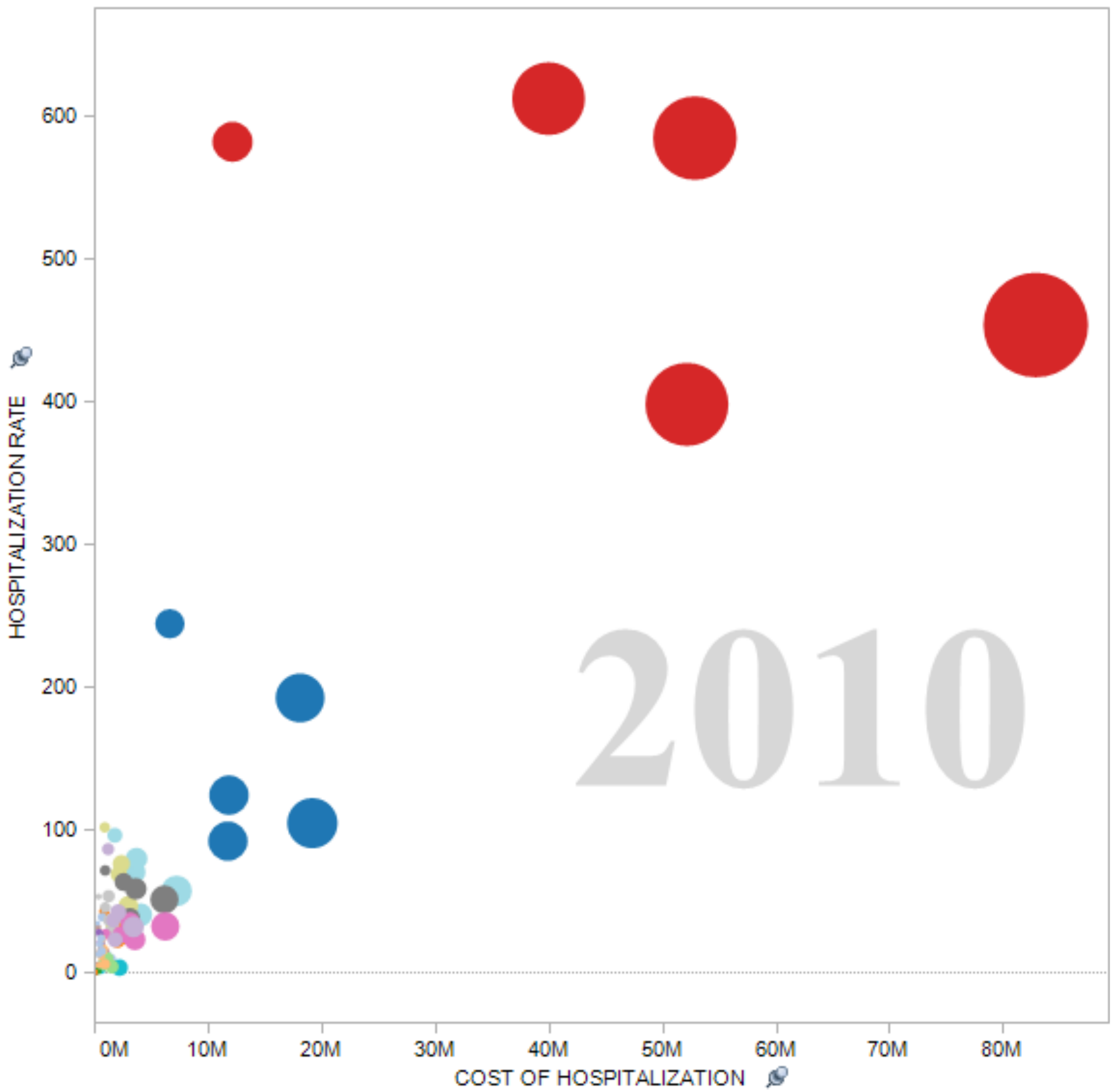


Figure 4.2. Animated Visualization Hospitalization Cost



We further designed two separate dashboards to represent the hospitalization and mortality injury data (Fig 4.3 and Fig 4.4 respectively). Each dashboard incorporates multiple views of Visual Analytics representations of injury data including temporal, geospatial and demographic representation to provide injury stakeholders with a comprehensive picture of the injury data as well as to amplify their capabilities to understand and reason about the dynamic injury situations.

Figure 4.3 Interactive Visual Analytics System Dashboard (Hospitalization)

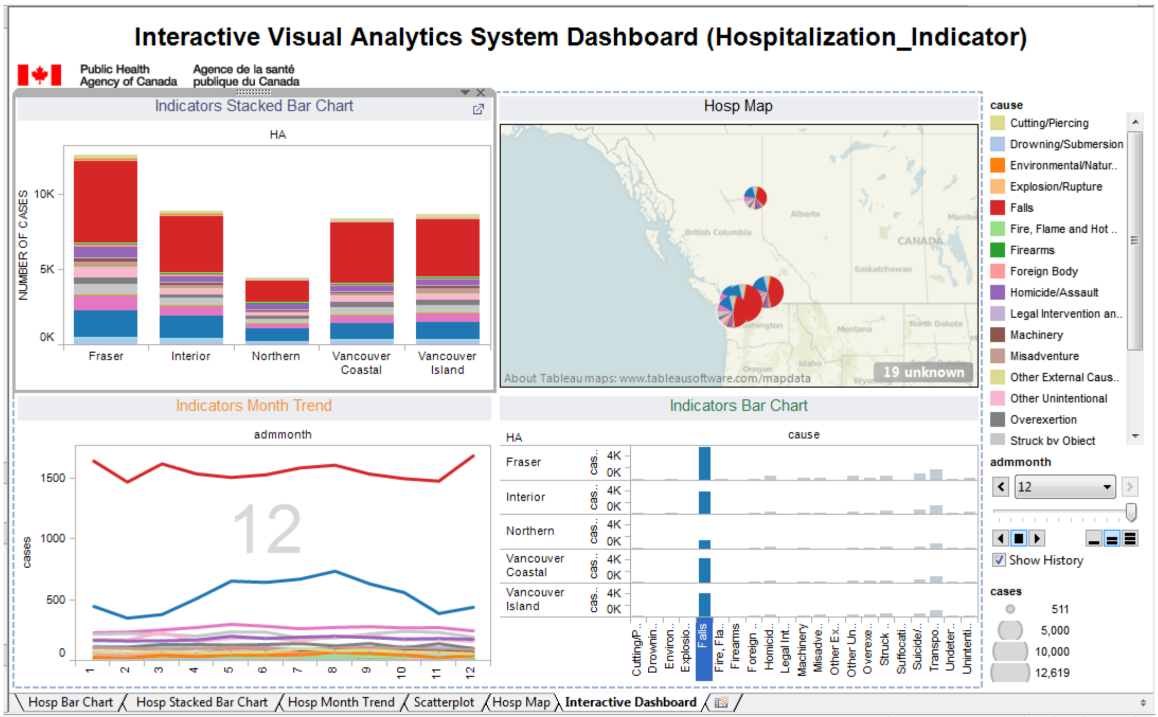
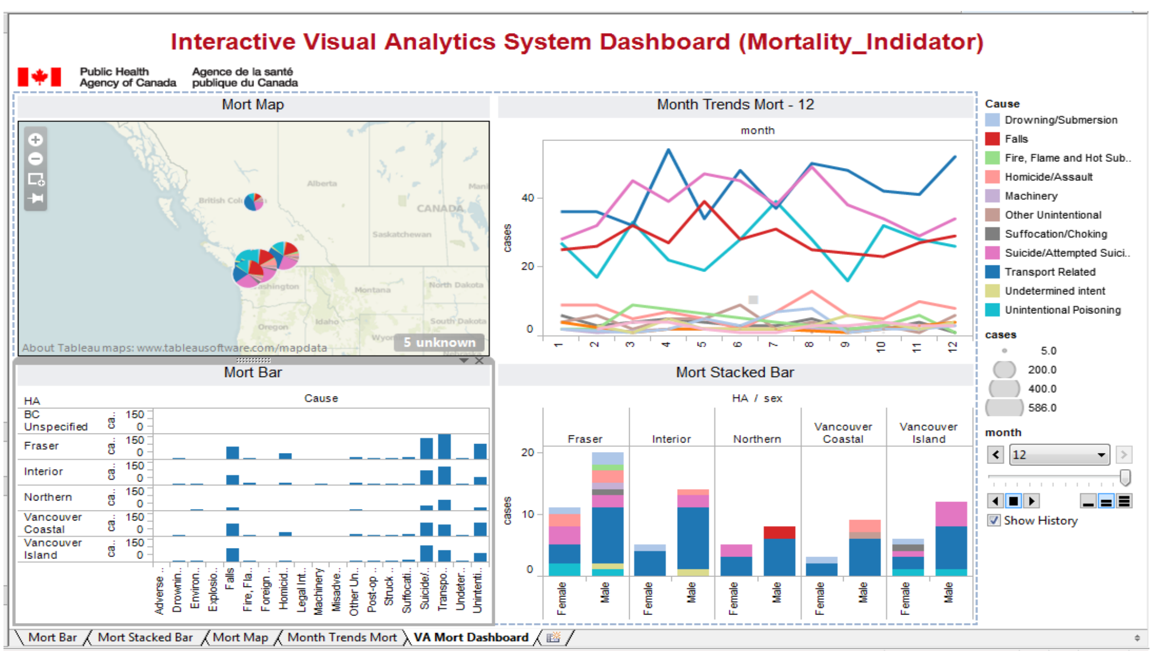


Figure 4.4. Interactive Visual Analytics System Dashboard (Mortality)



The exploratory nature of the pilot permitted exploration of the numerous aspects of the PA and GA methodologies (Please refer to the published paper #3 in Appendix G). In turn, improved understanding of the Paired and Group Analytics methodologies allowed for further consideration and modification of methods that would increase the chances of success in the study.

4.1. Pilot Study Phase I: Group Analytics

In Phase I, we conducted a pilot Group Analytics (GA) study. The pilot study involved one GA session with one Visual Analytics Expert (VAE) and multiple Subject Matter Experts (SMEs) who were injury stakeholders, working at regional and national injury prevention programs. The GA pilot session lasted 45-50 minutes. During the Group analysis session, VAE demonstrated to the focus group, (SMEs) the created time series visualizations as well as the interactive Dashboard for the Hospitalization and Mortality data. Injury Stakeholders explored the injury indicators data and constructed a comprehensive image about injury situations across BC's provincial health authorities. This author was in charge of gathering field notes and recording additional observations throughout the GA session. The GA pilot study was audio- and video-recorded in order to conduct analysis of the group process, including for example, injury stakeholders' interactions, communications, gestures decisions and actions taken.

The Group Analytics pilot study served to refine the adopted GA methodology and test its application within the healthcare community and with real injury stakeholders. The main objective of this pilot study was to ensure that the GA methodology is a realistic and practical methodology that can be used to effectively test various social, interactive and collaborative aspects of the Group analysis sessions. These aspects, discussed in the following lessons learned section, are essential for selecting the most appropriate social and collaborative measures in preparation to be adopted for future research studies.

4.2. Pilot Study Phase II: Paired Analytics

In Phase II of the pilot study, we conducted paired analysis sessions to pilot test the current version of the *i*AID dashboard in a collaborative setting with real injury stakeholders. For the purpose of this pilot test, the dashboard was populated with retrospective injury morbidity and mortality data for British Columbia from the Hospital Discharge Abstract Database (DAD) and Vital Statistics (VS). The PA sessions were structured as a series of one-on-one ten-minute sessions. Each session involves one VAE and one SME working together on a particular analytical task using the designed *i*AID visualization tool.

Injury stakeholders' feedback was collected through a series of Paired analysis sessions, which were recorded using video- and audio-recording devices, together with this author recording observational field notes. Following the PA sessions, Injury stakeholders were asked to complete a questionnaire, which asked them to rate the *i*AID interface and functionalities. The questionnaire consisted of 20 rating questions that are scaled on a 7-point Likert scale (1- Strongly Disagree, 7-Strongly Agree) to solicit stakeholders' feedback about the perceived usefulness of the visualizations and their potential to help stakeholders generate insights, build knowledge and support decision-making.. The pilot tests served to provide input in order to enhance the prototype *i*AID dashboard and to prepare a more final version for testing in the research study.

4.3. Lessons Learned

Transcripts generated from the audio- and video-recordings, as well as field notes were compiled and analyzed. The focus of the analysis was on the research methods and process so as to ensure that the research study methodology was feasible, practical, underpinned by theory and would achieve the goal to test the *i*AID interface with injury professionals. The pilot study also served to identify potential pitfalls and to remove any errors that may otherwise arise in the research study. The findings of the pilot study were essential to both the refinement of the visualization tool, as well as the final design of the research study methodology. Lessons learned were classified into two categories:

4.3.1 Lessons Learned: *i*AID Dashboard Design

Stakeholders' interactions with the *i*AID dashboard helped this author to refine the tool's visual interface to fulfill domain experts' preferences and needs following exposure in a 'real world' situation. The primary goal of this pilot study was to observe the use of the *i*AID dashboard with real injury stakeholders in a collaborative visual analytics setting. We intended to investigate how the *i*AID dashboard would facilitate multiple injury stakeholders' data exploration as well as enable them to convert complex data into knowledge essential to make informed decisions and take suitable actions. Throughout the PA sessions, we noticed that injury stakeholders were mainly interested in detecting, at a glance, major leading causes of mortality and morbidity across regions. Stakeholders were also interested in observing temporal and geospatial trends of the health issue as well as identifying the distribution of mortality and morbidity across gender and age groups. The following excerpts were retrieved from scripts the Paired and Group analysis sessions:

Example 1 - SME expressed their experience interacting with the visualization tool and explained about the system potential:

> SME: This is amazing; I think it has a lot of potential to do, because I come…I manage the trauma registry for provincial data in trauma, it's a bit different from that because you need to follow certain criteria
>
> VAE: I see, exactly, so you need a system that can aggregate the whole thing and show you a comprehensive picture of all that.
>
> SME: yeah

Example 2 - SME referred to the visualization and the way it helps SME raise new questions and generate new hypotheses:

> SME: but look at the 'Suicide', low, rise, rise, plateau, and then, but look at that…it's very interesting!
>
> VAE: why this is happening…
>
> SME: why, what happened down here, why did it go down?

Example 3 – Referring to the decrease in the number of injuries, SME suggested that we annotate the graph to explain the reason for the decline:

SME: if you knew, you could put a text box and say: "policy"

VAE: yeah, annotate that section.

SME: annotate that, yeah

Example 4 - VAE showed SME the features related to 'Comparison and Trending':

VAE: what we're trying to do here is to compare two regions and the trend over time for different regions.

SME: Oh My God, I wish I could use our data and do that

Example 5 - SME emphasized the importance of including the time trending feature to be able to understand temporal variations in the injury data together with an understanding of how well the health system performed:

SME: you want to trend it…

VAE: yeah, you want to trend it and see how can I read the story behind these data.

SME: yeah, I want to trend it

VAE: yeah

SME: are we doing well, are we not doing well…what is going on?

Example 6 - SME highlighted the importance of male and female comparison for the different injury causes: 'Suicide' and 'Transport Related':

VAE: for the 'Suicide', you can see it for gender, it is way different

SME: Yeah

VAE: you can see for Male the 'Transport related' is high,

SME: yeah

VAE: while the 'Suicide' is really high for women compared to Male.

SME: yeah, is it that amazing!

Example 7 - SME emphasized the importance of the Drill Down feature in order to more closely examine particular information of interest:

SME: Do you have drowning?

VAE: yeah, drowning would be the sub-causes

SME: oh!

VAE: if I'm looking here…drowning and let's say 'Keep Only'

SME: yeah, 'Keep Only'

VAE: then I could see how it is trending compared to others.

SME: so this is drowning involving…what is that?

VAE: 'Bathtub', 'Swimming pool' and this is the 'Unspecified'

SME: look at that, hey!

Example 8 - SME explained the importance of linked multiple Database:

SME: it would be nice to have other datasets linked in here

VAE: ok

SME: because of course the more data that you have in there, the more ways you can look at the output of the data.

VAE: that's right.

Example 9 – SME raised the issue related to the busy display of all injury causes in one visualization. As a proposed solution, we reduced the number of injury causes displayed to only the top 5 leading causes of injuries in order to keep the interface less busy:

SME: It's interesting…though I find the interface quiet busy

VAE: lots of information

SME: yeah

Example – 10 SME emphasized the importance of the Information Sharing feature in SME domain work:

SME: Can any one of theses visualizations be copied, printed out or shared?

VAE: yeah, if you want to share the graph visualization with your colleagues, you can copy it and save it, or save it as a PDF and share the PDF file or add it to a report.

After gathering and reviewing stakeholders' feedback from the pilot study workshop, we were able to identify the aspects of the *i*AID dashboard that were most important to injury stakeholders. Following the pilot study, new metrics were selected and new visualizations were introduced and incorporated into the final version of the *i*AID dashboard to reflect stakeholders'' task requirements and needs.

4.3.2. Lessons Learned: PA and GA methodology

This pilot study provided us with essential principles to refine the Paired and Group Analytics methodologies and improve the process and the outcome of the research study. Firstly, the pilot study offered us the advantage of conducting the initial testing of the Group analysis session with real injury stakeholders using real injury data. The Group pilot session helped us to study the social and collaborative aspects of the Group analysis process established though SMEs interactions and argumentations intended to pool their expertise, exchange various perspectives about the injury situations and discuss data uncertainty in order to collaboratively optimize the decision-making process. Understanding these aspects provided us with insightful approaches on how to efficiently design the setting of the GA sessions to promote social and collaborative interactions among SMEs and VAE.

Secondly, the GA sessions enabled SMEs to get familiarize with health data. Getting SMEs to be familiar with the health data increases SMEs knowledge about the data and therefore the potential of efficiently manipulating the data using the designed dashboard to retrieve information and solve analytical health problems.

Thirdly, the pilot study highlighted the importance of selecting the right stakeholders to conduct the study. The success of the Group analysis process and outcome resides in the selection of the right experts that effectively and efficiently contribute to the analysis sessions. The success of the Group analysis sessions greatly depended on SMEs willingness to participate, listen, and exchange knowledge and expertise to solve the analytical problem. It also depended on SMEs commitment to compromise, reach a consensus and find a solution to the problem.

Fourthly, the pilot study emphasized the importance of including a trained facilitator who was knowledgeable regarding the injury data, the process and the investigated problem. The success of the Group session resided in the presence of a skilled facilitator that managed stakeholders' argumentation and guided the sessions towards consensus and problem solving. Including a facilitator in the Group session ensured a well-structured and organized session, an orderly and logical flow of conversation and helped stakeholders to stay focused on the analysis problem.

Finally, the pilot study helped us to decide on the choice of equipment, the suitability of the devices and the placement of the recording instruments to capture the session. When transcribing the audio and video files from the Group pilot session, we faced the challenge of efficiently capturing the shared computer screen, as well as the challenge of documenting participants' over-talking conversations during the Group session. To overcome these obstacles, we used a software called "Camtasia" to capture screen shots when we manipulated the data and refined the visualizations.

The pilot study helped us to plan the configuration of the room and the physical placement of the equipment including the laptop, the microphones and the recording camera. Consequently, in the research study, we placed a camera facing the computer screen as well as the participating injury stakeholders in order to capture interactions with the visual display. We also used sophisticated 4-channel microphones in order to effectively and concurrently capture the main conversation as well as different side conversations that occurred. The final configuration of instruments and devices, based upon the learning form the pilot study, enabled this author to more efficiently capture and transcribe the details of the recorded verbal and non-verbal communications among stakeholders.

Chapter 5. Interactive Dashboard Design

The primary objective of this chapter is to outline the stages of designing, prototyping and evaluating the proposed *interactive* Analytical Injury Dashboard (*i*AID). The chapter's first contribution is the design of *i*AID dashboard based on injury stakeholders' needs and preferences derived from the analysis of the "Look, Feel and Function" compiled data. The chapter's second contribution is testing the *i*AID dashboard and demonstrating its application using real injury data retrieved from the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP). The final contribution of this chapter is the conception of task taxonomy of injury health professionals. The task taxonomy classifies domain experts' main tasks based on conducting a Paired Analysis qualitative user study with injury stakeholders.

5.1. Proof of Concept and Design Considerations

The initial concept of the dashboard derived from the need to integrate an analytical tool into public health injury prevention programs. The main objective of such a tool is to assist injury stakeholders in translating injury data into useful information regarding key injury indicators using visual displays (e.g. similar to gauges on a car dashboard or flight cockpit) [Pike et al, 2010]. Within the context of injury prevention, a visual dashboard should serve as a decision support tool that can help injury stakeholders identify and confirm the injury prevention status by visually examining key health indicators at a glance.

Earlier phase of this research project was the development of injury indicators that can be used for injury surveillance in Canada. A panel of national and international injury experts met in Ontario in 2006 to develop a comprehensive set of the Canadian child and youth injury indicators. Through a multi-phase modified Delphi method, injury experts defined, selected and decided on 34 key Canadian injury indicators related to child and youth injury outcomes, risk factors and policies. These indicators were selected to be used as standard measures to monitor child and youth injury prevention as well as to prompt actions to reduce injuries in Canada [Pike, 2010]. The next phase of this project was to design and develop Canadian Child and Youth Injury Dashboard as an interactive visual display tool that depicts the injury indicators and enables the dissemination of injury data in a user-friendly way to injury stakeholders across Canada (Please refer to Appendix L for early research summary). The main objective of the proposed visual dashboard is to provide researchers, health professionals and practitioners in the field of injury prevention with a standard measurement of the child and youth injury indicators and readily accessible information about the injury situation in order to effectively and efficiently inform and monitor the development of injury prevention research and activities (i.e. injury prevention programs, injury strategies assessment, policy and legislation).

We met with key injury stakeholders at the BC Injury and Prevention Unit in 2011 in Vancouver to discuss the Dashboard design phase of the Injury Indicator Project. We discussed in details the major steps that need to be taken in order to inform the design and functionality of an interactive dissemination visualization tool. The initial stage of the visual tool design consisted of a series of informal meetings and interviews with key injury stakeholders across Canada to identify existing domain tasks, gather an understanding of the domain tasks that needed to be conceptualized, the type of injury indicators that should be visualized and the most efficient types of visualizations that accurately depict the injury indicators data. The Canadian Injury Indicators' Development Team [Pike and Macpherson, 2007] conducted meetings with local and national injury prevention stakeholders to gather input and to initiate the design of the look, feel and function of the injury dashboard interface, with the goal to develop a prototype. Data were collected from injury stakeholders using paper and pencils chart boards (i.e. sketches of potential dashboard interfaces) as well as compiled injury stakeholders field notes at various workshops, conferences and events nationwide, including:

- The Atlantic Conference on Injury Prevention, Newfoundland (June, 2010).
- Toronto Meeting of Injury Stakeholders, Toronto (October, 2010).
- The BC Injury Conference, British Columbia (November, 2010)

At each venue, a workshop entitled “Injury Indicators for Children and Youth in Canada” was provided to participants (Please refer to Appendices C, J, and K for meeting agendas and summaries). A total of 120 injury stakeholders participated in the three workshops. To put this number of participating stakeholders in perspective, it’s worth to mention that while there are many public health official, public health medical officers or public health nurses who work on injury prevention projects, very few of them are fully dedicated to injury prevention in Canada. Therefore, the 120 participants represent a significant number of health professionals who are dedicated to injury prevention and attended the bi-annual conferences and meetings on injury prevention.

Throughout the three workshops, participating injury stakeholders outlined and discussed the “Look, Feel and Function” of the potential injury dashboard as well as the relevant tasks that the dashboard should facilitate and support. Using a modified Delphi method approach [Okoli, 2004], a panel of expert stakeholders shared ideas and exchanged thoughts and viewpoints about the anticipated injury dashboard. The generated solution synthesized opinions and judgments of the involved stakeholders. Solicited feedback about the look, feel and function of the dashboard was collected (Appendix B). We coded and categorized the collected data into three main categories to depict the “Look, Feel and Function” of the proposed Injury dashboard.

Table 5.1. Coded Summary of the ‘Feel and Look’ Data.

Code	Look	Feel	Function
Summary of Concepts	Look like a Dashboard. Display leading causes of injuries. Map-geographic location of injuries. Display indicators by Sex/Age/SES. Ability to work with one graph at a time. Ability to Drill down. Ability to Customize graph. Ability to annotate graph (See what interventions worked).	Easily accessible. Simple. Use common terminologies. Interactive. Intuitive Drop-down menus. User-friendly. Customizable on Desktop.	Audience: practitioners, policy-makers, researchers. Ability to compare indicators. Ability to search. Ability to enlarge views. Ability to cross tabulate the data. Ability to give overall injury summary. Ability to get Detailed information Ability to view all provinces.

	Display Injury Clock/National Death Clock. 3D.		Ability to link national and provincial data. Ability to customize to own work. Ability to share chart/data for publications/reports. Trends over time. Similar Views. Continuity of information between levels. Information overtime/over geography (e.g. Gapminder). Ensure security and confidentiality of data.

We analyzed the compiled data and exploited them to model and prototype the injury dashboard concept. Analysis of the compiled data enabled us to understand the needs and preferences of domain experts in order to inform the design of an effective and efficient injury dashboard. The compiled data served as foundation for the dashboard conceptual model and guided the selection of essential features that need to be incorporated into the design of the dashboard prototype.

5.2. Modeling and Concept Prototyping

Designing an effective and efficient dashboard should reflect the sole needs of stakeholders [Carr, 1999]. Prior to the modeling and prototyping the *i*AID dashboard, we closely communicated with expected end-users in order to understand their challenges and acknowledge their needs in order to integrate them into the design implications for the proposed dashboard [Kang & Stasko, 2011].

We conducted a series of meetings with injury stakeholders to decide on the injury indicators' metrics that should be visualized using the dashboard, as well as the most effective way to visualize them. Choosing and integrating the right metrics are vital to the success and effectiveness of the proposed *i*AID dashboard [Wang et al., 2011]. The metrics should reflect stakeholders' priority injury information while complementing stakeholders' operational task analysis. Through an iterative process, we reduced the existing metrics to the most relevant and meaningful that can depict the injury situation and can be abstracted in a space-limited visual display. We prototyped the *interactive* Analytical Injury Dashboard (*i*AID) based on the injury stakeholders' compiled feedback. The unique needs and goals of injury stakeholders informed the design of the *i*AID dashboard main components and functionalities. We classified domain task requirements into four principal tasks and we suggested the following four key features to be included in the design of the *i*AID dashboard:

1. **Data Exploration**: This feature enables injury stakeholders to explore multidimensional data and get a comprehensive overview of the data. Data exploration assists stakeholders in gaining insight into the injury data, building knowledge about the overall health situation as well as generate hypotheses [Keim, 2002].
2. **Data Zooming and Filtering:** The zooming feature enable stakeholders to drill down to higher resolutions and get detailed information on subsets of the injury data or on areas of interests [Keim, 2002]. Subsequently, the filtering function provides stakeholders with the ability to select and filter a particular subset in order to conduct further investigation.
3. **Data Brushing and Linking**: the brushing and linking features refer to highlighting specific data items and communicating the selection with other visual representations of the data in multiple visualization windows [Keim, 2002]. These features enable stakeholders to connect data variables and observe multiple visualization methods of the same dataset, therefore exploring the data from different perspectives (i.e. geospatial and time trend lines).
4. **Data Sharing:** The data-sharing feature represents a critical element of the *i*AID dashboard. It empowers stakeholders with the ability to share the analysis results and communicate their findings with other stakeholders.

We closely examined stakeholders' task needs and requirements to ensure that we can afford to integrate them into the *i*AID prototype while maintaining an easy to use and manipulatable dashboard [Norman, 2005]. The iterative process of designing, prototyping and refining the *i*AID dashboard interface was repeated until key stakeholders were satisfied with the final version of the prototype. We built the *i*AID dashboard tool based on the agreed design suggestions.

5.3.The Analytical Dashboard: Tool Design and Description

Borrowing from the cognitive science theories and Visual Analytics methodologies, we applied principals of visualizations and design guidelines to select the main features and functionalities of the *i*AID dashboard [Carr, 1999; Ware, 2008]. The main objective of the *i*AID dashboard is to help health professionals understand complex and heterogeneous injury data and effectively solve real-world injury problems. Typically, a dashboard is limited to the visual display of key indicators. In addition to the visualization of key indicators, we aimed at designing a dashboard that integrates stakeholders' analytical process and supports their reasoning through the use of interactive interfaces and customized visualizations. The proposed visualization dashboard should provide a common external representation for the group to aid in reaching common ground and better decision-making processes. A careful study was conducted to select the types of visualizations that are appropriate to the injury data and suitable for domain tasks. The visualizations were selected to depict relevant aspects of the injury problem and assist injury stakeholders in building knowledge and making informed decisions about dynamic health situations for child and youth Injury prevention initiatives.

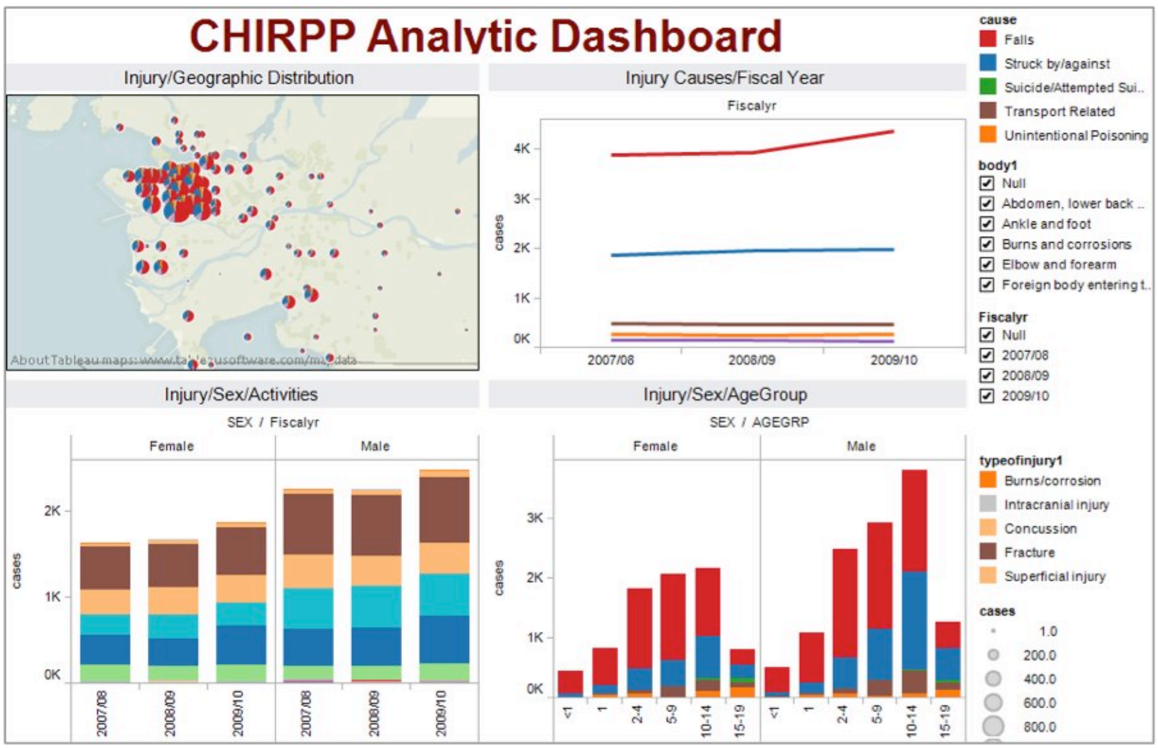
Ware (2008) in his book 'Visual Thinking for Design' explains that 'effective design should start with a visual task analysis, determine the set of visual queries to be supported by a design, and then use color, form, and space to efficiently serve those queries [Ware, 2008]. We closely examined the unique needs of domain analytical task and used them to sketch a paper and pencil prototype of the various visualizations that constitute the main components of the *i*AID dashboard. We initially decided on the main aspects of the analysis process that would benefit from the automation and visualization approaches.

Prior to prototyping the initial dashboard interface and through a series of cross country consultations with more than 250 key injury stakeholders in Canada, suggestions and proposals on potential injury dashboard visualization were collected (Please refer to Appendix B). Key injury stakeholders from across Canada discussed data dimensions and elements that should be automated and visually presented in the main visual dashboard interface, including: geographic distribution of injury cases, the time trends and seasonal variations of injury cases, as well as the distribution of injuries across different data variables (i.e. age groups and gender). Using paper and pencils, injury stakeholders sketched potential visualizations that best depict the injury data. They suggested a four-view dashboard visual interface that synthesizes their collective recommendations and suggestions.

We used Tableau Software (version 7.0) to design and build the main visualizations of the *i*AID dashboard based on injury stakeholders solicited suggestions. Tableau is commercially available visualization software that uses the Visual Query Language (VisQL) to visually represent large databases through interactive visual interfaces. We didn't integrate novel visualizations, as we were constraint by the limitations and available types of visualizations offered by Tableau. Initially, we designed individual visualizations based on the compiled domain task taxonomy as well as to best map the injury stakeholders' analytical tasks. As presented earlier, Injury stakeholders were mainly interested in specific functionalities, including identifying leading causes of injuries at a glance, detecting major injury causes, observing temporal and geospatial trends of injuries as well as revealing how injury causes are distributed across data variables (i.e. sex, age group and fiscal year). We designed the dashboard interface as to support injury stakeholder's analytical tasks. As Ware explained, "effective design should start with a visual task analysis, determine the set of visual queries to be supported by a design, and then use color, form, and space to efficiently serve those queries" [Ware, 2007]. Color theory and integrate pop-out features were integrated into the design of visualization tool to ensure clarity and improve visual cognition. For instance, the use of colors is significantly important within the public health community. Health stakeholders are pressed with deadlines and faced with the challenge of understanding multidimensional and heterogeneous data in a short amount of time. Using effective colors and color gradients is fundamental to accentuate relevant health information, depict the range of health values and denote the magnitude of health situations. Furthermore, effective use of colors highlights health events and alert health stakeholders about peak data values or values exceeding the expected range. According to Few (2007), visualization tools should enable users to observe numerical and textual information and intuitively discover patterns, spot outliers to determine out of range data values as well as identify trends, which are vital steps to advance the analytical reasoning process [Few, 2007]. To efficiently illustrate trends and patterns in injury data, we selected appropriate visualizations such as stacked bar charts, pie charts overlaying British Columbia provincial map, and time trend line visualizations to quantify the injury data and to represent the most essential analytical information needed to complete analytical domain tasks. On the one hand, the stacked bar charts were effective in allowing injury stakeholders to compare the injury data across various categories. For instance, we selected bar charts to represent how leading causes of injuries are distributed across main data variables including sex, age group and injury activities (Fig 5.1, bottom visualizations). The staked bar were useful in helping injury stakeholders to identify high injury data values at a glance based on the height of each showed bar. On the other hand, the trend lines offered injury stakeholders built-in temporal functionalities to measure and identify how leading injury causes are trending over time and compared to other causes of injuries. For instance, as shown in Figure 5.1, the time trend view illustrates how 'Fall' injury cause represents the leading cause of injuries trending upwards through time from 2007 to 2010 compared to other injury causes such as 'Suicide' and 'Transport Related'. As Edward Tufte (1997) indicated, 'information consists of differences that make a difference' [Tufte, 1997]. When designing the dashboard interface we integrated advanced visual interface techniques to efficiently represent the characteristics of the injury data and convey the information and knowledge about the injury situation in a salient and user-friendly way. Compared to cross tab, visual representations are easier to explore and compare. Effective graphical displays help public health analysts derive scientific insights and acquire knowledge to accelerate health discoveries. For instance, analysts observing visual information can detect pop out graphical elements such as the high points, the low points, trends, and outliers as this information become salient and automatically visible using advanced graphical interfaces.

Once we decided on the most appropriate visualizations, we linked the created visualizations and adjacently integrate them into the proposed *i*AID dashboard. The rationale for building this coordinated visualization dashboard is to integrate side-by-side various types of visualizations to offer injury stakeholders a holistic view of the injury situation at a glance and support their domain task analysis. According to Carr (1999), visualization tools should take advantage of the human brain's visual bandwidth to expedite the analytical problem and help users to derive insights from datasets [Carr, 1999]. Perceiving information through humans' eyes is essential to accelerate the reasoning process. Hence, information displayed within the limited span of users' eyes support the flow of the visual reasoning process; it allows easy comparison among datasets and efficient detection of data similarities and contrasts at a glance. Similarly to instruments on a car dashboard, the prototyped *i*AID dashboard illustrates the various aspects of the injury health system and its performance in terms of specific key injury indicators [Pike, 2011].

Figure 5.1. *interactive* Analytical Injury Dashboard (*i*AID)



The iAID dashboard offers injury stakeholders summative information of key indicators in an intuitive interface, easy to use tool and easy to interpret visualizations. The dashboard provides the following main functionalities:

- It builds an overview of the injury situation and the injury indicators trending over time and across different Health Authorities (HA) and Health Service Delivery Areas (HSDA) regions, answering SMEs the 'WHEN' and 'WHERE' questions.

- It offers Drill Down capabilities for additional levels of granularity.
- It offers Interactive Filtering for stakeholders to be able to partition the data and focus on a specific interesting subset of the injury indicators data.
- It offers Interactive Zooming using the provincial map of British Columbia where the injury indicators data are compressed in the form of a pie chart to show an overview of the indicators' distribution across various Health Authorities.
- It offers Interactive Distortion to show areas of interests with high level of details while keeping other indicators displayed with low level of details.
- It offers Details on Demand to allows stakeholders to interactively select parts of data to be visualized in more details while providing an overview of the whole informational concept. Stakeholders can hover the mouse over a specific area of the visualizations and get Details on Demand information.
- It offers Interactive Linking and Brushing to combine different visualization methods to overcome the shortcomings of single techniques. Brushing means selecting a subset of the injury indicators data, by highlighting it with a mouse clicking and the linking technique will enable stakeholders to see how this particular data subset behaves in each of the visualizations in different windows of the Dashboard.

The objective of the *i*AID dashboard is twofold. First, it should offer rapid synthesis and interpretation of complex and multidimensional injury data. Second, it should support injury stakeholders' analytical and cognitive tasks to facilitate their problem solving and support decision-making process. Scholars and theorists in the field of interactive information visualization affirm that the ultimate purpose of visualization is "insights not pictures" [Card, Mackinlay, & Shneiderman, 1999]. They explain that effective and efficient visualizations should significantly enhance humans' cognitive and reasoning abilities, enabling an increased amount of information to be perceived through humans' visual memory to facilitate thoughts and ideas. As a result, we aimed at integrating simple and intuitive visual representations to help injury stakeholders to gain insights into the data exploration and data understanding. According to a study conducted by Moore et al., simplicity, functionality and flexibility of Graphic User Interface (GUI) are key criteria that influence users' acceptance of technology tools within the healthcare sector [Moore et al, 2008].

We built the *i*AID interface page as a single page that comprises 4 view windows with a summary of all indicators displayed in various simple and intuitive graphical representations including stacked bar chart, timeline trend, and geographic map [Fig.5.2] to facilitate injury stakeholders' analysis process. Our rational for designing the 4-view dashboard was based on advanced visualization techniques and design guidelines. For instance, to inform effective visual tool design, we looked at Ware's study (2008) related the capacity of human visual memory and its performance in side-by-side displays compared to sequential displays. The author concluded that, when comparing two graphic objects simultaneously, side-by-side visualizations dramatically increase the efficiency and the speed of the analytic task while reducing the memory's cognitive load. He claimed that it's faster and more efficient for humans' working memory to compare two entities and pick up a chunk of information in side-by-side visual displays [Ware, 2008]. Moreover, Ware argued that when examining and learning information, humans' eye movements are 10 times faster when comparing graphical objects placed side-by-side than objects placed on different pages. Furthermore, many researchers highlighted the importance of coordinating relationships and activities in multiple side-by-side visualizations to enable users to easily and efficiently compare data attributes and dimensions [Carr, 1999; Shneiderman; 1996]. Similar, Carr (1999) explained that coordination across multiple side-by-side visualizations enables users to simultaneously observe and compare datasets, generate insights and build knowledge of the visualized data without overworking or adding cognitive load to humans' working memory [Carr, 1999]. As a result, we designed the iAID dashboard to integrate multiple coordinated visual displays with embedded interaction capabilities and filtering techniques to help stakeholders easily retrieve injury data at multiple levels of abstractions. North and Shneiderman defined the term multiple coordinated visualizations as a "set of visualizations and a set of coordination between them" [North & Shneiderman; 2000]. The authors argued that multiple visualization windows should be coordinated to manage the limited graphical display of information while taking advantage of human's visual perception to reduce information overload and amplify cognitive skills [North & Shneiderman; 2000]. Information displayed within the limited span of users' eyes supports the flow of the visual reasoning process, allowing easy comparison among datasets and efficient detection of data similarities and contrasts at a glance. Several studies reported the benefits of combining multiple coordinated visualizations of data to enhance end-users' satisfaction and task performance [Carr, 1999; North & Shneiderman; 2000]. Within the context of public health injury prevention program, it is significantly helpful for injury stakeholders to simultaneously view temporal and geospatial visualizations of injury data to investigate seasonal injury variations and pattern changes as well as examine geographic distribution of injury cases across regional locations. When exploring health events, analysts need to observe temporal and geospatial data simultaneously in order to construct a comprehensive picture of the health situation [Moore et al, 2008].

The *i*AID multiple coordinated visualizations were designed to empower injury stakeholders with the ability to concurrently observe large amounts of temporal and geospatial information, relieving humans' memory from the challenges imposed by information overload. Placing multidimensional injury data visualizations simultaneously on one screen can dramatically increase stakeholders' data understanding and information processing capabilities. Displaying geospatial and temporal injury data in a coordinated manner is vital to enable injury stakeholders to examine datasets from temporal and geospatial perspectives. However, when designing the coordinated visualization, we realized that the integration of multiple visualizations comes with a trade-off cost between designing efficient visualization tools and assisting injury stakeholders in achieving fast and accurate analysis [Carr, 1999]. According to the guidelines for designing information visualization applications, designers should consider "computational requirements" and "display space requirements" when designing multiple side-by-side visualizations. Baldonado et al. (2000) explained that displaying multiple side-by- side visualizations requires extensive computational asset and display space from the visualization tool in order to display additional visualizations at once [Baldonado et al, 2000]. As a result, we limited the number of visualization to 4 views on the *i*AID interface in an attempt to balance between injury stakeholders' cognitive load and coordinated visualizations to support their domain tasks and advance the analytical process.

To ensure the design of successful Visual Analytics tool, Hanrahan et al (2009) presented what constitute the fundamental functions that Visual Analytic tools should support including: 1. Visual Exploration. 2. Augmentation of Human Perception, 3. Visual Expressiveness. 4. Automatic Visualization. 5. Visual Perspective Shifting. 6. Visual Perspective Linking. 7. Collaborative Visualization. As a result, the Visual Analytics *i*AID dashboard was designed to incorporate multiple coordinated visualizations in order to allow stakeholders to comprehensively explore the injury data and gain new insights into injury events and situations characterized by heterogeneous and complex datasets. The iAID dashboard aims to give injury stakeholders a comprehensive overview of the data, allowing them to see chunks of health information in a small space while enabling them to drill down for further details-on-demand information to reach additional levels of granularity and consequently lead to "discovery, decision-making and explanation" [Card, Mackinlay, & Shneiderman, 1999]. The iAID dashboard further provides injury stakeholders with automatic visualizations to boost their cognitive skills and capabilities while saving time and efforts. The automatic visualizations act as external visual aids that help to increase injury stakeholders' perceptual and reasoning capabilities to perform faster and more accurate analysis. Furthermore, the *i*AID dashboard offers various types of visualizations that are interlinked to enable injury stakeholders to investigate the multidimensional injury data from different perspectives. To incorporate Hanrahan's essential elements of Visual Analytics tool, we prototyped the iAID dashboard to encompass the following three major components: 1) A visualization interface component. 2) A data analysis component and 3) Interactivity Component.

Visual Interface: The design of the *i*AID visual interface was based upon diverse design methods and principles. According to Ware, 'a good design optimizes the visual thinking process' [Ware, 2008]. Ware, in his book *visual thinking*, indicated that in order to make sense of information and construct knowledge, humans' eye movements constantly perform visual queries to inspect data, sort them and look for relevant information. Through these series of visual queries, humans attempt to search for information needed to perform given cognitive tasks. Subsequently, humans synthesize existing patterns from their brains with patterns collected from external information to support and enhance users' reasoning process [Ware, 2008]. Understanding humans' pattern processing behavior informs the design of visualization tools that enable users to easily observe trends, identify patterns, spot outliers as well as comprehend the relationships among data items. According to Ware (2008), effective visualization tools should take advantage and encourage the visual thinking process to facilitate data exploration and analysis. The use efficient pop-out differentiators' elements such as color (i.e. hue, darkness/lightness contrast), shape (i.e. size, elongation, orientation), motion, and spatial grouping support the human visual queries and improves the outcome of the analytical task [Ware, 2008]. Our main objective was to build the iAID interactive interface in a way that integrate pop-out differentiators elements in order to embed the constraints of the analytical tasks into the visual interface itself and relieve injury stakeholders working memory from information overload inherited from the complex injury data. Integrating intuitive and easily interpreted visualizations into the iAID visual interface will help to offload stakeholders' working memory, enabling them to deploy their memory's limited resources to efficiently complete the analytical task.

Pop out features such as the use of colors and color gradients are significantly important within the public health sector. Health stakeholders deal with challenging multidimensional data that require timely decisions, therefore using effective colors and color gradients is fundamental to accentuate relevant health trends and increase the ability to distinguish alerting injury indicators in a quick manner. The *i*AID dashboard's interface effectively integrates information visualizations guidelines (i.e. color intensity and size) to depict the range of health values and denote the magnitude of various health situations. Using various colors or color gradients help injury stakeholders to visually highlight leading injury causes (i.e. Falls) as well as alert injury stakeholders about peak data values or values exceeding the expected range (i.e. youth aged 10-14 years old) and easily reveal trends and patterns (i.e. Male vs. Female injuries) that are essential to build a comprehensive picture about the injury data. The iAID visual interface integrate these pop-up color features to reduce time and cognitive efforts while seamlessly conveying the content of the injury data in a clear and unobstructed manner.

Data Analysis: The data analysis component of the iAID dashboard enables injury stakeholders to interact with the visual representations at various levels of granularities using advanced visualization techniques such as interactive distortion, zooming, filtering, brushing and linking [Keim, 2002]. As illustrated in Figure 4.3, the iAID dashboard presents a comprehensive picture of the leading injury causes displayed on a single screen of multidimensional views including temporal and demographic [Fig 5.3]. Each window view is connected to a full-page visualization with specific functionalities and features to integrate stakeholders' analytical models and facilitate the Exploratory Data Analysis (EDA) process [Fig 5.4]. Every time injury stakeholders select a particular graphical display, a comprehensive visualization window will be shown with advanced analysis capabilities and granularities, enabling interaction with the data and in-depth understanding of key injury indicators' performance [Fig 5.5]. This Data Analysis component of the iAID dashboard facilitates the Exploratory Data Analysis (EDA) process, allowing injury stakeholders to explore the data in order to understand and comprehend the different features of the complex injury data. EDA help stakeholders to inspect and observe the numerical information and intuitively discover patterns, spot outliers to determine out of range data values as well as identify trends, which are vital steps to advance the analytical reasoning process.

Moreover, the *i*AID Data Analysis component borrows from Shneiderman's Information Visualization Mantra (i.e. Overview First, Zoom and Filter, than Details-on-Demand) [Shneiderman, 1996] to incorporate visual analytics features and functions. Shneiderman's mantra highlights the essential elements that are fundamental to facilitate the Confirmatory Data Analysis (CDA) process. The zoom and filter capabilities empower stakeholders to zoom in and select areas of interest and examine the data at various levels of abstractions. In addition, the Details-on-Demand feature offers stakeholders detailed information about data subsets under investigation. The integrated features support the CDA process, allowing injury stakeholders to gain insights into the data and build knowledge essential to confirm or reject generated hypotheses.

Figure 5.2. Injury Situation Overview

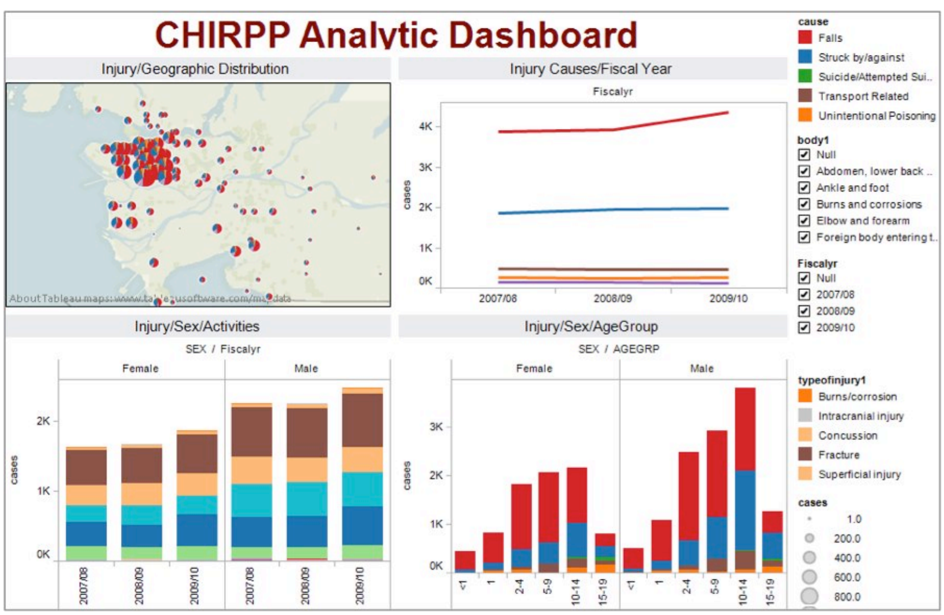
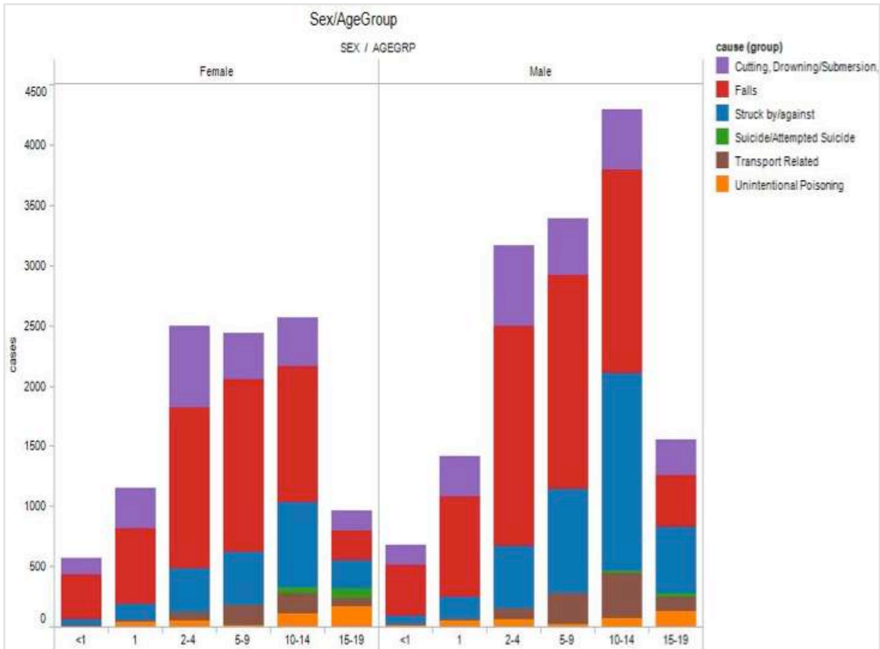


Figure 5.3. Details on Demand (Sex/Age/Injury Cause)



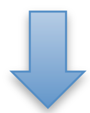
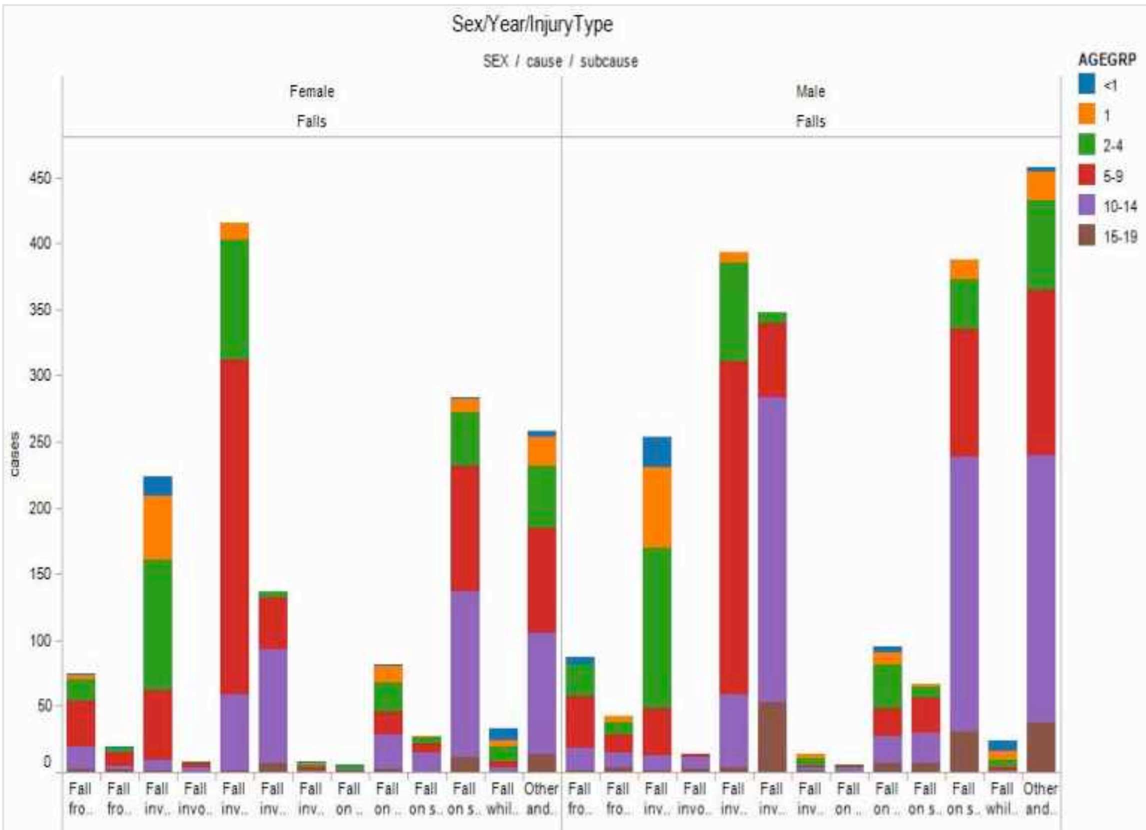


Figure 5.4. Brushing and Linking (Sex/Injury Causes/Injury)



Interactivity: Interactive interfaces are 'interfaces that translate user actions such as mouse events, key events and other input events into visualization specifications' [Ref]. Interaction with the visualization system represents a 'key element in the cognitive process' [Liu & Stasko, 2010]. Interactive visual representations reduce users' cognitive load; they turn cognitive tasks of reasoning about the "what-if" scenarios into perceptual tasks where users can predict and model the solution. As the loop between computers and humans tightened, interactive Visual Analytics tools and techniques provide a valuable external assistance that enhances humans' cognitive skills and expand their abilities to think, reason and conclude about analytical reasoning problems [Norman, 1993]. Interactivity is a critical component of the iAID dashboard, as it enables the integration of human judgment and reasoning into the automation and visualization process, which is vital to enhance the analytical problem solving [Keim et al., 2009]. Within the context of problem solving and decision-making, interactivity is needed to integrate domain stakeholders' knowledge and expertise into the analysis of health problems through back and forth interrogation and manipulation of the data, which result in refinement of the generated visualizations and consequently advancement of the analysis process.

According to Liu & Stasko (2010), the human reasoning process represents the synergy between external visualizations, mental modules, and interaction with the external visual representation [Liu & Stasko, 2010]. Hence, interactive visualizations play a vital role in the interconnection between mental models and external representations of information. Interactive visual interfaces help users to build accurate mental models that map the characteristics of the external data and convey the information about them. Furthermore, Interactive visualization systems refine humans' mental models and enhance their accurateness as they become more sophisticated through the interactions. The integration of interactive visualization techniques such as ad hoc filtering, zooming and drilling down techniques will enable injury stakeholders to examine only selected information. By limiting the amount of information displayed in the visual representations, stakeholders will be able to dynamically interact and understand and quickly synthesize information from large sets of complex and dynamic data as well as test different scenarios to understand the influence of various parameters. Interacting with the visualization supports the analytical process; it empowers users with capabilities such as external anchoring, information foraging and cognitive offload [Liu & Stasko, 2010] to advance the human cognitive and reasoning process

Tableau provided us with embedded interactive features that supported the functionalities of the iAID dashboard. The main objective of these embedded functions is to provide injury stakeholders with a flexible platform to test various scenarios and examine the underpinning claims of each carried out scenario. Interactive interfaces empower injury stakeholders to understand the structures and relationships among data dimensions as well as to comprehend the underlying characteristics of the injury dataset in order to facilitate data manipulation and exploration. Interactivity of the iAID dashboard can help internalize new concepts about the injury situation and get insights into the injury problem solving process. Interactivity helps to integrate injury stakeholders' prior knowledge and expertise into the analysis process, allowing them to ask the data multiple questions based on their prior skills in the injury prevention field.

Furthermore, interactivity is essential to tailor the iAID dashboard visual interface to fit injury stakeholders' unique goals and needs and adapt to their skills in order to support the analysis process, enabling them to closely examine situations of interest and interactively assess the pros and cons of the analytical injury problem.

Chapter 6. Methodology

This chapter describes the research methodology used in this study, and comprises three major sections. The first section describes the research design. The second discusses the rationale for selecting a mix (qualitative and quantitative) methods approach to address the research question. Section three describes in detail the use of the CHIRPP data to populate the *i*AID dashboard, the designed analytical tasks that were undertaken during the study, and the Paired Analytics (PA) and Group Analytics (GA) methodologies utilized to conduct the data collection.

6.1. Research Design

According to Burns and Grove, research design provides the framework to plan and integrate data collection methods that enable researcher to answer the research question and reach the intended research objectives [Burns & Grove, 1997]. This research study encompassed four discrete phases of data collection that were designed to simultaneously address the main and subsidiary research questions. These data collection phases included the Paired Analytics phase, the Group Analytics phase, the questionnaire phase and the interview phase. The research entailed the collection of data related to the collaborative and social activities of multiple Subject Matter Experts (SMEs) to capture their experience using the interactive data visualization tool (*i*AID) within the context of injury prevention problem solving and decision-making. Selecting the appropriate research methods greatly depends on the nature of the research question and the setting of the research problem. In this study, we used a quantitative and a qualitative research design to empirically explore the social and cognitive aspects of collaborative visual analytics and their impacts on SMEs problem solving and decision-making process within the healthcare sector. This study adopted a research design that employed the Paired and Group Analytics methodologies and the modified Delphi method to efficiently collect the study data. It further adopted the Joint Activity theory and the Distributed Cognition framework to effectively analyze the various types of collected data.

6.2 Research Question

Developing a research question is an insightful and exploratory process that influences all subsequent phases of the research study [Agee, 2009]. Marshall & Rossman (2006) classified research questions into various categories including the 'Exploratory Question' that aims to inspect and examine new concepts, the 'Explanatory Question' that tries to explain an investigated phenomena and the 'Descriptive Question' that intends to describe and depict an examined phenomena [Marshall & Rossman, 2006]. The nature of our study is explanatory and descriptive, which led to formulate a 'What' type of research question in order to gain in-depth understanding of the various factors and elements contributing to the phenomena under investigation. This research study presents a unique study of collaborative Visual Analytics and investigates its implications for problem solving and decision-making process for public health problems in general and, in particular, child and youth injury prevention program. A comprehensive review of the literature and related work helped us to frame the study's research question and enhance its relevance to the Visual Analytics field. Formulating the research question was an iterative process that evolved throughout the course of this study to interactively refine and finalize the question. Creswell & Clark (2007) explained this iterative modification of the research question as an advancement towards building more comprehensive knowledge about the research problem. The authors noted that research question 'change during the process of research to reflect an increased understanding of the problem' [Creswell & Clark, 2007]. We developed and refined the study's research question to empirically evaluate the collaborative use of the interactive Visual Analytics dashboard within the health care sector and assess its impact on problem solving and decision-making. This study suggests that using the interactive Visual Analytics dashboard in a collaborative setting will help injury stakeholders to better understand the wicked injury problem. Furthermore, we anticipated that the use of the interactive visualization tool will give injury stakeholders insights into valuable information about the injury indicators data in order to build knowledge and ultimately facilitate problem solving and support the decision-making process. As a result, we formulated the following core research question:

Research Question: "What is the effect of collaborative Visual Analytics on facilitating problem solving and supporting decision-making within the Public Health Injury Prevention sector?"

The study was designed to encompass social and cognitive theories with the objective to ensure contribution to various research disciplines diverse audiences related to injury prevention. As a result, the thesis was designed to answer the following subsidiary research questions:

Subsidiary Research Question #1: How do injury stakeholders interact with each other to approach problem solving? How do they use the interactive dashboard to support the process?

This question deals with the social aspects of the collaborative visual analytics phenomena. It highlights the role that the social setting plays on the way group members socially interact in a co-l integrated into the national public health web portal ocated environment to exchange knowledge, and pool expertise and judgment to collaboratively solve the given problem.

Furthermore, the thesis examines aspects of the social and cognitive dimensions of collaborative Visual Analytics, and their effects on the problem solving and decision-making process.

Subsidiary Research Question #2: How do injury stakeholders coordinate their activities to collaboratively solve the problem and make a decision?

This research question emphasizes the way in which injury stakeholders coordinate their actions and collaborate their activities to establish a common understanding of the data that can help them to advance the problem solving and decision-making process.

Subsidiary Research Question #3: How do stakeholders use language and non-verbal communication movements to advance the analytical problem solving process in a co-located collaborative environment?

Language use is essential in communicating verbal ideas and thoughts. This research question focuses on the importance of verbal and non-verbal communication among stakeholders and its role in improving their interaction and enhancing their collaboration to advance the problem solving and decision-making process.

6.3. Mixed Methods: Qualitative and Quantitative

To comprehensively address the research problem and answer the research question, we decided to carry out a mixed methods research design. This design integrates qualitative and quantitative approaches to explore the impact of collaborative visual analytics to facilitate problem solving and support decision-making with respect to injury prevention. According to Tashakkori and Creswell (2007), in a mixed methods research 'the investigator collects and analyzes data, integrates findings, and draws inferences using qualitative and quantitative approaches and methods in a single study or program of inquiry' [Tashakkori & Creswell, 2007]. Consistent with this definition, Johnson & Turner (2007) defined a mixed method study as a research design that "planfully juxtaposes or combines methods of different types (qualitative and quantitative) to provide a more elaborated understanding of the phenomenon of interest (including its context) and, as well, to gain greater confidence in the conclusions generated by the evaluation study" [Johnson & Turner, 2007]. The rationale for adopting a qualitative and quantitative research approach in this study was to strategically integrate observations and survey methods in order to capture the various fundamental aspects of the collaborative visual analytics process and to gain in-depth understanding of the interactions and collaboration among SMEs using visual analytics tool to facilitate problem solving and decision-making.

According to Creswell, a qualitative research method is 'an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. The researcher builds a complex, holistic picture, analyzes words, reports detailed views of informants, and conducts the study in a natural setting'

[Creswell, 2013]. The qualitative research approach helps us to understand the impact of collaborative visual analytics on problem solving and decision-making within a specific social and collaborative setting. According to Denzin & Lincoln (2005), the main task of qualitative researchers is to 'study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. [Denzin & Lincoln, 2005]. We gathered qualitative data with regard to SMEs social and collaborative interactions with each other using the visualization tool within the healthcare sector. Qualitative data emphasize experience and meaning that are 'socially constructed by individuals in interactions with their world' [Merriam, 2002]. The collected qualitative data are in the form of field notes, audio- and video-recordings, and screen captures, as well as interview notes.

In this study, we focused on the two main characteristics of qualitative research design: the descriptive and the exploratory approach. On one hand, descriptive research design provides information that enables observation and description of emerging phenomena that is occurring among SMEs in a particular social and collaborative setting [Brink & Wood, 1989]. On the other hand, exploratory research design assists in gaining in-depth exploration of the observed phenomena, and gathering insights into the given situation to formulate hypotheses [Merriam, 2002]. In this study, the descriptive and exploratory research designs allowed us to understand the nature of the phenomena under investigation. They helped us to explore and describe in details numerous aspects of the collaborative process including how multiple SMEs socially interacted with each other and with their environment, what emerged from their interactions with other group members and with the visualization tool, how SMEs collaboratively used the visualization tool to solve the problem and to make decisions in a specific social setting as well as how the social context shaped SMEs collaboration.

In addition to the qualitative approach, we adopted the quantitative research approach to more effectively address the research problem. As defined by Teddlie (2009) quantitative research is 'the techniques associated with the gathering, analysis and interpretation, and presentation of numerical information' [Teddlie, 2009]. In this study, we collected numerical data about SMEs rating of the visualization tool interface and functionality. The collected quantitative data were retrieved from a semi-structured questionnaire that participating SMEs completed following the interactive session with the tool. The use of questionnaires enabled SMEs to rate and report their evaluation of the visualization tool interface and functionality. The questionnaire consisted of 20 questions that used a 7-point Likert-type scale and 3 open-ended questions (Appendix A). Questionnaire data provided us with numerical and textual data that characterized the observed phenomena and enabled us to draw conclusions about stakeholders experience using the visualization tool. According to Aliaga and Gunderson (1999), the object of a quantitative study is to explain phenomena 'by collecting numerical data that are analysed using mathematically based methods' [Aliaga & Gunderson, 1999]. We compiled and analyzed the collected numerical data using statistical techniques to draw inferences about the tool's functionality and layout. The collected quantitative data helped us to understand how the visualization tool interface and functionality should be designed to serve the analytical needs and preferences of SMEs.

Combining qualitative and quantitative methods into one study is referred to as a methodological triangulation. Denzin defines the concept of methodological triangulation as the "combination of methodologies in the study of the same phenomena" [Denzin, 1978]. Within the field of social sciences, Campbell and Fiske (1959) emphasized the use of multiple techniques and approaches to collect data. They argued that methodological triangulation enhances the validity of the study by verifying the convergence of data findings from multiple methods to generate comparable results. In the case of this study, the nature of the research question guides us to adopt the triangulation method and benefit from its offered advantages. The first reason for adopting the triangulation method is the need to explore the research problem from different perspectives in order to acquire in-depth understanding of the various aspects of the research problem and uncover all characteristics of the studied phenomenon. The second reason is that the triangulation approach synthesizes the strengths of qualitative and quantitative methods to provide richer and more detailed data. Qualitative data or quantitative data alone are not sufficient to explain the phenomena under exploration and build a comprehensive picture of the research problem. The third reason is that this study involves the integration of multiple phases to address the research problem. A combination of multiple methods helps to further examine the explored results generated from each phase of the study. For instance, questionnaire data are combined with interview data to enhance the trust in the study findings and generate more valid and consistent results. Finally, this research employs a methodological triangulation in order to overcome the limitations of one single research methodology, reduce the threats to the study validity and to ensure greater generalizability of this interdisciplinary study.

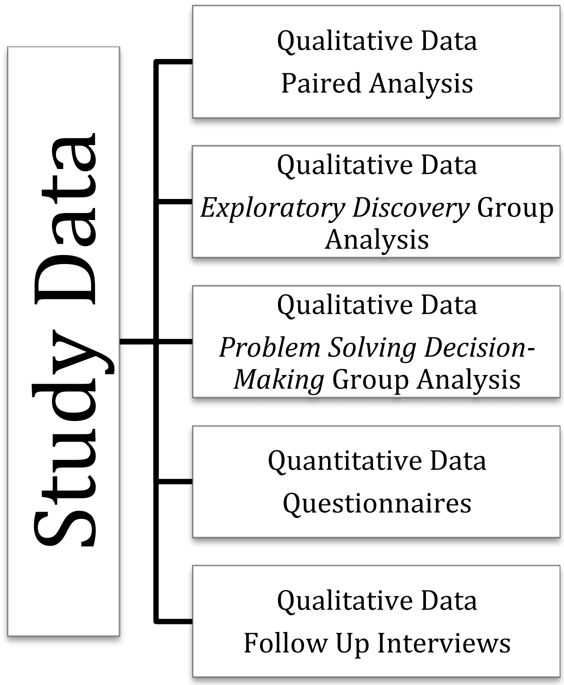
As explained earlier, the goal of this research study was to explore the impact of collaborative visual analytics on SMEs problem solving and decision making process within the context of the public health approach to injury prevention. We tailored the way that we combined the qualitative and quantitative methods according to the goal of this research study. Using the Priority-Sequential Model, we chose the qualitative method to be the *principal* method based on the nature of the research question and its focus [Morse, 1991; Morgan, 1998]. This principal qualitative study was supported by a combination of other *complementary* methods to assess stakeholders' feedback with regard to their collaborative experience interacting with the visualization tool. The following statement represents the sequence in which the mixed methods were integrated:

Figure 6.1. Qualitative and Quantitative Methods: Study Sequence

QUALITATIVE → quantitative → qualitative

We adopted the sequential triangulation of qualitative and quantitative methods as the compiled results of one method were used to design the next phase of the research design [Morse, 1991]. As depicted in Fig 6.1, the capitalization of 'QUALITATIVE' refers to the emphasis placed upon the qualitative methodology and the priority given to it as the main strategy for data collection. The arrows between the methods refer to the sequence in which the different methods were applied.

Figure 6.2. Data Collection: Qualitative & Quantitative.



As shown in Fig 6.2, the first three phases of the study were mainly designed to collect qualitative data. The last two phases of the study were focusing on the collection of quantitative and qualitative data as follow up data to pursue earlier results generated from the main qualitative study. The qualitative data (i.e. participants observation, video and audio recordings, screen capturing) were considered the primary source of data collected in this study to strengthen the potential to empirically evaluate the effect of using collaborative visual analytics on the problem solving and decision-making process. The collected qualitative data were supplemented with the subsequent quantitative data (i.e. semi-structured questionnaires) to further explore the various concepts generated from the early qualitative study. These quantitative data helped us to uncover additional information and examine additional aspects of the phenomena under investigation to strengthen our understanding of the explored concept.

In the last phase of the study, we collected qualitative method through follow-up interviews with SMEs. Summarizing inputs from the earlier qualitative and quantitative methods help to guide the design of the follow up interviews during this phase of the study. The interviews mainly focused on SMEs reflection on their experience interacting with other SMEs and with the visualization tool. Results from the preliminary qualitative and quantitative data analysis enabled us to formulate more focused interview questions. The interviews provided us with qualitative data to gain in-depth understanding of the phenomena observed early in the study. The qualitative data help to refine concepts and re-emphasize phenomena retrieved from the early phases of the study.

The triangulation of qualitative and quantitative methods provided us with rich, detailed and descriptive data to effectively examine, study and analyze the investigated concepts from various perspectives. Effective interpretations of the collected qualitative and quantitative data enabled us to detect and examine patterns in SMEs social and collaborative interactions as well as expand our knowledge of the explored phenomena. The Paired analysis and the Group analysis sections of this chapter will provide further details regarding the nature of the qualitative and quantitative data collected within the context of health issues problem solving and decision-making.

6.4. Study Participants

As this study relied heavily on the qualitative research design, sample selection became a compounded and complex process. In qualitative studies, effective sampling selection plays a critical role in increasing the possibility of obtaining rich data on the explored concepts. In this study, we chose a “purposeful sampling” strategy to select the study participants who were injury stakeholders [Creswell & Clark, 2007]. The aim of the purposeful sampling was to select knowledgeable and experienced injury stakeholders or Subject Matter Expert (SMEs) who enabled us to collect data with detailed description about the injury phenomena under scrutiny. As explained by Patton, “the logic and power of purposeful sampling lies in selecting information-rich cases for study in depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research, thus the term purposeful sampling’ [Patton, 1990].

In this study, a careful selection of SMEs was carried out based on a preconceived set of criteria. For example, roles and functions within the healthcare sector specific to injury were key criteria for inclusion, while age and gender were not essential to selection since these attributes were seen not to affect the outcome of the study. SMEs came from diverse backgrounds and disciplines; they were public health professionals, health researchers, policy makers and medical practitioners. We focused on three fundamental criteria when selecting participating SMEs including: SMEs background knowledge, SMEs heterogeneity as well as SMEs representativeness.

The first criterion was related to SMEs background knowledge. We selected knowledgeable injury stakeholders to participate in this study. As explained earlier, the Delphi method approach was used to structure this study's data collection. The Delphi method highlights the importance of including knowledgeable and cooperative participants that can contribute with valuable inputs to address the problem. In this study, SMEs had diverse backgrounds ranged from a public health analyst to a senior epidemiologist. Okoli & Pawlowski (2004) emphasized the significance of "choosing the right experts" to ensure a sound and accurate study [Okoli & Pawlowski, 2004]. Since the Delphi approach relies upon participants' background knowledge and judgmental information, selecting the right participant is critical to the outcome of the research study. Therefore, we made sure to include the right injury stakeholders who possess the essential background knowledge to solve the analytical health problem and make informed decisions.

The second criterion was related to SMEs heterogeneity, mainly emphasizing the diversity in SMEs skills and expertise. As explained earlier, wicked health problems are multifaceted problems that largely depend on experts' expertise and skills to evaluate the multiple contributing elements in order to reach an agreeable decision. Participants with different levels of expertise look at the problem with different background and perspectives and therefore may visualize the solution and approach it differently. The diversity of participants' skills and expertise was essential to ensure a wider coverage of information and perspectives about the analytical problem and ultimately improved decision-making. Participating injury stakeholders had diverse expertise and job titles, including:

- Trauma Surgeon
- Injury Prevention Program Leader
- Principal Investigator of a national injury prevention research team
- Injury Research Unit Director
- Child Death Review Unit Representative
- Injury Research Unit Clinical Faculty
- Child Health BC Representative

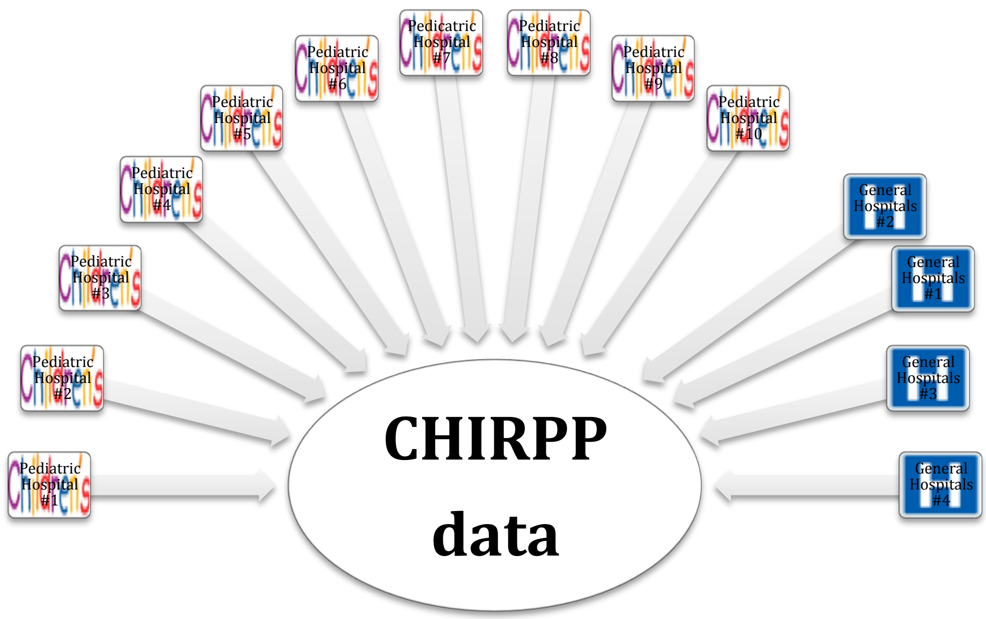
The third criterion was related to SMEs representativeness. To ensure representativeness, participating injury stakeholders included injury prevention practitioners, researchers, kinesiologists, epidemiologists, medical and health professionals as well as public health policy makers. As it was costly to include a large number of local and national injury stakeholders, each SME was purposefully selected based on his/her credibility and position to represent constituent peers in their fields within the public health sector. To comprehensively explore the concept and investigate the multiple perspectives, representative injury stakeholders who matched the required criteria were selected to take part in this study in order to gather rich data and uncover the breadth and depth of the injury concept under investigation.

After consultation with key injury stakeholders at the BC Injury and Research Prevention Unit (BCIRPU), we selected eight injury stakeholders to take part in this research study. We limited the number of participants to the minimum needed to conduct a modified Delphi structured group session. Based on a review of the literature, a small panel of participants in a Delphi session can generate good results [Alder & Ziglio, 1996]. Delbecq et al (1975) argued that in a Delphi approach, the number of participants should be limited to the minimum and sufficient number that should be included in the study [Delbecq et al., 1975]. A subsequent exploration process should follow up to validate the results generated form the Delphi process [Hsu & Sandford, 2007]. Furthermore, social psychologists Hackman & Morris (1976) indicated that as the number of group members grows, the group suffers from ‘coordination decrement’. They explained that the larger the group, the less coordination is established among group members, which negatively affect their task performance [Hackman & Morris, 1976]. In the context of this study, participating stakeholders were selected to represent their constituent peers. They were experts and interested injury prevention stakeholders with adequate knowledge regarding injury and injury prevention. They included representatives from provincial and national injury prevention organizations. In order to meet the generalizability needs of this study, only participants who matched the required criteria were selected to join in the study. The selected injury stakeholders came from diverse backgrounds and represented differing levels of expertise and knowledge. Each SME interacted with the analytical dashboard and as a member of the collaborative depending upon their experience, needs and goals.

6.5. CHIRPP Data

We used the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) database to retrieved data for this research study. CHIRPP is a computerized information system that collects and analyzes data on injuries to people, mainly children who are seen at the emergency rooms of the 10 paediatric hospitals and of 4 general hospitals in Canada (Fig.6.3). CHIRPP is a unique, richly detailed database of "pre-event" injury information obtained by asking: What was the injured person doing when the injury happened? What went wrong? Where did the injury occur? [CHIRPP, 2009]. The CHIRPP data were uploaded into the *i*AID dashboard to conduct the analytics sessions.

Figure 6.3. Data: Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP)



A pre-conceived set of indicators was used to collect injury data and populate the CHIRPP database. In previous work by Pike et al. (2010), injury stakeholders conceived a set of 34 injury indicators for Canadian children and youth through the use of a modified Delphi method process. These injury indicators were developed according to previous international criteria and standards and represent a means to standardize the understanding of injury among children and youth in Canada [Pike e al, 2010]. The pre-set indicators were grouped into 5 areas:

1. Overall Health Services Implications.
2. Motor Vehicle Injury.
3. Sports, Recreation and Leisure Injury.
4. Violence.
5. Trauma Care, Quality and Outcomes.

For the purposes of this research study, we retrieved CHIRPP data for the province of British Columbia (BC) for the period 2007-2010 from the Public Health Agency of Canada (PHAC). The data represented child and youth (0-19 years of age) injury cases that visited the BC Children's Hospital emergency department for treatment following an injury. These data were collected on all patients requiring treatment for injury with the purpose to inform child and youth injury prevention initiatives in BC. The preconceived injury indicators' data were uploaded to the interactive *i*AID dashboard for testing within the context of problem solving and decision-making. The *i*AID dashboard visually represented summative information for these injury indicators. The *i*AID dashboard provided vital information with real content to improve stakeholders' ability to monitor the health (injury) status of children and youth, assess health system performance in treating and preventing injury, and ultimately to assist them with decisions and actions.

A "Data confidentiality Agreement" between BCIRPU and PHAC was signed to permit access to the CHIRPP injury database in order to upload the data into the designed *i*AID dashboard and test it with real injury stakeholders. Data was de-identified to preserve patients' privacy and confidentiality, and injury classes with fewer than five cases were not disclosed in the *i*AID dashboard in order to safeguard patients' identities. The study was approved by the University of British Columbia (UBC) research ethics board.

In preparation for the analytical sessions, the CHIRPP dataset were cleaned and arranged to support the analysis process and match the requirement of the proposed task. Prior to the Paired- and Group-Analytics sessions, the CHIRPP data was prepared and loaded into the designed *i*AID dashboard. In addition to the traditional data cleaning process, a decision was made about the relevant dimensions and data variables that needed to be connected to the *i*AID dashboard. The researcher and key injury stakeholders thoroughly parsed the large CHIRPP files and reduced the number of columns of data to twelve of the most important data dimensions and linked them to the CHIRPP dashboard. We ensured the inclusion of fields that were relevant to the analytical task such as injury type, injury causes, injury sub-causes, injury location, injury intent as well as age group and gender.

6.6. Analytical Task

Selecting suitable tasks that simulated real domain tasks was essential to test the design and the functionality of the *i*AID dashboard with real injury stakeholders. Before selecting appropriate tasks for this study, it was fundamental to understand domain tasks and goals [Hackos & Redish, 1998]. As the *i*AID dashboard was designed for use by healthcare professionals within the injury prevention program, it should integrate functionalities and features that empower injury stakeholders to efficiently support their analytical tasks.

The objective of the Paired and Group analysis sessions is twofold. First, it allowed us to learn how SMEs use the *i*AID dashboard to effectively accomplish their tasks so as to refine the design of the tool to better support SMEs tasks. Secondly, it enabled us to capture how multiple SMEs collaboratively use the iAID dashboard to solve the analytical task and make informed decisions.

The researcher met with key injury stakeholders at BCIRPU to brainstorm ideas about the various scenarios that could be used to design the analytical tasks. For the Paired analysis sessions, we decided to ask each of the participating injury stakeholders to choose an injury scenario that was particularly relevant to his/her current domain work. The rationale for selecting to conduct this open-scenario approach during the Paired sessions was that SMEs had diverse expertise and breadth of understanding. Therefore, choosing their domain relevant analytical task to work on would provide us with the information that we needed as to whether the *i*AID dashboard was relevant and valuable to the SMEs analytical work.

For the Group analysis sessions, the researcher worked with key injury stakeholders to design two analytical tasks that enabled this author to empirically evaluate the collaborative visual analytics process and its impact on problem solving and decision-making using the *i*AID dashboard. The following task properties were selected as the main criteria for choosing the sessions' analytical tasks:

- The task should be a real life analytical task that could be solved using the available real CHIRPP data.

- The task could be solved in the allocated 30-minute time period for each session.
- The task assumed particular SME's background injury knowledge and expertise that a novice user would not possess. As a result, the task required the use of SMEs prior knowledge to address the analytical problem.
- The task should initiate conversation, engage interactions, and negotiate back and forth discussions among group members.
- The analytical tasks should be tightly aligned to the research question and have the potential to provide insights into the collaborative visual analytics process.

Following a series of discussions with key injury stakeholders, we decided on the analytical tasks in the form of two scenarios to be presented to injury stakeholders during the two separate Group analysis sessions. The two scenarios were:

> **Scenarios #1:** You have been brought together as injury prevention experts for the province. Your task is to inform the development of a targeted intervention that will reduce child/youth injuries presenting to BC Children's Hospital.

This task was of an exploratory nature. It required SMEs to explore the CHIRPP database and to become familiar with the numerous functionalities of the *i*AID dashboard. This exploratory analytical task entailed the use of the CHIRPP data to retrieve information required to complete the analytical task at hand. Injury stakeholders needed to interactively use the *i*AID dashboard to seek information through an iterative search process based upon their specific individual or group needs.

> **Scenario #2:** *Nutcase* wants to promote their brand of sport helmets by giving 1000 helmets to the BC Children's Hospital. Use the *i*AID to guide the development a helmet distribution strategy to prevent both concussion and head injuries.

This task is of a problem solving and decision-making oriented task. This analytical task was carefully designed to trigger discussion, argumentation and collaboration among injury stakeholders. The main goal of this task was to initiate the exchange of knowledge and expertise, as well as social engagement through conversations and human-to-human dialogue among SMEs to approach the problem solving process and reach informed decisions.

6.7. Equipment and Room Setting

We selected equipment and arranged the workshop room to meet the requirements of the analytical sessions and enable us to capture and record the details of SMEs verbal and non-verbal communications. Based on lessons learned from our previous pilot study, we paid particular attention to the placement of different video- and audio-recording equipment throughout the room so as to efficiently record the details of the interactions among SMEs, and with their environment, in a natural setting. Reliable video- and audio-recording of the analytics sessions was vital in order to capture and analyze SMEs cognitive and analytical reasoning process during their task performance. A video camera was set up to record SMEs movement and gestures when interacting with the visualization tool and with each other. We recorded session audio using voice recorders. To ensure efficient recording of SMEs verbal communication, we utilized multiple pieces of audio-recording equipment so as to capture SMEs voices and utterances with greater clarity and precision. All equipment was either used during the pilot test, prior to the actual study, in order that we were completely familiar with the device and its functions. These equipment devices included:

1. 4-Channel wireless microphone.
2. In-built camera microphone.
3. iPhone audio recorder.

The 4- channel audio-recording device was placed at the center of the meeting table in order to record SMEs voices from four different directions. Since some interactions and gestures could not be evaluated as relevant during the course of the analytical sessions, the audio- and video-recording provided valuable inputs for later analysis of the collaborative visual analytics process.

To complement the video- and audio-recording data, we collected screen captures of the graphical representations that best suited SMEs domain tasks and which helped to facilitate their performance. A screen capturing software called Camtasia was used to capture interactions between SMEs and the *i*AID dashboard interface and visualizations. Screen captures pertaining to the interactions with the *i*AID dashboard when solving the analytical task were matched with SMEs discourse and non-verbal gestures for insight and knowledge regarding the impact of the collaborative visual analytics on facilitating the problem solving and decision-making process.

6.8. Data Collection Procedure

The data collection process was conducted using two methodologies: the Paired Analytics (PA) methodology and the Group Analytics (GA) methodology. The PA methodology entailed the collection of qualitative data as well as individual inputs from injury stakeholders about the interface design of the dashboard visualization tool. The PA methodology mainly focused on the collection of data related to the design, layout and functionality of the dashboard. Collected inputs from the PA sessions served to inform the design of the *i*AID dashboard interface and to reflect the domain-task needs and preferences. The Group Analytics methodology was designed to integrate the *i*AID dashboard into SMEs analytical tasks and observe how SMEs functionally used the dashboard features and interface to facilitate their collaborative work. The Group analysis sessions focused primarily on the application and the functionality of the dashboard layout and how SMEs used the dashboard in an applied way to facilitate problem solving and support decision-making. Both sessions provided us with comprehensive data and enable us to obtain insights into how the *i*AID dashboard functioned in a real life health (injury) problem and how multiple SMEs could come together to dynamically use this tool and collaboratively address the injury problem.

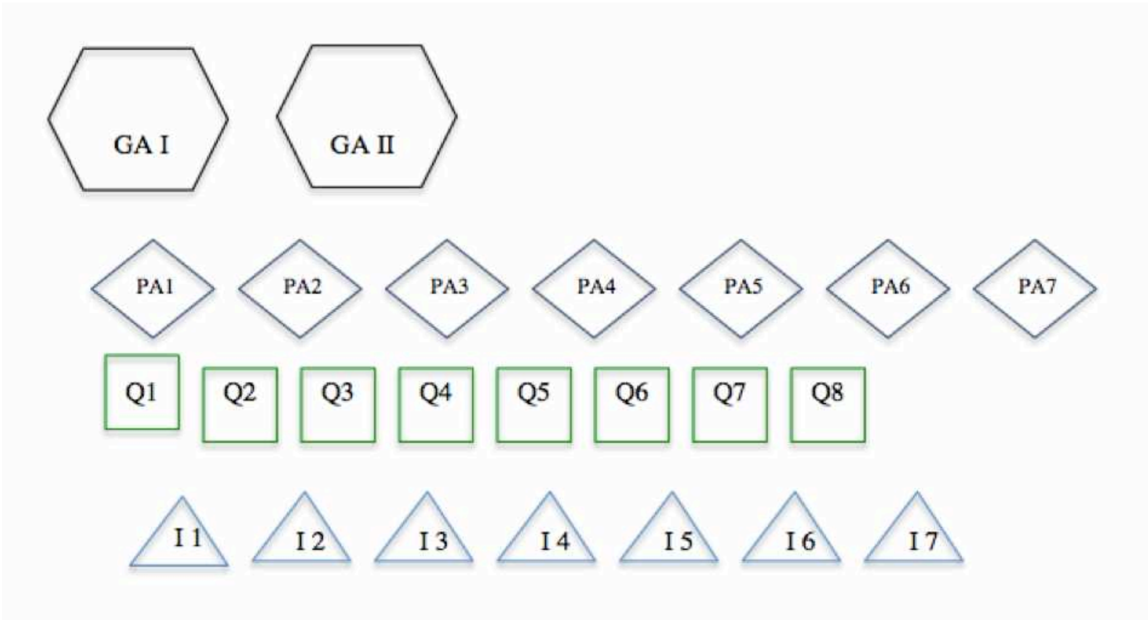
We decided to conduct the Paired analysis and the Group analysis sessions in the form of a one-day workshop. The lead of the CIHR Team in Child and Youth Injury Prevention and BC Injury Research and Prevention Unit (BCIRPU) invited selected local and national injury stakeholders to attend a one-day workshop meeting entitled, '*Child and Youth Injury Dashboard using BC CHIRPP data'* on March 21, 2013 at the BC Children's Hospital in Vancouver. The team at BCIRPU including key injury stakeholders, the project coordinator and the study researcher discussed and coordinated the time and location of the workshop. In addition, they planned and organized the workshop Agenda to include two Group analysis sessions and seven separate paired analysis (PA) sessions. The BCIRPU team also decided to host the workshop at the BC Children's Hospital in Vancouver as the location represented a focal point and central place for many local and national injury prevention stakeholders to meet and discuss child and youth injury prevention programs. Funding for this event was vital to cover travel expenses for attending injury stakeholders as well as to cover the workshop expenditures.

Planning and organizing the workshop was a labour-intensive process. We realized the challenge of incorporating such an event into the busy schedule of key injury stakeholders who were pressed with time and work commitments. In order to ensure a successful event and a smooth data collection procedure, we planned the workshop four to five months in advance of the actual event date. Email invitations were sent to participants along with the study consent forms. Injury stakeholders confirmed their attendance through emails along with their signed and authorized consent forms. SMEs who didn't email their signed form were asked to sign a consent form at the workshop prior to participating in the study. Consent forms were compiled to complete the ethics requirements of the study.

The majority of the participants were motivated to be part of this study as it provided them the opportunity to contribute and decide on the features and functionalities of the final version of the *i*AID dashboard. Injury stakeholders had notable incentive to participate; they were willing to commit time and effort to provide input on the *i*AID dashboard, as it was seen by them to be beneficial and directly related to their domain work.

During the workshop, The Group analysis sessions proceeded the Pair Analytics sessions. Each Group analysis session lasted approximately 30 minutes while each PA session lasted between 10 to 20 minutes each. Participants' ages ranged from 25 to 54 years old. Eight injury stakeholders participated in the two Group analysis sessions (37% male and 63% female). Seven stakeholders agreed to participate in the follow up Pair Analytics sessions. All participating injury stakeholders completed the feedback questionnaires. A few weeks after the workshop, we conducted follow up interviews with seven stakeholders. The data collection procedure was as follows: two Group analysis sessions, seven paired analysis sessions, eight Questionnaires (Q) and seven follow up Interviews (I):

Figure 6.4. Study Design: GA, PA, Questionnaires and Interviews



We used various methods to collect data including ethnographic techniques (e.g. stakeholders' observations, questionnaires and follow up interviews of the focus group). We supplemented these ethnographic techniques with video- and audio-recordings of the sessions as well as screen capturing of the analysts' interactions with the *i*AID dashboard in an attempt to capture all of the details of the process. These adopted techniques provided the researcher and the tool designer with detailed and rich descriptions of SMEs collaborative interaction with the tool interface within the context of solving the analytical task and making a decision.

Integrating multiple strategies to collect data produces consistent and more reliable results. As discussed earlier, data triangulation enhances the accuracy of findings through the integration of multiple sources of data collection [Mathison, 1988]. Collecting data from multiple sources confirms the study findings, enhances the confidence in the generated results as well as increases the study generalizability.

During the Paired and Group analysis sessions, the author/researcher observed injury stakeholders and took ethnographic field notes in order to capture the analysts' interactions that were not articulated through conversations and dialogues.

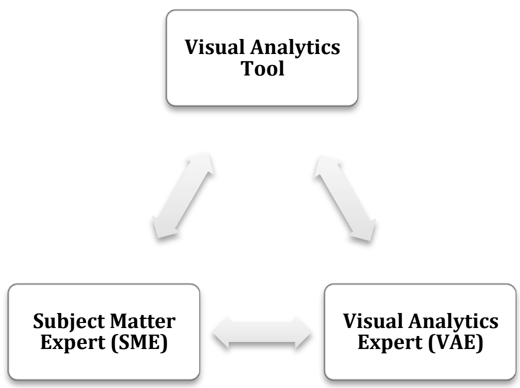
Ethnographic observations are defined as 'the systematic description of events, behaviours, and artefacts in the social setting chosen for study' [Marshall & Rossman, 1989]. Ethnographic methods are essential to accurately describe and analyze the natural setting of the analysis sessions in order to provide a complete picture of the analytical task carried out [Schneiderman & Plaisant, 2006]. We adopted the ethnographic techniques to provide us with detailed description and rich understanding of participants' social and collaborative behaviours when approaching the problem solving using the *i*AID dashboard. Observing group behaviours and interactions of the analysts during the analytics sessions provides the context for understanding the explored phenomena and therefore increases the study validity [DeWalt et al., 2002]. Understanding how group members work and interact together using the tool is essential to decide on the tool features and functionalities. In a study conducted by Microsoft Research, Morris and Teevan (2009) studied the various properties of group members to inform the design of collaborative search systems. The authors emphasized the importance of understanding properties and similarities among members of a group in order to improve the interface design of collaborative systems as well as to enhance the group collaborative experience [Morri & Teevan, 2009].

Analyses of the observations were conducted at a later stage when the researcher was not immersed in the fieldwork. Later analysis of the observations and field notes enabled the researcher to understand SMEs reactions to the data visualizations and detect patterns in their behaviours and performances. The collected field notes, questionnaires and follow up interviews helped the researcher to understand SMEs group reasoning and analytical approaches to problem solving and decision-making. Furthermore, these ethnographic techniques helped to elicit SMEs preferences and provided insight into the design of interactive visualization tools that integrated domain experts' needs and work requirements.

6.8.1. Paired Analytics Methodology (PA)

The Pair Analytics methodology is an approach that relies on the collaboration of two analysts to reach the intended analytical goal using a specific visualization tool [Arias-Hernandez et al., 2011]. Paired Analytics draws from cognitive science theories [Hutchins, 1995] and the "extreme programming" technique, in which two programmers work together on a single workstation and collaborate to develop computer software [Beck et al., 2004]. The Paired Analytics approach integrates the collaborative efforts of two analysts working side-by-side to solve the analytical task under investigation using a specific visualization tool. As shown in Fig 6.5, the Paired analysis (PA) session involves the collaboration and interaction between two main players: A) the Visual Analytics Expert (VAE), and B) the Subject Matter Expert (SME). The VAE, with abstract analytical training, is expert in conducting analysis using various visualization tools and techniques while the SME is expert in the subject matter and possesses the contextual knowledge needed to efficiently conduct the analysis. The VAE and the SME work together in a one-on-one pair setting to explore a specific dataset and solve a given analytical problem using a single visualization tool.

Figure 6.5. Paired Analytics Methodology



In a previous study by Arias-Hernandez et al. (2011), the Paired Analytics methodology was explored to capture and understand the collaboration of two analysts to solve a given analytical task using a Visual Analytics tool. According to the authors, the Paired Analytics methodology offered additional benefits compared to other methods including the ability to record the explicitly articulated SME-VAE reasoning approach in a naturalistic setting as well as to gain understanding of the cognitive and social aspects of the SME-VAE collaborative process [Arias-Hernandez et al., 2011]. We adopted the Pair Analytics methodology as a useful framework that enabled us to collect verbal and non-verbal qualitative data about SME and VAE's interaction and collaboration to solve the analytical task at hand. Within the context of this study, the paired analysis sessions fostered a real-life collaborative environment between the SME and the VAE and enabled us to capture their explicit exchange of ideas and thoughts about how to approach the analytical problem using the available functions and features of the *i*AID dashboard.

We conducted seven Paired analysis sessions during the workshop. In this study, the Visual Analytics Expert (VAE) was an analyst knowledgeable about various visualization tools and techniques, while the Subject Matter Expert (SME), was a public health professional that possesses knowledge, skills and expertise in the field of injury prevention. In each PA session, VAE collaborated with SME to work on a domain specific analytical task using the iAID dashboard tool. The VAE and the SME worked collaboratively in a one-on-one pair setting to explore the available CHIRPP data and to attempt to solve the analytical problem using the interactive *i*AID dashboard. We mainly focused on how SMEs exploited the features, interface and functionalities of the *i*AID dashboard to effectively solve their analytical tasks.

In the Paired analysis session, SME and VAE were sitting next to each other facing the laptop where the *i*AID dashboard was displayed. As shown in Fig 6.6, the video camera was mounted facing the SME to capture all the interaction details including facial gestures and finger pointing at the laptop screen. A 4-Channel wireless microphone was placed on the tabletop to record the verbal conversation that took place between SME and VAE throughout the session.

Figure 6.6. PA: Room Setting and Equipment.

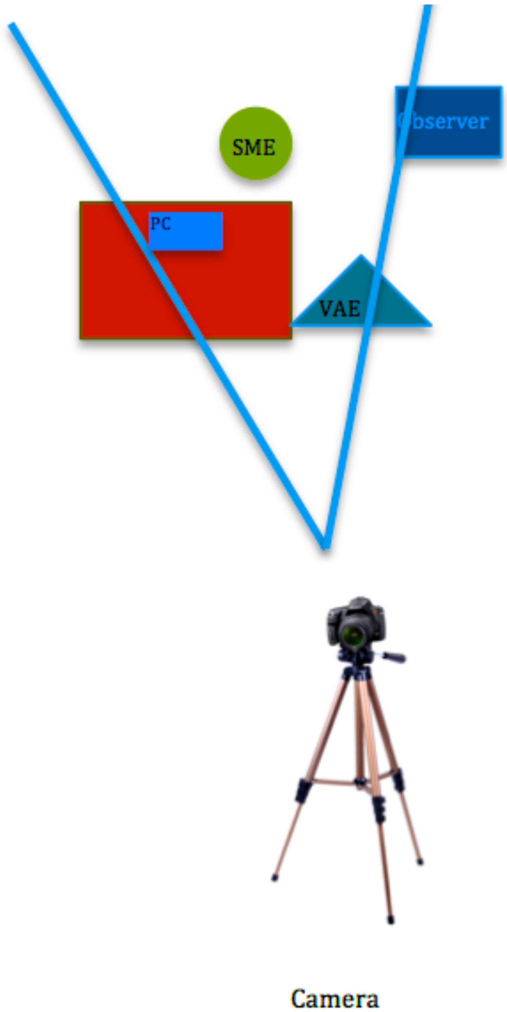


Figure 6.7. PA: SME-VAE Verbal communication.

The Paired analysis sessions allowed us to effectively capture SMEs adopted cognitive and reasoning approaches to solve the analytical task using the visualization tool. During the PA session, VAE assisted SMEs in operating the *i*AID dashboard and managed the visualizations based upon their needs and preferences. According to Lui & Stasko (2010), interacting with the *i*AID dashboard was essential to amplify analysts' cognitive and reasoning capabilities by facilitating the creation of accurate mental models [Lui & Stasko, 2010]. Mental models provide a theoretical framework for reasoning, understanding and making sense of information derived from original datasets. They represent the "lens" through which humans judge events and situations and make decisions; they shape the way human perceive and process information [Heuer, 1999].

As shown in figure 6.7, the setting of the PA sessions promoted a communicative environment that facilitated the exchange of knowledge through back and forth dialogues between the SME and VAE. The use of language through SME and VAE one-on-one dialogues and conversations was important to enable the two analysts to share and exchange their tacit knowledge and consequently build a comprehensive knowledge about the given cognitive task [Arias-Hernandez et al., 2011]. Exchanging knowledge and expertise enhanced both analysts' domain knowledge and enabled them to more efficiently solve the analytical task and reach informed decisions [Fischer et al, 2002].

The PA methodology fostered a dialogue environment for SME and VAE to discuss the various approaches to problem solving, the use of the dashboard interface to address the problem as well as the design of the dashboard to serve SMEs needs.

During the PA sessions, SME and VAE communicated using the 'think aloud' approach derived from the protocol analysis [Ericsson & Simon, 1993]. The 'think aloud' approach represents a fundamental technique adopted by SME and VAE in their collaborative work. It helps the VAE to understand SMEs needs and to act upon them. It also helps SMEs to learn about the tool functionalities and various features and how they can customize the visualizations to best reflect domain experts' needs and preferences. This 'think aloud' environment explicitly shows the knowledge transfer between SME and VAE and the knowledge building process occurring throughout the analytical sessions. We observed and recorded this 'think aloud' approach throughout the analytical sessions to gain an in-depth understanding of the steps taken by SMEs to approach the problem using the *i*AID dashboard features and functionalities.

The Paired analysis sessions were video- and audio-recorded to capture verbal and non-verbal communication between VAE and SMEs throughout the analytical reasoning process. We also collected screen captures of the interaction with the visualization to solve SME's analytical task. Furthermore, the researcher and author of this thesis observed the Paired analysis sessions and took field notes.

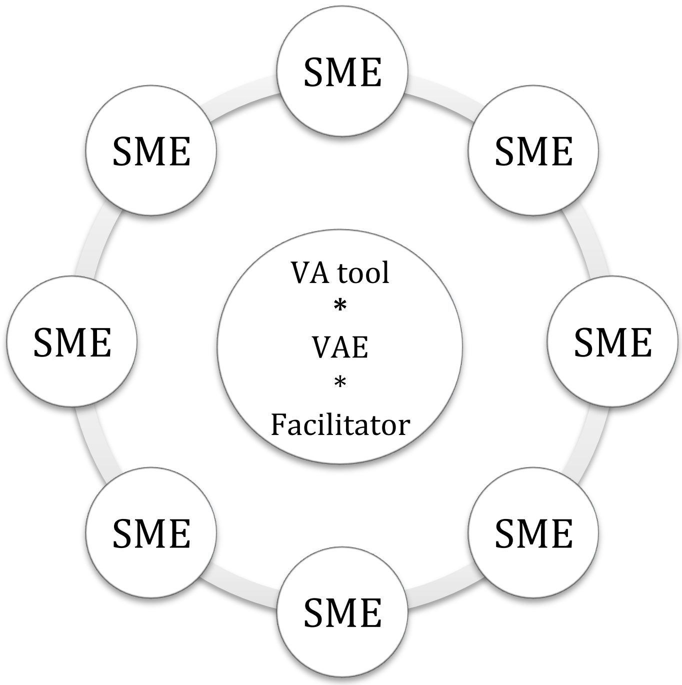
6.8.2 Group Analytics Methodology (GA)

As explained earlier, public health problems are categorized as ill-structured and wicked problems due to their multifaceted, multidimensional and complex nature. Ample number of methods have been developed and adopted to address and solve 'wicked problems'. Earlier in the study, we presented in details the IBIS and the Compendium methodology offered by Kirschner et al (2003) as argumentative methodologies to address wicked problems. In this study, we realized that solving wicked health problems entailed the integration of a methodology that included knowledgeable experts with different skills and expertise along with advanced tools and techniques to support the analytical problem solving process in a collaborative co-located setting. According to Adler and Ziglio (1996), solving public health problems requires the integration of “creative and judgmental” approaches due to the multidimensional aspects of these problems. We needed to design a methodology that provided SMEs with a suitable platform to pool their diverse knowledge and judgment within a structured social setting to discuss the nature of the wicked health problem, examine its underpinning factors as well as evaluate its social and environmental effects to make informed decisions. Our research study focused on the design of a new methodologies that would foster a collaborative environment to socially engage multiple stakeholders in an argumentative and informal reasoning approach to problem solving, similarly to the IBIS and Compendium methodologies [Kirschner, Shum & Carr, 2003]. We adapted these two existing methodologies to fit the context of public health wicked problems. As a more structured approach was needed to suit the requirement of our research study, we borrowed from the Paired Analytics methodology and took advantage of the structured collaborative and social approaches of the modified Delphi method to design and develop a new methodology. Consequently, we developed a newly designed methodology that we termed the ‘Group Analytics’ methodology. The new methodology enabled us to concretely capture the collaborative process of multiple expert stakeholders guided by a skilled facilitator and using the designed *i*AID visualization tool to solve wicked health problems and make decisions.

6.8.2.1. Group Analytics: A collaborative Analytical Delphi Approach

We suggested the proposed ‘Group Analytics’ methodology as a method for studying the collaborative and social aspects of visual analytics and their impact on facilitating problem solving and supporting decision-making of multiple stakeholders within the context of wicked health problems. The proposed Group Analytics (GA) methodology builds upon and advances the Paired Analytics methodology proposed by Arias-Hernandez et al. (2011). The Group Analytics methodology extends the Paired Analytics methodology to incorporate multiple Subject Matter Experts (SMEs) that interact with each other and with the VAE in a co-located social setting to solve a given analytical task using a selected Visual Analytics tool that matches the requirement of the dataset (Fig 6.8).

Figure 6.8. Group Analytics Methodology.



In addition to the IBIS and Compendium frameworks [Kirschner, Shum & Carr, 2003], we borrowed approaches from the Delphi method [Linstone & Turoff, 2002; Adler & Ziglio, 1996; Okoli et al., 2004] and the face-to-face group interaction techniques [Hiltz, Johnson & Turoff, 1986; Dubrovsky et al; 1991] to expand the Paired Analytics methodology [Arias-Hernandez et al, 2011] and to inform the design of the Group Analytics (GA) methodology. As a result, the proposed GA methodology is considered a '*Collaborative Analytical Delphi methodology*'. As previously discussed, we used the modified Analytical Delphi method as a pragmatic approach to design the Group Analytics methodology and to structure the Group analysis sessions. The Analytical Delphi method represents the foundation for the Group Analytics methodological framework; it is an effective approach for handling collaborative group work and dealing with unstructured wicked health problems that require iterative argumentative approaches. The Analytical Delphi approach is a particularly useful framework to empirically evaluate and capture the impact of collaborative Visual Analytics on problem solving and decision-making within the context of public health wicked problems. The characteristics of the Analytical Delphi structured approach help us to explore how multiple SMEs coordinate their activities and synthesize their subjective judgments to reach a solution and solve the analytical task while eliminating opinions predominance.

The Group Analytics methodology involved the co-located collaboration of multiple Subject Matter Experts (SMEs) with one Visual Analytics Expert (VAE) to solve a given analytical task using a specific visualization tool. The visualization tool acted as a single display groupware that was accessible to all SMEs in order to amplify their cognitive capabilities, enhance their collaboration and increase their ability to solve the given analytical problem. Within the context of this study, SMEs were injury stakeholders with diverse backgrounds, expertise and knowledge; they collaborated and worked together with the VAE to solve a defined analytical task using the *i*AID dashboard visualizations as a single common visual display. The GA sessions involved a skilled facilitator whose role it was to mediate the Group sessions. The facilitator was knowledgeable about the project and the data collection procedure. The main duty of the facilitator was to ensure that participants kept working and made progress on the given analytical task as well as limit their task time to the allocated 30 minutes per session. The session facilitator played a major role in mediating stakeholders' discussions and argument, and helped SMEs discussion to stay on track in an effort to converge on a solution.

6.8.2.2 Group analysis Room Setting

The Group analysis sessions involved a co-located collaboration process where multiple injury stakeholders placed a single visual display at the center and used it as a reference object or evidence to mediate their activities, conversation, discussions and argumentation. As shown in Fig 6.9, the room setting in the Group Analysis sessions was arranged in a way that facilitated social collaboration among group members. A large rectangular table was placed in the middle of the room in order to facilitate a group meeting. An augmented projection mounted on the wall faced all participating SMEs to allow them to synchronously access the interactive information and observe at once manipulations of the CHIRPP data to generate customized visualizations. The video camera was placed in a central position to clearly and efficiently capture verbal and non-verbal communications among participants including gestures, screen pointing, facial expressions, etc. A wireless 4-Channel microphone was placed in the middle of the table to capture SMEs conversation from all directions within the meeting room.

Figure 6.9. GA: Room Setting and Equipment.

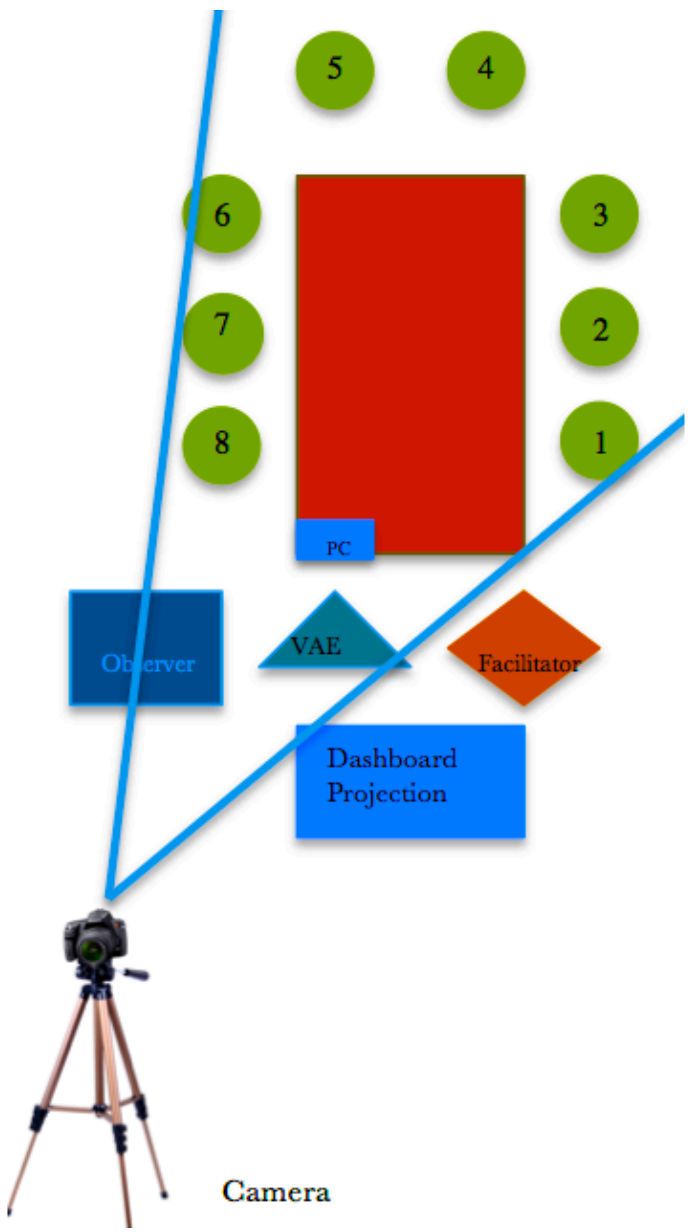


Figure 6.10. GA: Room Setting, Visualization Tool, Wireless Microphone, Video Camera.

The GA sessions were fundamental to initiate a co-located collaboration between SMEs with VAE. As shown in Fig 6.10, we designed the setting of the GA sessions to promote mutual cooperation and coordination of efforts among SMEs to explore the CHIRPP data through the interactive manipulation of the *i*AID dashboard. Furthermore, the setting of the GA sessions helped to initiate dialogue and conversation among SMEs. The flow of dialogue among SMEs and VAE allowed us to capture the explicitly expressed cognitive and reasoning process among analysts during the collaboration Visual Analytics process.

6.8.2.3. Group analysis Sessions

To design and structure the Group analysis sessions, we combined existing methods, mainly from the Delphi approach, the face-to-face group interaction techniques and the Paired Analytics methodology. We asked participating injury stakeholders in each Group analysis session to gather around a conference room table, in a natural work environment setting, while the Visual Analytics Expert manipulated the data visualizations using the common display of the interactive dashboard. In this environment of technology-involved communication, we created this empirical setting where injury stakeholders collaboratively worked on a realistic analytical task to reach a consensus and make informed decisions. The setting and the nature of the analytical task elicited a wide range of collaboration and interactions among stakeholders. The goal of the Group analysis sessions was to stimulate interactions among SMEs and to encourage the collaboration and exchange of stakeholders' knowledge and expertise in an attempt to pool creative and trustworthy inputs and judgments and ultimately solve the complex analytical task. Stakeholders needed to rely on multiple cognitive capabilities including other group members, the visualization tool and the environment to gather accurate and reliable information and build a comprehensive picture of the injury situation.

At the beginning of the analytics sessions, participants were given verbal instructions regarding the workshop agenda and expectations. At the beginning of the analytical sessions, participants were asked to provide information about their background, experience and research interests. They were also asked to explain their work projects in injury prevention and how the tool might help them to address existing injury issues and make informed decisions. The Visual Analytics Expert (VAE) provided SMEs with an overview tutorial of the *i*AID dashboard and explained its features and functionalities. SMEs were familiar with the CHIRPP data as they had all previously interacted with the data via an interactive web-based tool, The Injury Data Online Tool (*i*DOT) (www.injuryresearch.bc,ca) to perform data analysis and to generate descriptive data charts, tables and maps.

At the beginning of each Group analysis session, the facilitator presented SMEs with one pre-conceived scenario and solicited their opinions, thoughts and ideas about the analytical tasks. After reading the scenario to participating injury stakeholders, the facilitator invited them to discuss, share their views and inputs, and to address the issue with the help of the Visual Analytics Expert (VAE) and the *i*AID dashboard.

The Group Analytic sessions were audio- and video-recorded. This author served as the observer. She took notes and documented SMEs interactions with each other, with the VAE, with the *i*AID tool as well as with the facilitator. We used the ethnographic method to supplement the video- and audio-recording methods in order to effectively document the interactions and flow of conversation between SMEs and VAE as well as to explicitly articulate SMEs analytical reasoning process in a naturalistic group setting. Screenshots were also collected using Camtasia software to capture SMEs interactions with the *i*AID dashboard. Combining video- and audio-recording with screen captures and field notes increased confidence in the session findings and enhanced the validity of the study.

6.8.2.4. Group Analysis Process

The Group Analytics was designed to provide us the opportunity to collect rich qualitative and quantitative data regarding the investigated phenomena. We adopted various methods to gather the data including ethnographic techniques such as SMEs observations, questionnaires and follow up interviews. We also video- and audio-recorded the Group sessions in order to capture all of the details of the co-presence interactions and gestures among SMEs. Prior to starting the sessions, participants were given verbal instructions about the workshop agenda and expectations. The Group Analytics methodology encompasses the following four phases:

Phase I: Qualitative data was collected in the form of field notes, video and audio recordings as well as screen captures taken throughout SMEs interactions with the *i*AID dashboard.

Phase II: Qualitative data was collected in the form of field notes, video and audio recordings as well as screen captures taken throughout SMEs interactions with the *i*AID dashboard.

Phase III: Quantitative data was collected in the form of semi-structured questionnaires.

Phases IV: Qualitative data was collected in the form of follow up interviews to emphasize important concepts and inputs drawn from preliminary analysis of early phases of data collection.

Phase I: Exploratory and Knowledge Discovery

At the beginning of this phase, the facilitator presented SMEs with the first analytical task and reminded them of the session's allocated timeframe. The first analytical task was of an exploratory and knowledge discovery nature. The main objective of the session was to observe SMEs exploratory process of the CHIRPP data and the *i*AID dashboard as well as the emergence of *Common Ground* among multiple stakeholders [Clark, 1996].

At the beginning of this exploratory and discovery phase, SMEs explored their social settings and their roles as members of the group. As the session progressed, SMEs started to communicate with each other within this structured social setting; they interacted with each other through back and forth conversations and a series of questions and answers. This exploratory session served to capture the emergence of *Common Ground* among SMEs, which was essential for coordinating their actions and collaborating their activities to reach a consensus about the addressed health issue [Clark, 1996]. With the support of the VAE, SMEs started to manipulate the *i*AID dashboard and to interactively explore the CHIRPP data. Interacting with the visualization tool was intended to facilitate SMEs brainstorming and knowledge discovery process. These interactions were important milestones that enabled SMEs to exchange knowledge and expertise in order to 'identify variables of interest' in the data, 'explore issues that require judgment', as well as 'generate propositions' [Gordon, 1994]. These interactions were essential to help SMEs discover trends and patterns in the data and to identify relevant data elements and factors in order to formulate their opinions that could dramatically contribute to the problem solving and decision-making process.

During this exploratory and discovery phase, we observed how SME explored the social setting, the *i*AID features and functionalities and the CHIRPP data. The session was audio- and video-recorded to capture the emergence of *Common Ground* and the collaboration among SMEs to reach a level of equitable understanding about each other, the CHIRPP data, the visualization tool as well as the retrieved information from the visual display.

Phase II: Problem Solving and Decision-Making

In this phase, we exploited SMEs *Common Ground* asserted during the exploratory and discovery phase to advance SMEs collaboration and joint activities. At the beginning of this session, the facilitator explained the second analytical task to SMEs and helped to steer the session and ensure that SMEs kept working and made progress on the given analytical task as well as limited their time to the allocated 30-minute. This analytical task required SMEs to solve the presented health problem and make an informed decision about possible health interventions.

The structured session gave SMEs the opportunity to engage in conversations, share their personal experience and discuss their viewpoints in a natural collaborative setting to solve the analytical health problem and make informed decisions. Throughout the session, SMEs tended to brainstorm ideas and viewpoints on how to approach the solution and identified the 'targeted population'. They explored and discussed various approaches to problem solving as well as presented and argued their numerous thoughts and opinions. SMEs showed high-task engagement and a motivation to collaborate and solve the problem.

Through an iterative process, SMEs sought answers from the CHIRPP data by manipulating the data and refining the visualizations in order to understand the underpinning elements that contributed to the public health issue and to gain insights into the solution. VAE manipulated the data based upon SMEs requests and retrieved information that was relevant to advance SMEs analytical task. The *i*AID provided SMEs with basic visualizations such as time trends and geographic distribution of injuries. It also provided more sophisticated functionalities and features such as brushing and linking techniques to explore the data and drill down for further levels of granularities. VAE helped the group to establish a common understanding of the visual display and to accurately interpret the data. VAE played a substantial role in helping the group answer their questions and get the big picture and the detailed understanding of the injury data.

Video, audio and screenshots were collected to capture SMEs interactions with the visualization tool to support the data analysis process. This problem-solving and decision-making phase enabled us to observe various types of collaboration that took place during the problem solving and decision-making process. It provided us with rich data about the dynamics of the group collaboration process and its impact on problem solving and decision-making.

Phase III: Feedback Questionnaire

Upon completion of the '*Problem Solving and Decision-Making*' phase, quantitative data were collected using a semi-structured paper and pencil questionnaire. The objective of the questionnaire was to solicit stakeholders' feedback in an anonymous way regarding the functionality of the *i*AID dashboard and its potential to help injury stakeholders generate insights, build knowledge and coordinate their cognitive efforts to solve problems and to make informed decision. The semi-structured questionnaire allowed injury stakeholders to completely and honestly provide their individual feedback on their experience interacting with the *i*AID dashboard in the Paired and Group analysis sessions to solve the analytical problem. The self-reported questionnaire consisted of a 20 rating questions and 3 open-ended questions. To enhance the questionnaire scale's reliability, we adopted a 7-point Likert-type scale (i.e. 1- Strongly Agree, 7- Strongly Disagree). For instance, we used rating questions such as:

1. The Dashboard interface was organized and clear.
2. Dashboard system is easy to learn.
3. The Dashboard system is intuitive and self descriptive.
4. The Dashboard interface was organized and clear.
5. The visualizations/charts are easy to understand and interpret.
6. The visualizations convert data into useful information.
7. The Dashboard helps me share my ideas with other injury stakeholders.
8. The dashboard stimulated discussion, brainstorming new ideas.
9. In my opinion, group collaboration increased my learning.
10. In my opinion, group collaboration supported the decision-making process.
11. Overall, I'm satisfied with the amount of time it took me to complete the task.
12. I effectively and efficiently completed the task using the Dashboard. In my opinion, engaging with the VA tool expert enhanced my ability to understand the Dashboard.
13. In my opinion, engaging with the VA tool expert supported the problem solving process.
14. In my opinion, engaging with the VA tool expert supported the decision-making process.

These questions allowed SMEs to rate their perception of the dashboard's visual interface in terms of its clarity of content and organization. The main objective of these questions was three folds. The first is to assess the role of collaboration and its impact on the problem solving and decision-making process, the second is to analyze how the Dashboard assisted injury stakeholders with problem solving while working with a VA tool expert and the third is to assess the usability, feasibility, and ease of use of the Dashboard system. Other open-ended questions such as: ‘What other features would you like to see in the updated version of the Visual Analytics Dashboard?’, enabled us to solicit feedback from SMEs regarding additional features that are perceived by SMEs as essential components that needs to be integrated into the dashboard in order to help them efficiently and effectively complete their analytical tasks.

To ensure the validity and test-retest reliability of the designed questionnaire, the researcher submitted a draft version of the questionnaire to key stakeholders at the BCIRPU and obtained their feedback on the clarity and understandability of the designed questions prior to finalizing them. Furthermore, the questionnaire was pilot tested with staff and graduate students from the BCIRPU prior to the Analytics sessions.

At the beginning of this ‘*Feedback Questionnaire’* phase, SMEs were asked to complete the semi-structured questionnaire and to return it to the researcher. The questionnaire was administered immediately following the early phases of the Analytics sessions to collect data about stakeholders’ interactions with the *i*AID interface using queries and applying various scenarios during the Paired and Group analysis sessions. The response rate for completing the questionnaire was 87%. The goal of the questionnaire completion was to generate quantitative data that helped us to uncover further information and to examine additional aspects of the Visual Analytics collaborative process in order to strengthen our understanding of the explored concepts derived from the early qualitative phases of the Analytics sessions.

Phase IV: Feedback Follow up Interviews

Subsequent ‘*Feedback Follow Up Interviews*” followed the Group sessions and the questionnaire phases. The researcher decided to supplement the qualitative and quantitative data collected during the Paired and Group Analytical sessions with follow up phone call interviews. The purpose of the follow up phone interviews was to emphasize important concepts and inputs drawn from preliminary analysis of early data. The interview data were of a qualitative nature. The researcher decided to conduct the interview with the same focus group that attended the Paired and Group analysis sessions using open-ended questions. Interviewing a small number of stakeholders and using semi-structured open-ended interview questions lead to a richer and more in depth qualitative data [Creswell & Clark, 2007]. We decided to adopt semi-structured open-ended interviews to encourage stakeholders to express their personal opinions and viewpoints in more detail without being limited by close-ended or structured questions. An example of Interview questions is: ‘In your opinion, how does collaboration and the exchange of knowledge and expertise influence the decision making process in the Group Session compared to the Paired Session?’. The choice of these types of questions is to provide SMEs with the opportunity to fully explain their experience interacting with the *i*AID dashboard and with each other and to thoroughly describe how this collaboration enabled them to exchange knowledge and expertise and to advance the decision-making process during the analysis sessions.

Prior to conducting the interviews, results from the preliminary qualitative and quantitative data analysis were summarized and emailed to SMEs to inform them, in an anonymous, aggregated way, about other SMEs points of views and perspectives. These compiled inputs from the earlier phases guided the design of the follow up interviews as the last phase of data collection process as well as enabled us to formulate more focused interview questions. The researcher sent an email to participants with a request to schedule a follow up telephone interview in order to complete the last phase of the data collection procedure (Appendix D). Interview questions were prepared beforehand and sent to interviewees via email so as to provide SMEs the time to prepare responses to the questions and therefore increase the likelihood of obtaining richer, more complete answers (Appendix E). The initial response rate for the interview request was very low (1 out of 7). As a result, we decided to create a *Doodle Poll* invitation and meeting request to enable high profile injury stakeholders to specify the interview’s time and date that best fit their busy schedules.

After reviewing the summary of the session inputs and questionnaire feedback, the researcher conducted the follow-up interviews via telephone with each stakeholder individually, asking them the prepared questions in a specific order. The follow up interviews served to solicit stakeholder opinion and views on the Paired and Group analysis sessions and to verify phenomena retrieved from the early phases about the use of *i*AID dashboard and its impact on facilitating problem solving and supporting decision-making in a collaborative setting.

Rather than discussing and introducing new concepts, the follow up phone call interviews represented a flexible qualitative research technique that served to emphasize and clarify concepts derived from the Paired and Group analysis sessions. The follow up interviews helped SMEs to elaborate in their own words their experience interacting with the *i*AID dashboard individually or collaboratively. In addition, the interview offered the advantage of discussing various aspects of the explored concept and collect responses that were unlikely to emerge in a paper and pencil or online survey. This advantage enabled us to gain deeper insights regarding problem-solving approach that SMEs used to address the analytical task as well as their collaboration and interactions with the *i*AID dashboard at various social settings. Furthermore, the interviews solicited and examined SMEs feedback on the strength and weaknesses of the *i*AID dashboard within the context of assisting SMEs in the problem solving and decision-making process.

The follow up interviews were audio-recorded for later analysis. This phase of the Group analysis process provided us with richer and detailed qualitative data and more in-depth understanding of the phenomena observed early in the study. The compiled qualitative data generated from this session were analyzed to refine early concepts, expand our knowledge of the explored phenomena as well as to provide us with insights into the effective interpretation of the preliminary results generated from early phases of the process.

6.9. Data Transcription

We transcribed the qualitative data (i.e. audio- and video-recordings) collected during the Paired and Group analysis sessions and saved them as text files. The data transcription process was a labour intensive process and time consuming, as we needed to transcribe more that 180 minutes of audio-recordings accumulated from seven Paired and two Group analysis sessions (Please refer to Appendices I and J).

We decided to conduct full transcriptions of all of the sessions, to ensure collection and documentation of all the aspects of the analytical process related to the study. Transcribing the details of the conversation was fundamental to examine and re-examine from multiple perspective and through different lenses the existing phenomena in the data. We used InqScribe Software (http://www.inqscribe.com/) to upload and transcribe the audio-recordings. The software was compatible with the collected audio files. Additionally, the InqSribe software offered many features that facilitated the transcription process including adjustable play rate and volume as well as keyboard activation of sound to help us effectively manipulate the play/pause activity of the audio recordings.

Along with the transcription process, we prepared memos that we used to document our reflections on the transcription process as well as the transcribed data. As we transcribed the data, we documented our experience trying to adopt various techniques to facilitate the transcription process and make it less time consuming as well as to improve the efficiency and accuracy of the transcribed data. Upon completion the transcription of each analytics session, we conducted a quality check by reviewing the text and compared it against the audio-recordings before finalizing the transcribed data. In order to ensure consistency throughout the data collection process, we created a template that outlined the common format of the Paired and Group Analysis transcripts. The template served as a tool to confirm uniformity of the transcripts while saving time. To conceal the names and safeguard the identity of participating injury stakeholders, upon completion of each session transcripts we replaced the name of the stakeholders with a number assigned to each SME (i.e. SME1, SME2, SME3…).

6.10. Data Coding

Following data transcription, the author of this thesis coded the transcripts through multiple passes using different coding techniques. The coding process enabled us to categorize SMEs recorded verbal and non-verbal interactions and to identify the various themes related to investigated collaborative Visual Analytics phenomena. We went through the collected data systematically and coded the two types of data:

- Text files (the Paired and Group analysis sessions transcripts, interview transcripts and field observations)
- Video files (gestures and interactions during the Paired and Group analysis sessions)

Coding refers to the process of segmenting and assigning categories to collected data [Coffey & Atkinson, 1996]. Coding represents an essential component of the analysis process that enables researchers to gain deep understanding and interpretation of the examined phenomena. In the context of this study, our coding process focused mainly on the close examination of video files and the transcripts generated from the audio-recordings. On one hand, coding video files was a challenging process, as we needed to watch the video repeatedly to capture and code SMEs different patterns of interactions. We coded and categorized these non-verbal communications and gestures among SMEs within the context of collaboration and coordination of activities. Coding non-verbal interaction provides insights into the SMEs social behaviour in a computer-mediated environment. On the other hand, coding textual files was an iterative process. We thoroughly examined the texts of transcripts and assigned various codes to concepts, themes, and meanings as they emerged. Codes were applied to segments of data and later classified into categories. We adopted multiple coding techniques including open, axial and selective coding techniques [Corbin & Strauss, 1990] to label the textual transcripts. Saldaña, in his book 'Coding Manual for Qualitative Researcher', defined code as 'a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data [Saldaña, 2012]. To efficiently manage the coding process, we decided to follow a specific set of criteria:

- Use short words for coding.
- Reapply existing codes to reduce the application of multiple codes referring to the same concept or idea.
- Refine existing codes, collapse similar codes or merge identical codes to create a manageable list of codes.

Throughout the coding process, we created memos to document our interpretations of the observed themes and emerging concepts, to connect codes and events based on their contexts as well as to reflect on SMEs conversations and performed actions. Furthermore, we used the memos to retrieved and collect relevant quotations from the transcripts to support later analysis of the data.

This coding process was conducted by a single coder – the author of this manuscript. Some research experts argued that having multiple coders ensures reliability and validity of the coded data [MacQueen et al., 1998] using an inter-coder agreement approach, while others argued that a single coder is ‘sufficient and preferred’ [Bradley et al., 2007] to conduct a reliable coding process. In this study, we were restricted with the selection of additional coders as coders need to possess the essential information related to Clark Joint Activity Theory, the Distributed cognition framework, the Delphi method, Visual Analytics tools and techniques along with knowledge in the public health domain in order to conduct efficient coding and analysis. Therefore, it was challenging to assign a second coder to this particular study. As a result, to ensure a coherent and comprehensive approach to coding the data, the author conducted the coding process, as she possesses the required contextual and technical knowledge to code and analyze the retrieved instances of the collaboration VA process within the context of dealing with complex public health problem.

6.10.1. Coding Filters

We examined the data through the theoretical lenses of the Joint Activity Theory (JAT) and the Distributed Cognition (D-Cog) framework. According to Saldaña ‘the act of coding requires that you wear your researcher’s analytic lens. But how you perceive and interpret what is happening in the data depends on what type of filter covers that lens’ [Saldaña, 2012]. Within the context of this study, the D-Cog and JAT theory represent powerful frameworks to guide the process of coding the transcribed stream of audio and video files collected during the analytics sessions.

We interpreted and coded the textual transcripts based on JAT and D-Cog perspective derived from the conceptual and theoretical framework that we initially used to design and structure the study. The transcripts were examined from the lenses of JAT and D-Cog to capture and understand the coordination of joint activities among stakeholders while addressing the proposed analytical task throughout the analytics sessions. We first subdivided the data and decided what segments needed to be coded while focusing mainly on the textual segments that represented meaningful events from the JAT and D-cog perspectives. As we examined the data, we interpreted the various events and we developed new codes that emerged from the text. Furthermore, we filtered the coding process to emphasize the codes related to the study’s main research question to examine how multiple SMEs established a Common Ground, how SMEs used their coordinated devices (i.e. Common Ground, *i*AID dashboard) to coordinate their actions, and how SMEs exploited artefacts from their environments to facilitate problem solving and support decision-making process.

6.10.2. Analytical Coding Unit

When coding and analyzing the compiled textual transcripts, we initially started by defining the unit of analysis. We specified this unit of analysis to be any instance of SMEs 'joint activity' pertaining to the collaborative process that occurred throughout the analytics process. We subdivided the textual transcripts into a series of purposeful units of joint activities. Each joint activity embeds a series of joint actions undertaken by SMEs and intended to solve the problem and make a decision. We adopted Clark's definition of joint action as "one that is carried out by an ensemble of people acting in coordination with each other" [Clark, p.3]. Defining the unit of analysis helped to systematically structure the transcripts in an insightful way and supported the coding and analysis process. We segmented the data into meaningful analytical units that we called 'events' based on Joint Action Theory and we assigned codes that characterized these events. The Joint Activity Theory offered us a framework to draw event boundaries (i.e. *entry* and *exit)* and to observe how SMEs coordinated their joint activities within the boundaries of each event. We further observed and coded embedded nested activities that took place within the boundaries of a larger event or joint activity. Framing SMEs activities into nested ones helped us to structure subsequent activities and to understand them within the context of the larger activity. The following excerpt illustrated the segmentation of the data into units of joint activities:

ENTRY

{

SME 1:We want the type of injuries at the bottom. By…
VAE: By?
SME 1: Sex.
VAE: All right

}

EXIT

ENTRY

{

SME 5: Umm...

SME 8: If you exclude everything, it's not head injury related?

SME 5: yeah, because they have it

VAE: we can, but you have to go one by one.

SME 4: the body part yeah,

SME 5: the body part might give you the head injuries

VAE: Uh , huhh… body parts, then let's get the body part instead of the causes

SME 4: and then just keep "Head", exclude all others.

SME 1: (short laugh)

VAE: (short laugh), all right

SME 1: there you go!

}

EXIT

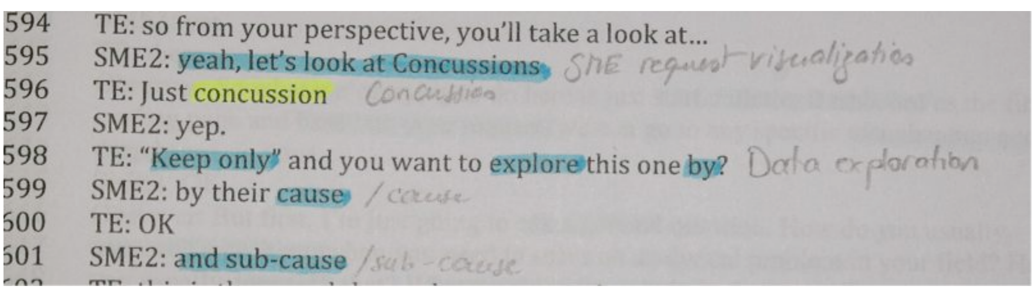
6.10.3. Coding Process

We coded the textual transcripts using various coding techniques termed by Corbin and Strauss (1990) as open coding, axial coding and selective coding [Corbin, & Strauss, 1990]. According to the authors, open coding is the preliminary examination of the ideas, concepts and meanings derived from the data. Axial coding is linking theses retrieved concepts and connecting them to conceptual categories. Finally, Selective coding is selecting codes and structuring the relationship between categories of codes into a theoretical framework [Corbin & Strauss, 1990]. We adopted these coding techniques and applied them on the textual transcripts in order to classify all data characteristics and dimensions and link them to core categories (Please refer to Appendix H for coding strategies).

6.10.4. Open Coding

During the first stage of coding the data, we focused on reading the whole transcript and asked data questions. This phase was carried out manually using printed copies of the textual transcripts, pencil and highlighter. As we went systematically through the transcript document, new codes emerged and existing codes were refined while we questioned the data and sought answers to questions such as: ‘what event or activity is going on in this particular data segment?, ‘what concept or theme does this textual data convey?’. We read the textual transcripts and closely examined line by line the different segments of the data. We highlighted relevant segments of the text and annotated them with assigned codes. As shown in Figure 6.11, in this open coding phase, we applied descriptive codes to depict and summarize key words in the text (i.e. cause) as well as analytical coding to reflect on the text (i.e. data exploration). We further reflected on the general themes using marginal notations and codes. This iterative process was repeated until data saturation was reached. This paper and pencil coding process provided us with general reflections on the main ideas and concepts in the data.

Figure 6.11. Manual Coding: Line-by-Line.


TE: so from your perspective, you’ll take a look at...
SME2: yeah, let’s look at Concussions SME request visualization
TE: Just concussion Concussion
SME2: yep.
TE: “Keep only” and you want to explore this one by? Data exploration
SME2: by their cause /cause
TE: OK
SME2: and sub-cause /sub-cause

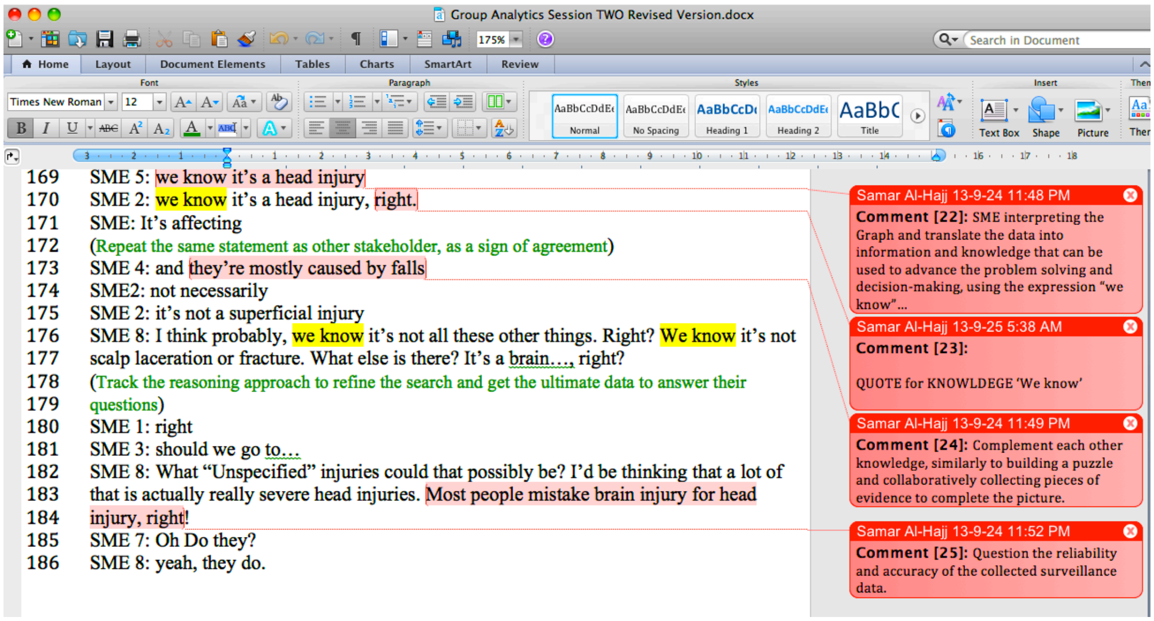
6.10.5. Axial Coding

Before proceeding into the axial coding phase, we conducted a comprehensive literature review to examine the coding approaches adopted by various studies to investigate and code the collaborative process among multiple participants. As a result, our axial coding process was inspired by previous research and coding schemes completed by Kastraa et al. [2012], Tang et al. [2006], Isenberg et al. [2009], Scott et al. [2004], and Kruger et al. [2003]. These studies examined and coded the collaboration and coordination of activities among multiple participants that used interactive tools to mediate their collaborative work. We extended these existing coding schemes to incorporate the different collaborative activities carried out by SMEs throughout the Paired and the Group analysis dynamic environment.

We started the coding process with a pre-set list of codes in mind. These pre-set codes were derived from the conceptual framework underlying this study, the design of the analytics sessions, in addition to well-known codes in the literature. Miles and Huberman (1994) refer to this pre-set list as the 'start list'. The authors explain that the 'start list' offers researchers the advantage of integrating important concepts retrieved from the field literature and refine them to enhance the quality of the coding process [Miles & Huberman, 1994]. Within the context of this study, this pre-set list included codes like 'SME-Personal Experience', 'SME-Attend to Information', 'SME-Knowledge Building', 'SME-Common Goal Emphasis', and 'SME-Interpret Visualizations'.

During this stage of the axial coding process, we used Word documents to re-read the textual transcripts from the sessions and further examine them with a more directed approach. We focused on confirming already retrieved codes from the open coding phase. We also examined the context of the concepts and tried to relate the retrieved concepts to categories and themes by asking questions such as 'what does this concept relate to?', 'how is this concept linked to the main theme or category', and 'what is the nature of the relationship?'. We assigned line numbers for the document to facilitate reference to specific quotations that were relevant to the investigated concepts and themes.

Figure 6.12. Word Manual Coding.



We reflected and reasoned the textual transcripts and the retrieved codes from the early phase. We highlighted core concepts related to the theme of the passage and reflected on meaningful events and concepts. We integrated 'green' comments in brackets within the lines of the transcripts to reflect on relevant concepts and themes emerging from SMEs interactive conversations and collaborative activities. We also used the margins at the right of the transcribed text to insert remarks and comments on pertinent concepts and thought-provoking quotations.

When conducting the axial coding, we examined and emphasized how particular codes related to a specific category. Applying particular codes was based on either describing the text or reasoning about its underpinning concepts. For instance, in figure 6.12 we chose the category of this passage to be 'Knowledge Exchange' as this passage translated into the transfer and exchange of knowledge among multiple stakeholders when dealing with refining the visualization. This passage revolved around the repetitive use of the word '*we know*', and further described SMEs experience interacting with the tool and with other members of the group. Based on the context and the setting of the sessions, this exchanged knowledge was derived from:

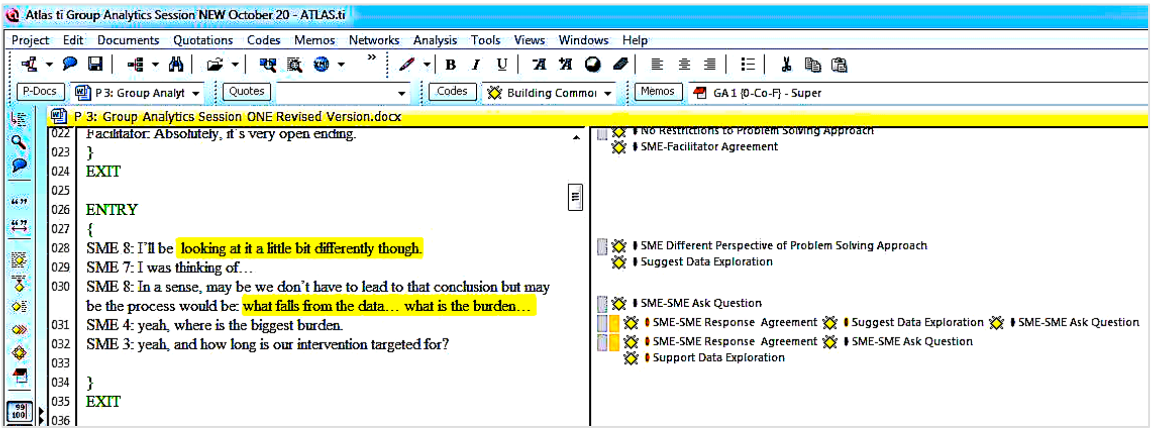
1. Stakeholders interpreting the visualization by referring to the *i*AID dashboard displayed on the shared screen: '*we know it's head injury*', '*we know it's not all these other things*', '*they're mostly caused by Falls*'.
2. Stakeholders' retrieving prior knowledge related to the discussed topic, 'we know it's not scalp laceration or fracture', 'most people mistake brain injury for head injury'.

6.10.6. Selective Coding

In addition to the manual coding, we decided to conduct electronic coding using a qualitative data analysis Software. The rationale for selecting an electronic method was that it facilitated the coding process and enabled us to comprehensively explore the existing codes. Adopting analysis software facilitated the coding process and helped us to manage the retrieved coded data and link them to different categories and sub-categories. According to Basit (2003), choosing manual or electronic coding methods is mainly associated with factors including the amount of collected data, the available time and funds provided for the study as well as the researcher's preference and technical expertise [Basit, 2003]. We decided to use Atlas.ti qualitative analysis software to electronically conduct the selective coding process. While using Atlas.ti reduced the substantial time needed to code, categorize and connect the themes of the transcripts, it took a considerable amount of time to become familiar with the tools' features and functionalities.

We first uploaded the transcripts into Atlas.ti and exploited the software features to conduct the open and axial coding electronically. We initially segmented the data into 'events' and applied codes line-by-line using Atlas.ti software. We analyzed the instances of *joint actions* taking place within the boundaries of each event and classified them according to the related activities they achieved. Figure 6.13 illustrates how we coded the wide variety of collaborated actions that occurred among stakeholders throughout the interactive group sessions along with the activities resulting from these actions.

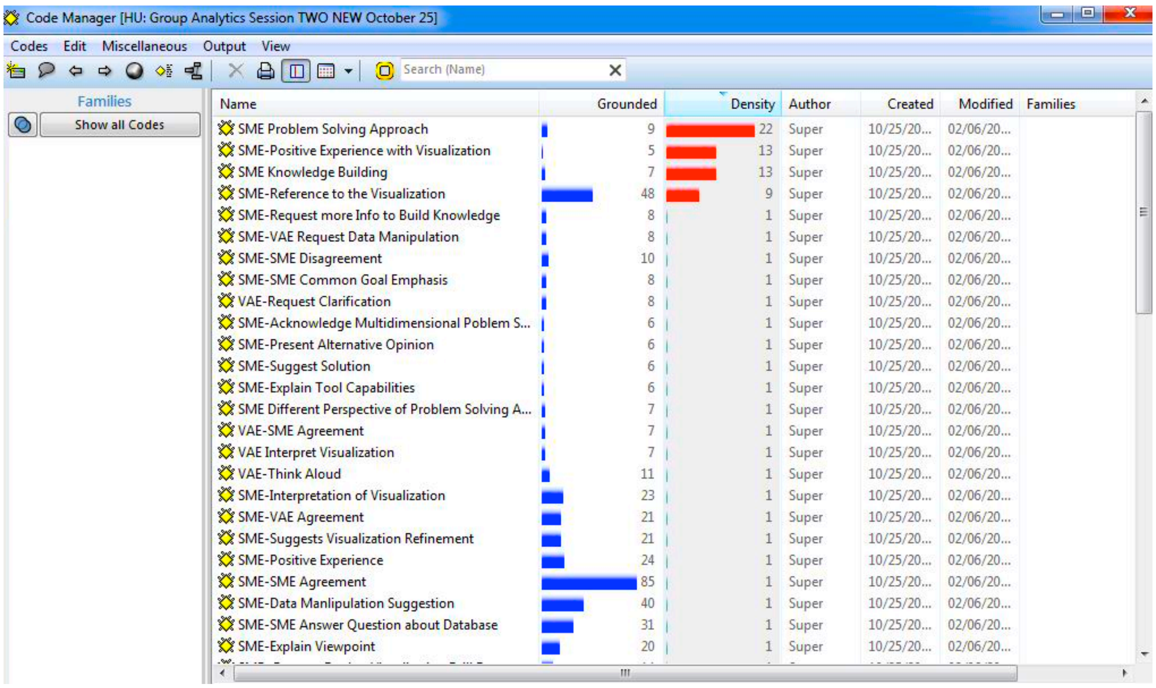
Figure 6.13. Line-by-Line Open Coding Using Atlas.ti.



Compared to the initial phase of manual coding, Atlas.ti was efficient in expediting the data coding and the categorization process. Atlas.ti features enabled us to reapply the same codes to similar concepts encountered in the textual segment. Many of the created codes were reapplied repeatedly throughout the transcripts. This was due to the pattern of interaction and communication among SMEs as well as between SMEs and VAE. Codes like 'Suggest Data Exploration' and 'SME-SME response Agreement' were repeatedly used throughout the coding process and across the different transcripts as SMEs continuously suggested data exploration to investigate and refine the visualizations at every stage of the problem solving and decision-making process. As shown in the Figure 6.13, some codes co-occurred at different events in the transcripts, some other events were assigned more than one code as they referred to more than one idea or concept (i.e. ' SME-SME Response Agreement' and 'SME-SME Ask Questions').

Upon completion of the initial phases of the open coding, we started the process of axial coding by categorizing the codes to capture patterns and meaning in the data. We categorized the codes based upon two main criteria. Firstly, codes that shared same data patterns, characteristic, similar concepts and ideas were clustered and categorized together. Secondly, applied codes that related to a common activity or event (i.e. 'Data Manipulation', 'Visualization preferences') were grouped together under one category. The categorization process was conducted using Atlas.ti. We first sorted the codes to observed occurrence and identified the frequency of each code. As shown in Figure 6.14, the code 'SME-Data Manipulation Suggestion' occurred 40 times in the Group analysis session, compared to the code ‘SME-Explain Viewpoint’ that was encountered 20 times in the transcript.

Figure 6.14. Atlas.ti: Code Manager, Code Frequency & Density.



We clustered similar codes, compiled them and structured them into categories using Atlas.ti network building feature. We built hierarchical networks to visually show the link between difference codes and depicted the characteristic of the relationships between codes and the main category. Building these tree-like networks in Atlas.ti enabled us to observe the different patterns in the data by mapping the codes and looking at them through various lenses. Networks are useful tools that enable us to visually and comprehensively explore the emerging codes and themes in the data as well as understand their underpinning relationships. Networks range from a simple network (i.e. Fig 6.15) to more complex networks (i.e. Fig 6.16.) based on the number of codes incorporated in the network. We used the Atlas.ti network feature to specify the relationship that existed between codes and categories. For instance, the category ‘Data Exploration’ had several codes and sub-codes related to it. Atlas.ti network structured the data into nodes and connected each node to the main category. Observing how codes were linked enabled us to set min-hypothesis about the data and observe the relationship and association between different codes as well as how related to the study's research question.

Figure 6.15. Atlas.ti: PA Network.

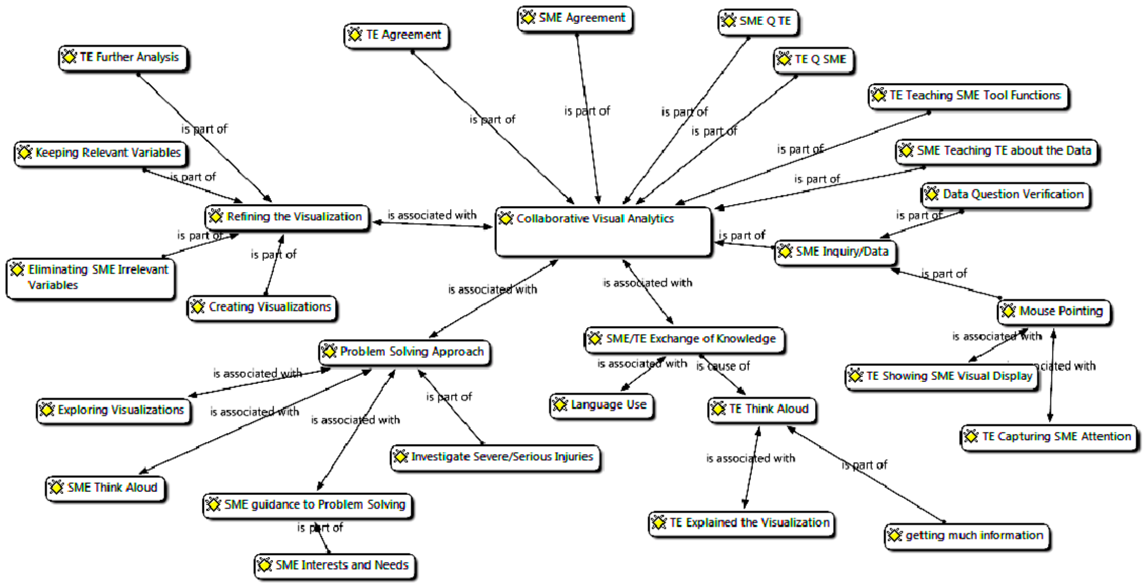
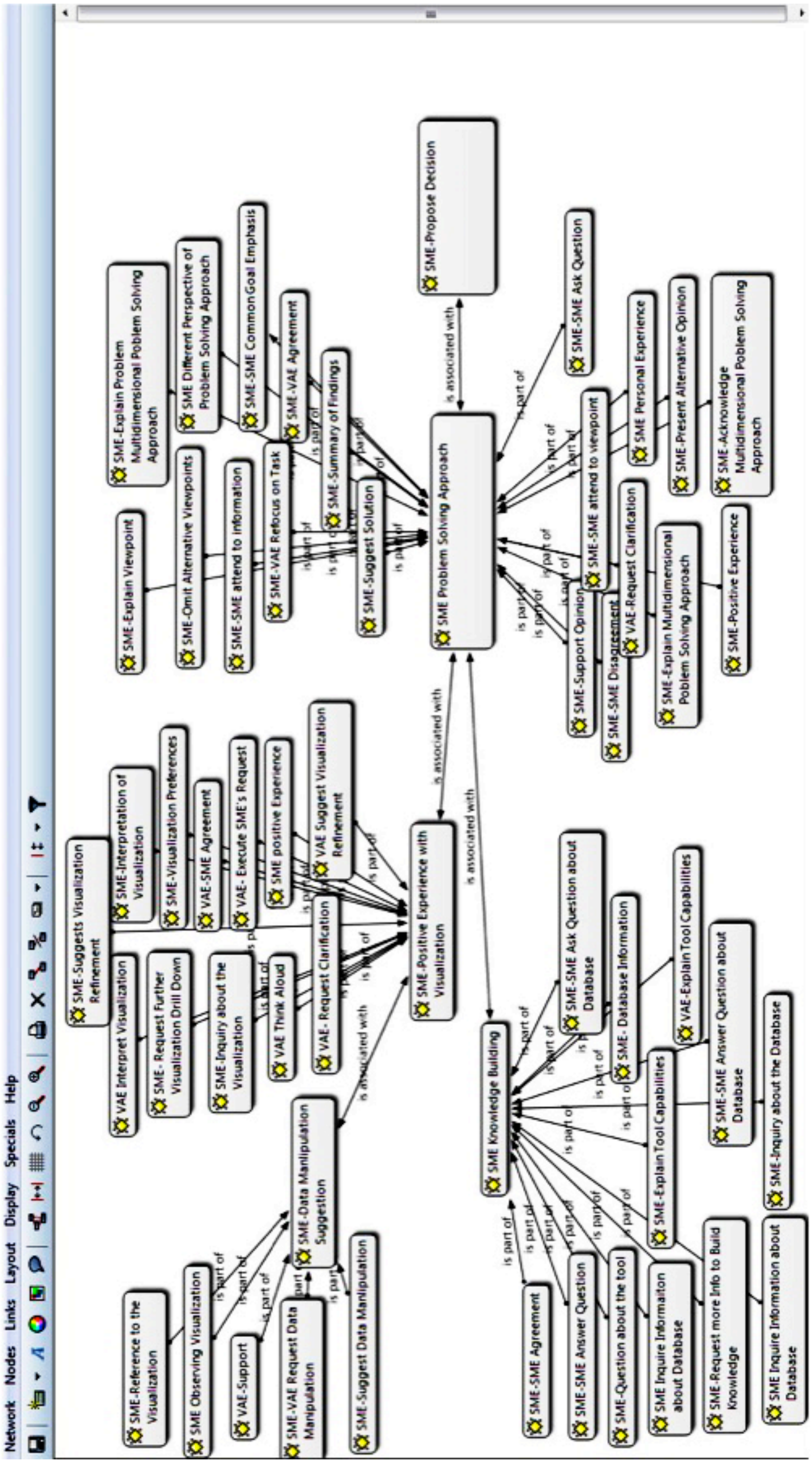


Figure 6.16. Atlas.ti: GA Network.



Another way of managing and exploring our coding process was sorting the categories into chronological phases in order to observe the progress of the different phenomena through time during the Group analysis sessions and to identify the various collaborative activities that occurred in each category. We used the Atlas.ti feature of color coding to assign colors to various codes within each of the categories, ranging from dark green to light green to yellow in an attempt to emphasize the number of time each of the codes occurred in the analytics sessions (Fig 6.15.). For instance, on one hand the code 'SME-SME agreement' was coloured yellow to signify the substantial number of times SMEs agreed with each other on a point of view or approaches to problem solving. On the other hand, the code 'SME-Summary of Findings' was coloured dark green as only few injury stakeholders took the lead to summarize and articulate the information retrieved from the shared dashboard interface.

Figure 6.17. Atlas.ti: Color Coded Chronological Display of codes.

In the last stage, we conducted selective coding by refining earlier categories generated from the open and axial coding process. We placed the categories into diagrams and network trees to comprehensively understand emerging theories. For instance, we identified and selected the core category 'Collaborative Problem Solving'. We used this category to investigate how other categories such as 'Data Manipulation', 'knowledge building' and 'Experience with Visualization' to connect with this main category in an attempt to develop a theoretical claim. As depicted in Table 6.1, the 'Problem Solving Approach' category was associated with several concepts and themes that enabled us to understand the investigated phenomena and explain SMEs behaviours throughout the collaborative problem solving process.

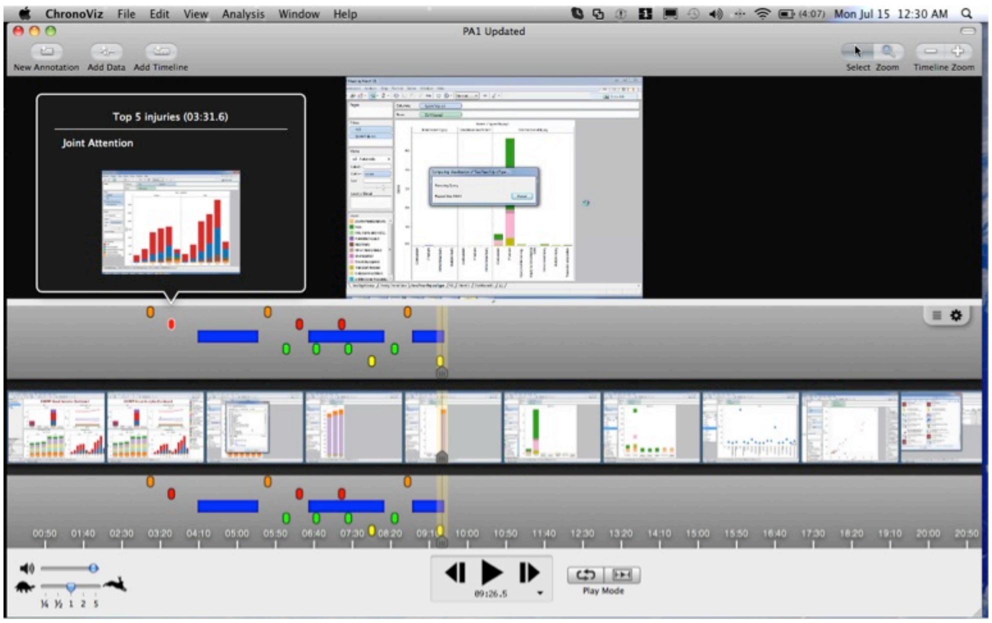
Table 6.1. Category Classification: Joint Actions.

Suggest Data Manipulation Request Data Manipulation	Data Manipulation	Collaborative Problem Solving
Inquiry about the Visualization Suggest Visualization Refinement Suggest Drill-Down Interpret Visualization	Experience with Visualization	
Database Information Tool Capabilities Request more info to build knowledge	Knowledge Building	
Summary of Findings Different perspective to problem-solving approach Explain view point Support opinion Personal Experience	Problem Solving Approach	

We took advantage of the Atlas.ti memos feature to document and reflect on the emerging themes from the transcripts. Memos were important data repositories that included details about our reflections and analysis. These memos were valuable resources that we used later to retrieve relevant information related to the analysis process.

In addition to Atlas.ti, we used a visualization system called 'Chronoviz' to explore and visualize the various aspects of the collected video data. Chronoviz is a visual aid system designed and developed to assists analysts in data exploration and data analysis [Fouse et al, 2011]. Chronoviz encompasses two main components: a video pane, individual video frames and a timeline to visualize analysts' annotations and observations (See Figure 6.18).

Figure 6.18. Chronoviz System



The main objective of the Chronoviz system is to visualize and analyze time-coded multimodal data. Screen captures collected using Camtasia software during the analytics sessions' were uploaded into Chronoviz system. The functionalities of the Chronoviz system enabled us to explore and examine SMEs data manipulations using the *i*AID dashboard throughout the interactive analysis session. As shown in Figure 6.18, we navigated the screen captured video data, indexed and annotated major SME's interactions events on the timeline with their associated time. Every time we hovered the mouse over the timeline, an image corresponding to the *i*AID visualization appears on the screen with its time-linked activity. Chronoviz represents an appropriate system that effectively supported this study's video data analysis process and provided us with more in-depth understanding of SMEs interactions with the *i*AID dashboard over time to refine the visualizations and advance toward solving the analytical task.

Chapter 7. Analysis and Discussion

7.1. Qualitative Analysis Group and Paired Analytics

The overall goal of this study was to analyze the observed and captured collaboration process carried out by multiple stakeholders working together in a face-to-face setting to solve a pre-defined complex analytical task using an interactive Visual Analytics tool. As Bohdan and Taylor (1975) described data analysis is the ‘process, which entails an effort to formally identify themes and to construct hypotheses (ideas) as they are suggested by data and an attempt to demonstrate support for those themes and hypotheses’ [Bogdan & Taylor, 1975]. Studying the collaborative aspects of Visual Analytics within the context of dealing with complex wicked health (injury) problems is vital to understand the impact of collaborative Visual Analytics on the problem solving and decision-making process as well as to inform the design of new innovative Visual Analytics tools and techniques.

Screen captures pertaining to SME and VAE interactions with the *i*AID dashboard when solving the analytical task at hand were matched with SMEs discourse and non-verbal gestures for insight and knowledge about the impact of collaborative VA on the advancement of the problem solving and decision-making process. We analyzed the captured observations using the Clark’s Joint Activity Theory and the Distributed Cognition framework to understand:

- How multiple stakeholders coordinated their joint actions to establish a ‘Common Ground’.
- How multiple stakeholders interacted with the visual analytics tool to collaborated their activities and reached a consensus.
- How multiple stakeholders advanced the problem solving process and made a decision.

7.1.1. Qualitative Analysis of Group Sessions

We grounded the analysis of the collected data in Clark's Joint Activity Theory (JAT) and the Distributed Cognition (D-Cog) framework. We viewed the modified Delphi-structured collaborative sessions through the lenses of JAT and D-Cog in order to comprehend injury stakeholders' coordination of joint activities as well as their interactions with artefacts in their environment. We triangulated the data analysis process by examining the transcripts, observing the videotapes, listening to the audiotapes as well as tracking the screen captures of the interactions in order to ensure transparency and validity of the results.

The analysis of the transcribed audio and video recordings as well as the screen captures of the collaborative sessions were conducted using Atlas.ti and Chronoviz software. The software enabled us to concurrently examine and document SMEs joint activities, use of language and interactions with the *i*AID dashboard. Each software package offered a different perspective into the data and empowered us with more in-depth understanding of the investigated phenomena.

When analyzing the compiled data, we specified the unit of analysis to be any instance of participants 'joint action' pertaining to the process of joint analytics activity intended to solve the problem and make a decision. The JAT framework enabled us to structure and identify the various joint actions triggered by conversation and linguistic dialogue among SMEs. The theory guided the process of analyzing the transcribed stream of audio and video files collected during the analysis sessions by segmenting them into a series of purposeful units of joint activities. Each joint activity was outlined with defined boundaries with unique entry and exit to study the coordination of actions within each social activity. Screen captures pertaining to SME and VAE interactions with the *i*AID dashboard were matched with SMEs discourse and non-verbal gestures for insights and knowledge about the impact of collaborative VA on the advancement of the problem solving and decision-making process.

Video and audio recordings collected during the analytics sessions were first analyzed using open coding techniques to categorize SMEs recorded verbal and non-verbal interactions and to identify the various themes related to collaborative Visual Analytics. Following the audio and video open coding process, axial and selective coding were performed in order to classify all data characteristics and dimensions and link them to core categories [Corbin & Strauss, 1990]. This iterative process was repeated until data saturation was reached. A second coder examined the code schemes separately using common coding methods in order to ensure inter-related reliability of the data analysis process.

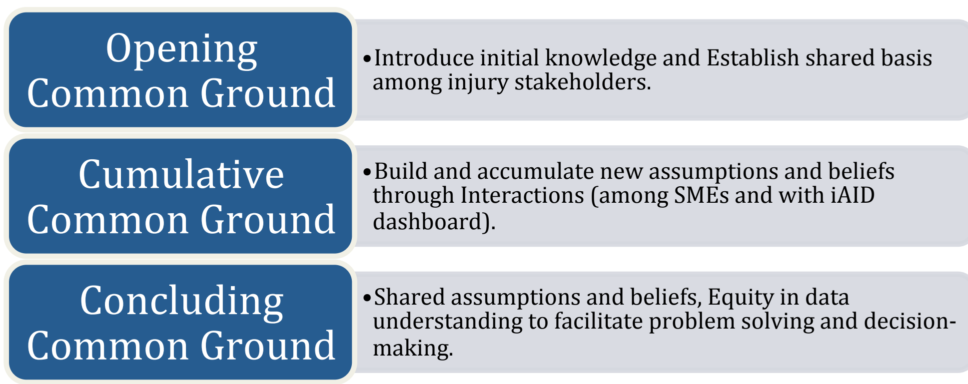
The transcripts were coded through multiples passes to conceptually identify the social and cognitive phenomena grounded in the collaborative Visual Analytics data analysis. We classified the retrieved codes into the following six main categories: Common Ground, collaboration activities, Interaction styles, thinking with the visualization tool, dialogue and verbal communication, role awareness and gesture awareness.

7.1.1.1. Common Ground

The concept of Common ground is related to establishing effective collaborative analysis. Establishing *Common Ground* among multiple participants is associated with their various shared activities and artefacts. In his book "*Using Language*", Clark (1996) defined the notion of *Common Ground* as the set of shared bases between two individuals [Clark, 1996]. Clark addressed the establishment of *Common Ground* between two people; he argued that *Common Ground* is developed in a "strata" process, in which multiple layers of shared bases are built one upon the other to constitute the foundation of the established *Common Ground* [Clark, p.119]. This study extends Clark's concept of *Common Ground* to include multiple individuals working on forming layers of *Common Ground* that enable them to efficiently and effectively solve a complex analytical task. We aimed to facilitate SMEs communication and interactions with the support of the designed *i*AID dashboard to facilitate the emergence of an artificial *Common Ground*.

Throughout the analytics sessions, SMEs interacted with each other and communicated thoughts and ideas regarding the given analytical task. The analysis sessions fostered a communicative environment for SMEs to discuss, argue and agree on a set of shared understandings to support the emergence of a *Common Ground*, which was fundamental to advance the problem solving and decision-making process [Clark et al., 2004]. Through the grounding process, we observed that the analysis of the collaborative sessions reveals evidence of Clark's notion of *Common Ground*. We modeled and further extended Clark's previously defined concept of *Common Ground.* We empirically evaluated the model through the observation of a practical Common Ground establishment among group members during the analysis sessions. We documented the emergence of different types of *Common Ground* that we classified as follows:

Figure 7.1. Types of Common Ground



1. Opening Common Ground

At the beginning of the analysis session, we observed that each SME possessed a set of assumptions, beliefs and expectations that they shared and verbally communicated with other group members in an attempt to establish a *Common Ground*. Clark in his book "Using Language" explained, "when people take part in conversation, they bring with them certain prior knowledge, beliefs, assumptions and other information" [Clark, p. 38]. The exchange of SMEs prior knowledge through conversation and dialogue led to the establishment of a *Common Ground* among SMEs. Having common beliefs, intents and goals enabled SMEs to coordinate their actions and joint activities. We referred to this early phase, as the phase to establish the "Opening Common Ground" where each SME introduced a new knowledge space, based on their prior experience, to support the emergence of different types of *Common Ground* throughout the analytics session. The established *Common Ground* represented a key component to advance SMEs collaborative work. In this "Opening Common Ground" phase, we observed the early development of two types of *Common Ground* identified in Clark's book as the *Communal Common Ground* and the *Personal Common Ground*.

Communal Common Ground is defined by Clark as the set of shared bases that people belonging to a specific community possess [Clark, p.101]. These shared bases are unique and held solely by members of this community. In this study, SMEs had a shared basis for Communal *Common Ground* since they are all associated with the child and youth injury prevention community. SMEs had common or shared background knowledge, shared understanding of "communal lexicons" [Clark, p.107] and injury terminologies as well as shared skills and expertise regarding injury prevention. Communication among SMEs revolved around these shared bases and their tacit communal knowledge, skills and experience being part of the injury prevention community. SMEs used these community or cultural shared bases to enhance their *Common Ground* and subsequently advance their communication and collaboration.

In addition to the *Communal Common Ground* that existed, we observed *Personal Common Ground* among pairs or a group of SMEs. According to Clark, *Personal Common Ground* is established between individuals who worked jointly on common past projects and shared experience and knowledge [Clark, 1996]. During the session, we noticed that SMEs tend to sit next to people with whom they share Personal Common Ground. SMEs previous joint collaboration enhanced their joint knowledge, improved their *Personal Common Ground* and ultimately influenced their current collaboration during the analytics sessions. For instance, we noted many side conversations that occurred between adjacent injury stakeholders. These conversations were built upon their previous joint work experience on injury problems and served to highlight SMEs collaboration based on their *Personal Common Ground.*

The location and venue of the analytical sessions positively shaped SMEs Opening Common Ground; it reinforced and added further dimensions to SMEs contextual *Common Ground.* As the sessions took place at the BC Children's hospital, SMEs tacitly communicated their association with the children's healthcare community. SMEs implicitly perceived the location as the right common place for them to collaborate and address children's health issues. Furthermore, SMEs occupations and affiliations with children and youth injury prevention programs added another piece of "*circumstantial evidence*" [Clark, p.98] to SMEs emerging *Common Ground.* SMEs mutually assumed that other SMEs are knowledgeable with regard to injury prevention and assumed to have a shared vision on how to address the injury problem. The following excerpt illustrates how SME verbally communicated with each other to advance the problem solving process:

> SME4:"We had a common goal but we might have taken different pathways to get there, but they're coming together to talk about it in one group, you know, we have the trauma surgeon, we have the epidemiologist, we have the policy makers, we have the researcher, the coordinator."(27/06/2013)

Despite the fact that SMEs came from a diverse background and had varying expertise, they all had common goals and shared common expectations. They were all motivated to reduce injuries and improve the health and wellbeing of children and youth in Canada. The analytics sessions gave multiple SMEs a unique opportunity to communicate with group members and established a *Common Ground* that reflected their common goals and improved their collaboration.

Clark explains in his book "Using Language" that the initial phase when establishing a *Common Ground* is to find the "right shared bases" [Clark p.116]. The early phase of the session presented a collaborative environment for SMEs to communicate knowledge and combine shared bases to establish the Opening *Common Ground*. This communication and exchange of knowledge during the Opening Common Ground phase ensured that SMEs had equity in understanding the injury problem as well as shared information and common knowledge about the injury issue. These several different types of established *Common Ground* were summed and exploited to handle the joint activity. They represented the basic foundation upon which SMEs coordinated their actions and collaborated their work.

2. Cumulative Common Ground

As the conversation and argumentation evolved throughout the sessions, SMEs Opening Common Ground emerged to advance their initial *Common Ground* to integrate new assumptions and beliefs gained from two main sources:

1. Effective interactions among SMEs: To enhance the established *Common Ground* and advance the joint activity, SMEs needed to coordinate the content and the process of their joint actions. Interactions among SMEs improved the coordination of content and process of their joint actions. SMEs coordinated the content of their joint actions by explicitly identifying the goals and objectives of their collaborative joint activities. Furthermore, SMEs coordinated the process of their joint actions by harmonizing their verbal and non-verbal cues to progress their collaborative joint activities. SMEs verbally communicated with each other to discuss the injury problem and argue the potential problem solving approaches. SMEs commonly agreed on the choice of relevant variables that needed to be integrated into the generated visualization. SMEs learned from each other's background experience and built new knowledge and beliefs about the injury data. As one SME explained:

Example 1:

> SME 2: "and I think you sort of, **add to SME 4 point**, maybe we want all this types of injuries, we don't want playground head injuries. But maybe we're ok with a couple of kids breaking their arms trying to climb on playgrounds."
>
> SME 1: "yep."

Example 2:

> SME4: "that exchange (of knowledge) in the group session got us all on the same page." (27/06/2013)

The modified Delphi structured group sessions incited interactions and exchange of thoughts and ideas among SMEs through conversation and dialogues. This exchange of knowledge served to supplement additional layers to Cumulative Common Ground and consequently improve SMEs coordination and collaboration of activities.

2. Resourceful interaction with the visualization tool: Analysis of the sessions showed that sharing the visual display of the *i*AID dashboard constituted a substantial part of SMEs Perceptual *Common Ground* that improved their collaboration and coordination of actions. In his book, "Using Language", Clark emphasized the role of external visualization and data manipulation in action coordination and collaboration. He explained that external representation of the data is important to the advancement of individuals' joint actions [Clark, p.46]. The dashboard visual representation acted as a *Coordinated Device* to synchronize SMEs thoughts and harmonize their collaborative work. The dashboard encompassed information that enabled SMEs to focus their attention and awareness on the context of data analysis. For instance, when exploring the types of injuries causing "Fractures", VAE worked with SME to iteratively refine the visualization and presented the results. Once the final visualization was displayed on the screen, one of the SMEs pointed at the screen and said: "*Oh, look it's "Fall*" (21/03/2013). Attending to a joint salient event, such as referring to a co-present piece of visual evidence, constituted a substantial piece of SMEs *Common Ground* and greatly contributed to advance their collaborative problem solving process. According to Clark, 'the ideal solution to a coordination problem among two or more agents is the solution that is most salient, prominent, or conspicuous with respect to their current Common Ground' [Clark, p.67]. The refined visualization generated by VAE's manipulation of the dashboard visual display presented SMEs with information that brought them all to a *Common Ground* and common understanding to solve the injury problem. During the session, we noticed multiple instances of SMEs finger pointing at the visualization to support their argument by referring other SMEs to particular information on the visual display - their *Common Ground*. SMEs referred to the visual display as a piece of evidence and agreed on this 'shared salience' to progress their joint activities.

Building the right piece of the *Common Ground* was fundamental for SMEs to coordinate their joint actions and collaborate on the problem solving process [Clark p. 99]. Within the context of this study, it was essential to ensure that the meaning derived from the display and the interpretation of the visualization was similarly perceived and comprehended by all SMEs. Throughout the analysis sessions, VAE explicitly articulated the accurate interpretation of the visual display in order to convey the correct information to all SMEs. Non-conflicting understanding of the visualizations constituted the core for establishing SMEs *Common Ground* [Clark p.98]. Inconsistency in interpreting the visualization can result in knowledge inconsistency and information discrepancy among SMEs and consequently impact SMEs *Common Ground*. This shared knowledge and common beliefs regarding the content of the injury data added a substantial piece of evidence to SMEs Cumulative Common Ground and played a crucial role in their collaboration and coordination of actions.

3. Concluding Common Ground

Based on the pieces of *Cumulative Common Ground* that SMEs established through their interactions with each other and with the visualization tool, the final product of their *Common Ground* expanded to include new shared beliefs, shared knowledge, shared understanding of the injury issue as well as shared goals. This final phase of the analysis process was labelled SMEs Concluding Common Ground. This Concluding Common Ground exploited the Cumulative Common Ground to synthesize shared knowledge and consequently facilitate SME's consensus building and decision-making.

Example 1:

> SME 7: "So, we see that the major thing here is head injuries and 8 and 4 years old and it's about "Falls". So that at least really does start narrowing it down but it still say: "So, what are you going to do about that?"
>
> SME 1: '…and I think you're right on. Because, I mean the point of this tool is to get some refinement and understanding about where to target the resources."

Example 2:

> SME 4: "It's ok, I mean what it's (iAID) telling us is that for younger kids, it's playground equipment and for older kids, skis skateboards, etc…"
>
> SME 8: right, right
>
> SME1: Uh, huhh.

As explained earlier, *Common Ground* represents the vital foundation for SMEs joint activities and collaboration [Clark, 1996]. By increasing their current *Common Ground*, SMEs intuitively improve their coordination and advance the performance of their joint activities [Clark p.92]. Once SMEs had shared knowledge, shared intent and shared goals, they were able to coordinate their actions and collaborate their work to progress the problem solving and decision-making process. We observed, towards the end of the analytics session, the Concluding Common Ground synthesized and represented SMEs cumulative assumptions and judgments. The Concluding Common Ground was the new *Common Ground* accepted and adopted by all SMEs to reach a solution that was believed to be the optimal solution to the given injury problem. SMEs embraced this Concluding Common Ground to agree and make an informed decision regarding the analytical injury problem.

7.1.1.2 Collaboration

Collaboration is essential to foster a cooperative problem-solving and decision-making environment among multiple stakeholders. The term 'collaboration' is defined as the interactions that occur between participants to exchange knowledge and expertise to coordinate their actions and share the task performance to reach a goal []. The success of group collaboration significantly depends on the presence of two main components, common goals and division of labor [Dillenbourg, 1999]. On the one hand, the existence of common goals and common interests among SMEs enhance the establishment of Common Ground among SMEs. On the other hand, shared labor is another relevant component that enhances the success of group collaboration through cooperation among members to distribute the task performance. According to Clark (1996), collaboration refers to the 'Joint Activity' that involves multiple participants where each one takes a specific role in the activity. These roles are substantial to coordinate participants' actions in an attempt to perform a domain task or achieve a common goal [Clark, p.33]. Contrary to the HCI context, where collaboration is referred to the 'equal participation' of involved players with no specific roles, this study presented that various types of collaboration that occurred not only among and between the SMEs but also between the VAE and SMEs as well as between the facilitator and SMEs. The Paired and Group analysis sessions manifested two different types of collaborations: 1) Collaboration between SMEs-VAE-Facilitator, which takes the form of a 'joint activity' that helps to mediate and to arbitrate the paired or group analysis sessions. Each participants is assigned a very specific role that is part of this joint activity 2) Collaboration among SMEs-SMEs, which refers to the exchange of knowledge and expertise to establish a Common Ground that facilitates the argumentation, the distribution of cognition and the advancement of the problem solving. Throughout the sessions, SME-VAE-Facilitator collaboration clearly has a different collaborative role compared to SMEs-SMEs collaboration that occurred when SMEs are discussing potential meaning and solution to the wicked health problem.

This type of cooperative environment promotes the exchange of new ideas, elaboration of new alternatives and discussion of broader perspectives concerning a particular analytical problem. Within the public health sector, stakeholders come from diverse background and disciplines; they are health professionals, health researchers, policy makers and health practitioners. When addressing a wicked health problem, public health stakeholders rely on their background knowledge and expertise to bring along multiple perspectives and various approaches to solve a specific analytical health problem. Therefore, health stakeholders need to collaboratively discuss their various perspectives of health problems, argue the optimal solution and reach a consensus in order to effectively enhance the analytical problem-solving and decision-making process. According to Clark, '*Common Ground* is prerequisite for coordination- for joint actions' [Clark, p. 66]. Establishing a *Common Ground* emphasized SMEs common background, common beliefs, common expectations and common interests to achieve the goal. Once SMEs establish this *Common Ground*, they implicitly understand that they have a common goal and consequently coordinate their actions in order to achieve this common goal. As Clark explained 'To reach their goals, they have to coordinate their individual actions in a joint action' [Clark, 1996].

In this thesis, the transcripts of the video and audio files were closely examined and investigated using open, axial and selective coding techniques [Corbin & Strauss, 1990] using Atlas.ti. We observed the compiled data from the perspectives of Clark's Joint Activity Theory and the Distributed cognition framework to analyze the instances of *joint actions* among injury stakeholders or SMEs. Analysis of SMEs joint actions provided us with an understanding of the patterns of collaboration, communications and coordination among SMEs during the analytics sessions. Furthermore, this analysis enabled us to perceive and comprehend the emergence and advancement of *Common Ground* that laid the foundation for collaboration and coordination of joint activities among SMEs while addressing the proposed analytical task. In his book 'Using Language', Clark explained that according to Thomas Schelling (1960), people coordinate their activities to address coordination problems. He further argued, 'two people have a coordination problem whenever they have common interests, or goals, and each person's actions depend on the actions of the other' [Clark, 1996]. During the interactive group analysis sessions, we noted how SMEs actively engaged with each other to coordinate their joint activities and how their involvement in joint activities revolved around their joint goals, joint intentions and joint incentive to find a solution to the wicked problem. The observed patterns of collaborative activities were categorized into five main activities within the context of their impact on the problem solving and decision-making process. Five types of collaborative analytics activities were identified including Collaborate to Explore (C2E), Collaborate to Visualize (C2V), Collaborate to Argue (C2A), Collaborate to Solve (C2S) and Collaborate to Decide (C2D). The rest of the section discusses in details these various types of collaborative activities and how they impacted SMEs problem solving and decision-making process.

1.Collaborate to Explore (C2E)

The analytics session fosters a dynamic and learning environment for SMEs to explore the data and the health problem in a collaborative social setting. Each SME brings personal prior knowledge and expertise into the collaborative process. Through their joint actions, SMEs collaboratively explored the injury problem; they shared their personal goals and expectations and learned from each other's expertise and background knowledge. As one SME emphasized it*: "it's like a learning that happens in Groups."* This exchange of knowledge led to the establishment of shared understanding and the negotiation of a *Common Ground* to collaboratively solve the analytics problem.

To efficiently tackle the injury problem under investigation and reduce its impact on individuals and communities, SMEs needed to effectively explore and consider the injury data to make sense and gain an in-depth understanding of the data content. As explained earlier, the injury data were multidimensional data that included temporal and spatial information related to the time trends variation of leading injury causes (i.e. which month exhibits peak rates of a particular injury cause) as well as the distribution of injuries across geographic locations (i.e. which province shows the highest rate of a particular injury cause). During the session, we documented the various ways in which injury stakeholders collaboratively explored the data using the *i*AID dashboard. For SMEs to coordinate their actions, they need to mutually understand the same information in the same social setting. The *i*AID dashboard acted as a *Coordination*

Device and a focal point for SMEs to use the visualization as a reference to their communications and evidence to support their claims. This *Coordination Device* constitutes a mutual bases and goals to converge SMEs individual actions and coordinate their activities [Clark, 1996]. The *i*AID dashboard enhanced SMEs coordination of actions, enabling them to commonly observe similar information and acquire similar knowledge from the visual display. As SMEs agreed upon the visualization interpretation, represents 'explicit agreement' for SMEs to build their joint activities. The *Coordination Device* is essential to allow SMEs to 'choose the right participatory actions to perform' [Clark, p. 65]. The iAID dashboard constitutes an additional piece of SMEs 'explicit agreement' and ultimately additional piece to their *Common Ground*. We observed that injury stakeholders collaboratively interacted with the *i*AID dashboard and manipulated the injury data with the support of the VAE. They sought answers to questions such as 'What is the leading injury cause?', 'What types of injuries occur for each of the causes', 'Who is the most affected by this injury cause?', 'How is this injury cause trending over time?', and "what is the geographic distribution of this injury cause?'. The following script excerpt illustrates the collaboration and communication between SME and VAE while exploring data related to the injury cause 'Window Falls':

SME 4: we wanted to look at trend data, for example.

VAE: Ok, so mainly trending.

SME4: we had few interest, first we… let's look for trends over time. Our "Window Falls" are going up or down?

VAE: OK

SME4: We also wanted regional, because different provinces have different building codes and requirements and so you might expect that there will be different…See the problem here is we want rates of course…and say different numbers in different regions depending on their building codes and so on…

VAE: Uh, huhh…

SME4: So then the other thing we're interested in is the age groups that are most affected because we're expecting, really expecting that the under 3s…

VAE: Uh, huhh

SME4: …And, we also had to look for sort of mechanism, so for example: 'Are they climbing on furniture and falling off the *windows?', 'Are they on a balcony and they're just kind of falling over the edge?' Or you know…what are some of those things that could happen?*

VAE: yeah.

SMEs interactions with the data were of an exploratory nature. These interactions helped to communicate key information about selected injury indicators, bringing SMEs to a Common Ground and common understanding of the complex data. These interactions further raised the flag for alerting areas of high injury rates while giving injury stakeholders a comprehensive picture of the health situation. Furthermore, they oriented injury stakeholders' efforts and timely decisions towards areas of urgent need for interventions and injury prevention programs. The following example shows the interaction between SMEs and VAE to further explore the major burden of injury: 'Falls', investigate its sub-causes, as well as identify the age group at risk:

SME 8: So, what we're looking at. Is this incidence or …?

VAE: This is the type of injuries…Umm, per year.

SME 4: The Falls were over and above. Like they were way higher than others.

VAE: Those are the causes. Yeah. Then, let me go to the dashboard, then, you want to explore further the causes of…Uhh, so, let's take a look at this…this one (See the Falls).

SME 4: and then the subtypes of the "Falls".

VAE: Uh, huhh.

SME4: That's 'Chairs', etc.…'Furniture', 'Falls from Furniture' looks like it's big. I want to see the Age Groups. Is that Ages?

VAE: Yeah, since I have so many categories, I have the Age Group up there. Is there any particular sub-cause that you're interested in?

SME 5: can you get it to show the way it's stacked...Uh, so within each of that, so the "Falls from bed, chairs and furniture", within it to show the Age Group? Can you get to be that way?

Furthermore, Injury stakeholders collaboratively explored the dataset to learn more about its various dimensions and variables. The data exploration also served to offer internal verification of the injury data collection and categorization process:

SME 7: So do concussions not show up as head injuries?

SME 4: they have separate categories.

SME 5: yeah.

SME 8: Severe injuries, right. So maybe, yeah… So can we get both?

VAE: let me go back to the types of injuries here.

SME 5: yeah, they're Intracranial

SME 4: Intracranial.

SME 5: yeah, so normally concussions are counted with cranial when we do the coding.

SMEs 8: What are the 3 categories?

SME 5: there is normal head injuries, there is the severe ones and the 'Cranial' and 'Concussion' is grouped as part of the 'Cranial'.

2.Collaborate to Visualize (C2V)

The *i*AID dashboard combined multiple coordinated views to present the multidimensional aspects of the injury problem on a single interactive platform. The interactive dashboard was perceived as a *Coordinated Device* [Clark, 1996] that provided stakeholders with a dynamic technology to visualize complex injury data in order to uncover key information about leading injury causes and to identify areas that require investigation. During the Group sessions, we observed SMEs collaboratively interacted with the shared visual display of the dashboard that is engineering to be part of SMEs shared environment and support their established *Common Ground*. SMEs collaboratively contributed, agreed and decided on the relevance of each variable, combining and integrating their knowledge and coordinating their actions to create and refine the most useful the visualization. The final refined visualization represented SMEs new *Common Ground* that could be exploited to advance the problem solving process. This example shows how SMEs collaborated to conduct a series of refinements to select relevant variables, through Drill-downs and Brushing/linking techniques to finalize the visualization in a way that supported the problem solving approach:

Example 1:

SME 8: "Struck by/against", OK

VAE: OK

SME 1: exclude the..

SME 8: so "Falling"

VAE: "Legal interventions"?

SME 1: yeah

VAE: "unintentional"?

SME 4: Keep that one for now

SME 3: Keep that one

SME 1: yep, keep that one

SME 1: "Overexertion"?

SME 4: You can get rid of that one, I think

SME 1: yeah

SME 4: Keep that one.

VAE: Yeah

SME 1: "Suffocation" and "Chocking"? There shouldn't be any of those here.

VAE: Should I exclude this one?

Example 2:

SME 3: "Fire Flame"

SME 4: yeah, get rid of "Fire and Flame"

SME 1: yeah, get rid of "Fire and Flame".

SME 4: 'Firearms' are going to…

SME 1: I'm sorry, helmets will not going to serve you, I don't think so…

SMEs: (laughs)

The visualization tool was intended to amplify SMEs analytical reasoning and cognitive capabilities to facilitate their problem solving and decision-making process. The observed interactions with the visualization helped SMEs to internalize the information and ultimately gain knowledge about the injury data. As one SME summarized the experience, "*So, I think what you have up there right now actually supports the beginning of this discussion. So you can actually start seeing, you know, what is the burden right now? And what are some of the trends? Where the trends are going? And, you know, Male/Female and Age groups even."* In the context of Visual Analytics, Liu et al (2008) argued, "External visualizations are internalized as mental models. A mental model of an interactive visualization can be constructed and simulated in working memory for reasoning" [Liu et al., 2008]. This observed process of collaboratively interacting with the visualization enabled SMEs to build accurate mental models of the external visual display to comprehend the content of the data and therefore more effectively perform correct analysis of the injury problem. In a study conducted by Fischer et al. (2002) related to the use of visualization tools to foster collaborative knowledge construction, the authors demonstrated that by providing participants with a content-specific visualization tool, they noticed improvement in both the outcome as well as the process of the collaborative work [Fischer et al, 2002].

Collaboratively interacting with the visualization helped SMEs to understand the data and effectively interpret the generated visual displays. The following excerpts show how SMEs collaborated to refine the generated visual display based on their needs (Example 1,2,3) and visual preferences (Example 4):

Example 1:

> SME 4: So these are all ages… all females and males.
> VAE: that's right, yeah.
> SME 4: so it would be nice to have the age group
> SME 1: So let's drag the age group there
> VAE: where are my age groups? Up here, there you go!

Example 2:

> SME 1:We want the type of injuries at the bottom. By…
> VAE: By?
> SME 1: Sex.
> VAE: OK

Example 3:

> SME 5: "…and then once you've done that (knowing the injury causes), you want to know what types of injuries are occurring for each of these causes" (l. 1569-1571).

Example 4:

SME 8: Can you do that in a bar form, or is it (addressing the request to the VAE)? Can you do that? That would be nice.

VAE: A stacked bar? Yes.

SME 1: yeah… we wanted stacked, yeah

SME 4: Humm….yeah…useful

SME 8: Here you go!

SME 1: OK!

Another type of collaboration was observed during the group analysis sessions: The SMEs-VAE collaboration. This type of collaboration between SMEs-VAE revolved around the use of the visualization tool in a way that could improve the efficiency and effectiveness of the analytical collaborative to advance the problem solving process. SMEs collaborated with VAE to resourcefully exploit the visualization tool and accurately interpret the visual displays. This collaboration helped SMEs to focus on the analytical problem rather than on learning the tool's functionalities. The following excerpt scripts, retrieved from the follow up interview, confirmed our observation and illustrate SMEs experience on the SMEs-VAE collaboration:

> SME1: "it (collaborating with VAE) meant that I could focus on being a researcher and a content expert without having to worry at all about the tool."

> SME2: "… usually when I approach a research project, I have to think about all aspects of it. But in this one, you (VAE) took care of the technical aspect of it and came up with some suggestions, so that was great for me because that's not one of my biggest skills."

> SME3: "I think it's important to have that (collaboration) because the Subject Matter is an expert in the subject matter and the Tool Expert is the expert in the tool so there might be something that the subject matter may not be aware that the tool is able to do… and if you do not work together hand in hand, it's not going to be very effective."

3. Collaborate to Argue (C2A)

The interactive collaboration among SMEs engages their perceptual and cognitive capabilities to discuss and argue their various viewpoints in order to improve their *Common Ground* and agree on a shared goal and a common solution to the problem. The analytics sessions promoted a collaborative setting for SMEs to explore each other's ideas and thoughts, establish a common understanding of the data based on SMEs *Common Ground* and shared knowledge and experience. During the analytics sessions, SMEs argued numerous concepts and tried to persuade each other to adopt a viewpoint that extended each SMEs limited perspective about the analytical problem under investigation.

The analysis of the quantitative questionnaire data, collected after the group sessions, suggested that the interactive group sessions fostered a collaborative environment that empowered SMEs to share their ideas and to learn from each other's background knowledge and experience. The analyzed data states that 71% of SMEs strongly agree while 28% agree that the group session stimulated discussions among SMEs. Furthermore, 50% of SMEs strongly agree, while 33% agree and 16% somehow agree that the group sessions helped SMEs to brainstorm new ideas and share them with other SMEs. According to Fischer (2002), collaboration among a group of participants helps to elicit the retrieval of prior knowledge related to the task [Fischer, 2002]. We observed that the collaborative sessions provided a stimulating platform for SMEs to interactively talk about their personal experience, suggest new perspectives into the data interpretation, explain their thoughts and ideas, and support their viewpoints based upon prior knowledge and skills.

Within the context of the proposed analytical task, SMEs collaborated to present various viewpoints, argue broader perspectives and suggest solutions about the use of helmets as a preventive measure to avoid specific types of injury causes. During the sessions, SMEs communicated their viewpoints with other SMEs and tended to justify their thinking, clarify their perspectives and support their claims. By explaining and conveying ideas to other SMEs, they developed new ideas and refined the solution. We noticed that during the group sessions, SMEs showed willingness to listen to each other's perspective and understand each other's position in order to reach a *Common Ground* that advanced the problem solving process. The following excerpts show how SMEs negotiated taking turns in harmony with the activity to present their viewpoints and argue the relevance of each data variable to the problem solving process:

Example 1:

SME 8: very good! So you can see 'Concussions', 'Others'…that others is concerning!

SMEs: (laughs)

SME 4: so "Open Wound", we can get rid off…because helmets aren't really…

SME 3: they might...

SME 2: yes, they do!

SME 7: yeah

SME 3: something comes of it too.

SME 4: Yeah… But helmets kind of don't prevent cuts

SME 3: well in skiing

SME 2: yeah, skiing.

SME 8: We're really interested in head/brain injuries, right. I assume that "Open wound" is excluded, just because of 'Open Wound' is not a possible brain injury. That wouldn't be in that category, right.

Example 2:

SME 4: you can get rid of "Eye Injuries". (Addressing the comments to the VAE)

SME 1: get rid of "Eye Injuries".

SME 2: Really?

SMEs: (laughs)

SME 7: Hockey helmets counts for the big part of Eye injuries.

SME 1: yeah, Hockey helmets

The collaboration around the visual display served to support SMEs argumentation and align their goals and interests. The *i*AID dashboard enhanced SMEs effective communication and collaboration through the use and exchange of common visual displays as a *Coordinated Device* to clarify their arguments, validate their claims and emphasize emerging injury issues. During the analytics sessions, we observed that SMEs collaboratively used the visual display to communicate their ideas, explain their viewpoints and support their arguments using evidence from the display. The visual display helped SMEs to coordinate their actions and collaborate their activities in order to expedite the problem solving and decision-making process. One SME expressed her experience within the group session, she said: *"It's more than sharing, it's also further exploration. So, because undoubtedly questions will come up when we start sharing our perceptions... So it's sharing, plus further analysis."*

Collaboration among multiple SMEs was fundamental to exchange knowledge and expertise. Through conversations, discussions and argumentation, SMEs were able to constructively exchange thoughts and ideas about the data, communicate and transfer knowledge in order to reach a consensus about the optimal solution. During the follow up interviews, we asked SMEs to reflect on this collaboration and its impact on the exchange of knowledge, they explained:

> SME1: "So I thought the interaction and having the other experts there as well, people who have used the data differently, I thought that the interaction was really helpful."

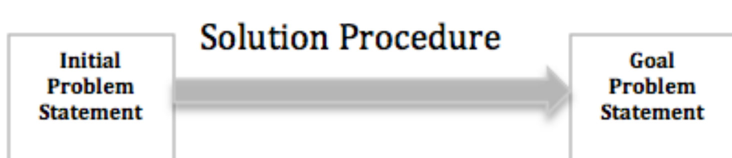
> SME2: "I think that our group session was great because we sort of all everyone got some words in and they were able to work together on that."

> SME3: "That (Group session) was very good, because as a group other people were able to bring in ideas that maybe some other people have not thought of, so it's more like a brainstorming kind of session where everybody chips in, you can get a better picture of the whole entire thing versus when you just by yourself, you might not be able to think of those ideas that might come up in a group."

4. Collaborate to Solve (C2S)

A problem solving process is defined as 'any goal-oriented sequence of cognitive operations [Robertson, 2003, from Anderson, 1980]. According to Robertson (2003), the problem solving process refers to the process of moving from the initial state of the problem to the goal state of the problem [Fig 7.2].

Figure 7.2. Problem Solving Process

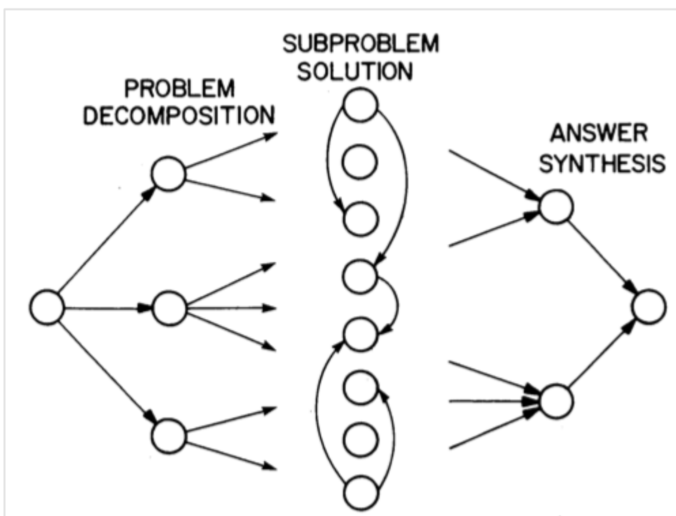


Robertson postulated that problem situation along with prior knowledge constitute the fundamental components of the problem solving '*Initial State'* that experts rely on to progress toward a solution (i.e. the '*Goal State'*). Problem situation, on the one hand, constitutes a critical element to situate the problem and its associated solution and decisions. For injury stakeholders, identifying a peak in 'Fall' injuries indicates an alarming health problems that needs to be closely examined and addressed. This problem situation is important to gain insight into the problem solving by studying the problem major elements and investigating its characteristics to build in-depth understanding of and construct a comprehensive knowledge about the problem. Gaining insights into the current status of the issue is important to solve the problem in order to make better decisions and take appropriate actions. Pirolli & Card (2005) proposed the sense-making process to obtain insights into problems. The sense-making model (i.e. Information -> Schema -> Insight -> Product) consists of four phases including: gathering information, re-representing the information in an easy-to-understand format manually or using a computer-supported system (i.e. schema), gaining insights into the data, and finally building a knowledge product based upon the gained insights that is necessary to solve analytical tasks [Pirolli & Card; 2005]. Using the iAID dashboard, SMEs manipulated the injury data and re-represented the information to gain insights into the injury situation.

On the other hand, prior knowledge is essential to assist analyst in making sense of situations to solve the problem and make appropriate decisions. Possessing problem-specific knowledge represents a crucial step towards reaching a solution or decision. Wang et al. (2009) underscored the role prior domain knowledge plays in the data analysis process. The authors postulated that integrating domain knowledge into the data exploration process enable analysts to gain insights into complex data and consequently enhance the analytical process [Wang et al., 2009]. Within the context of this study, SMEs were able to effectively interpret visualizations and effectively process retrieved information based on prior experience and expertise in the field of injury prevention. SMEs prior knowledge and diverse expertise were combined to constitute an invaluable source to address the injury situation and solve the analytical task.

Collaboration proved to be necessary for SMEs to efficiently and effectively distribute the problem solving process among group members. Many models and theories explained the various types of collaboration among group members within the context of problem solving. An early work by Smith and Davis (1981) described the two main forms of cooperation that can be established among a group of experts within the context of distributed problem solving: 1. Task *Sharing* (i.e. divide the task and workload among group members) and 2. *Result Sharing* (report the findings and share the results among group members). According to Smith and Davis (1981), a group of human experts can cooperate to solve a problem either by partitioning the problem into sub-task or sub-problem and an expert or a group of experts can solve it independently, or by interacting with other experts periodically to seek assistance or share results [Smith & Davis, 1981]. Furthermore, Smith and Davis (1983) proposed a distributed problem-solving model as a framework that integrates these two cooperation forms (Fig 7.3). The proposed distributed problem-solving model tends to separate the problem solving process into three main phases: the Problem Decomposition phase and the Sub-problem Solution phase, the Answer Synthesis phase [Smith & Davis, 1983].

Figure 7.3. Distributed Problem Solving Model



Within the context of this thesis, we extended this model to adapt it to the collaborative and social setting of the Group analysis sessions. SMEs worked together to decompose the problem into manageable chunks and work on them collaboratively, rather then independently. The distributed problem solving approach underscores the need to cooperate among SMEs to partition and share the problem as well as exchange the results in an attempt to solve the problem. Drawing from their collective knowledge and background, key injury stakeholders and decision-makers collaboratively interacted with each other and with VAE to efficiently mine the injury data and retrieve salient information that facilitate the problem solving process. SMEs contributed numerous viewpoints and approaches to tackle the health issue. In both group sessions, we observed that group members efficiently manipulated the visualization tool with the support of VAE to successfully solve the analytical problem.

> SME3: "Having a Tool Expert there, having someone to talk through, that really knew the data intimately, cause I'm going to the data to ask a question, I don't know all the details in the data… but when I do have the question, it's really helpful to be able to know if there are any issues or to be able to talk to someone who is immersed with the data who can help me out with the problem solving."

SMEs and VAE's collaborative interaction with the visualization tool enabled SMEs to conduct dynamic analysis of the multidimensional and complex health data. The diversity of injury stakeholders or SMEs expertise, the technical knowledge of VAE and the use of the interactive dashboard enhanced the problem solving process. Each SME presented a new perspective of the problem and the approach to solve it. A subsequent synthesis of the proposed solution combines SMEs suggested solutions and approaches to solve the problem.

The following 2 scripts illustrate how SMEs voiced their approaches to problem solving:

Example 1:

> SME 8: I'll be looking at it a little bit differently though.

Example 2:

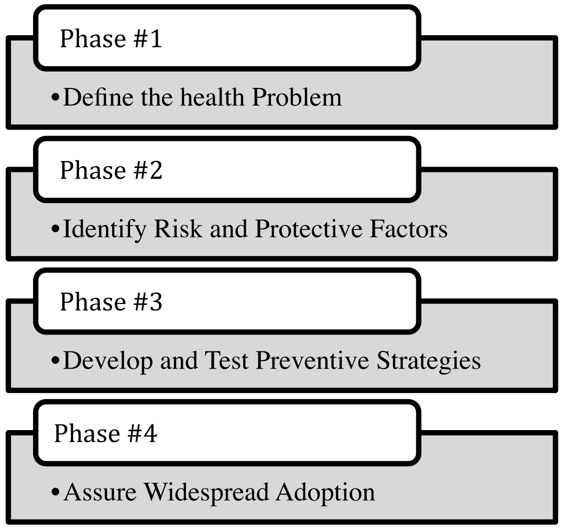
> SME 3: We want helmets; can we look at what uses helmets, what for? What if we isolate sports, bicycle?
>
> SME 8: we're trying to, but we don't know what "Struck by/against" means and we don't know what …
>
> SME 3: No, but what if we search by that instead of by the causes? Can we take that out and …
>
> SME 4: like falling from skateboards, something like that?
>
> SME 3: yeah, switch it, like. So we're actually looking by the things that we know there is helmets for.

During the group analysis session, group members collaboratively embraced an interdisciplinary discussion and argumentation to enhance the chain of inference through the distributed cognition process to ultimately solve the analytical problem and reach an informed decision. The collaborative session fostered a socially distributed cognition environment that relied on stakeholder interactions and engagement with their surrounding environment including tools, artefacts and other people [Hutchins, 1995]. Communications were established among SMEs to exchange knowledge, discuss viewpoints and propose solutions. This phase integrates SMEs interactions with each other and with VAE to manipulate the injury data and retrieved information. From a cognitive science perspective, SMEs gain insights into complex data and dynamic situations to advance the analytical task within a distributed cognition framework. Hutchins stressed the role distributed cognition process among individuals and artefacts including the environment and cognitive tools. The combination of cognitive properties of a group along with artefacts and social environment constitutes a cognitive system that provides the right context to promote the distributed problem solving process based on the collaborative interactions between multiple components of this cognitive system.

Analysis of the quantitative data confirmed this social cognition phenomenon. The analysis reported that the majority of the SMEs explained that interacting with the visualization provided them with useful information to support their task analysis (33% strongly agree and 50% agree). Retrieving information from the visualization enable SMEs to gain knowledge about the injury data. Collaboratively discussing and evaluating the gained knowledge among SMEs enhanced the quality of their problem-solving outcome and led to a superior solution compared to what might have been reached by a single stakeholder.

Within the context of the proposed analytical task, we observed that SMEs partitioned the problem using the public health approach. SMEs coordinated their actions to approach the problem solving and make an informed decision using the *i*AID dashboard to manipulate the CHIRPP injury data. SMEs examined the data and approached the problem solving process through the lens of the four stages of the Public Health Model [Fig 7.4].

Figure 7.4. The Public Health Model.



In the first phase, SMEs were interested in defining the health problem and identifying the leading injury causes. Throughout the next phase, SMEs exploited the knowledge gained from the first phase of data exploration to advance through the process of problem solving. SMEs started to generate hypotheses and formulated new research questions about the potential risk factors that might be causing the occurrence of specific types of injuries.

SME 1: ... All of these "Fractures" are severe enough; they should be prevented... where do we go next? I would say we would look at the causes of "Fractures" next.

SME 2: yeah.

SME 3: Let' s look at the "Fractures"

VAE: Uh, huhh. So, I'm just going to keep the "Fractures"

SME 4: Keep the Fractures,

VAE: and then I'm going to add the causes.

SME 4: and the causes go up there and that should stack it up...

SME 1: Oh Look, it' s Fall! [Pointing at the visualization]

Thirdly, SMEs interpreted the visualizations and used the generated findings as an evidence-based approach to address the injury problem. SMEs tried to use the acquired knowledge to decide on appropriate actions that should be considered in order to control or prevent the likelihood of child and youth injury. And fourthly, SMEs were not able to actually apply this last phase of the public health model nor observe the effects of such long-term decisions during the analytics sessions. However, SMEs were able to identify the impact of previously implemented injury prevention strategies through the observation of the injury yearly and monthly trend lines especially noticing the decreased number of injury cases that followed the integration of particular health promotion programs, deployment of additional health resources as well as enforcement of new public policies.

Furthermore, we used Chronoviz system to study how SMEs collaborated with each other throughout the analytics session as well as to observe how the phases of the problem solving process unfolded through time (i.e. SME research question → create visualization [Fig 7.5]→ refine visualization [Fig 7.6]→Drill downs [Fig 7.7] → Analysis and further refinement [Fig 7.8]):

Figure 7.5. Chronoviz: Creating Visualization based on SME's task requirement.

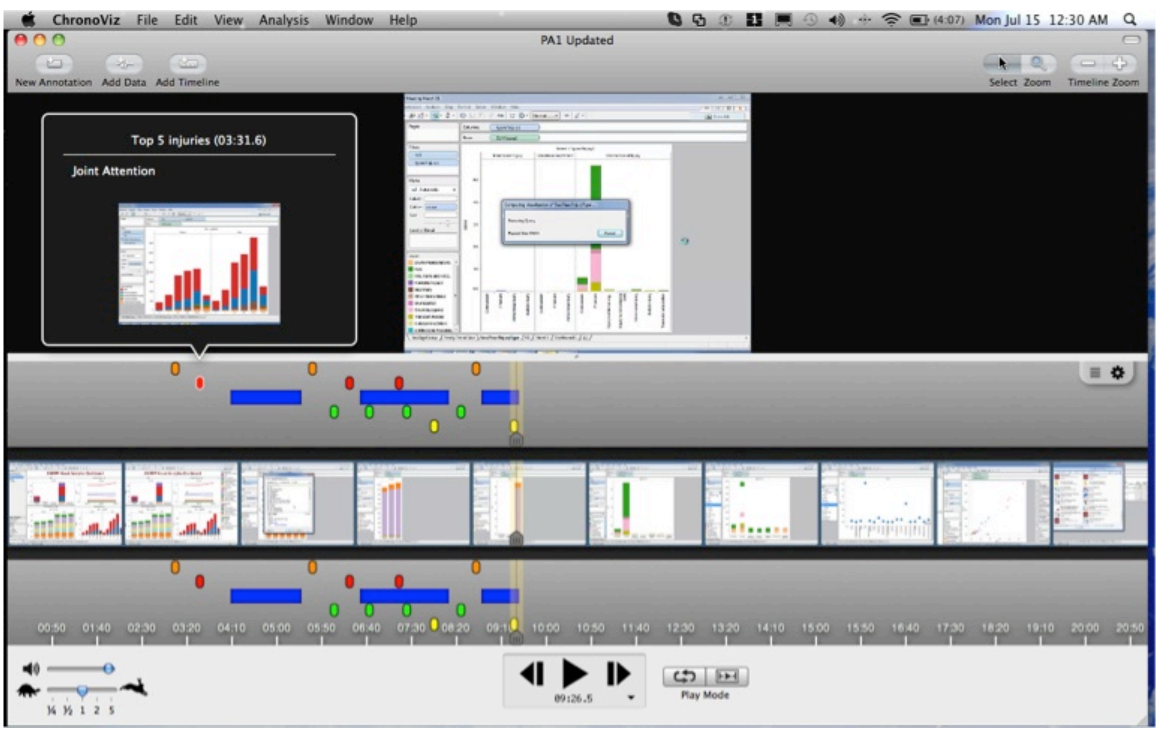


Figure 7.6. Chronoviz: Refining Visualization through Variable Selection.

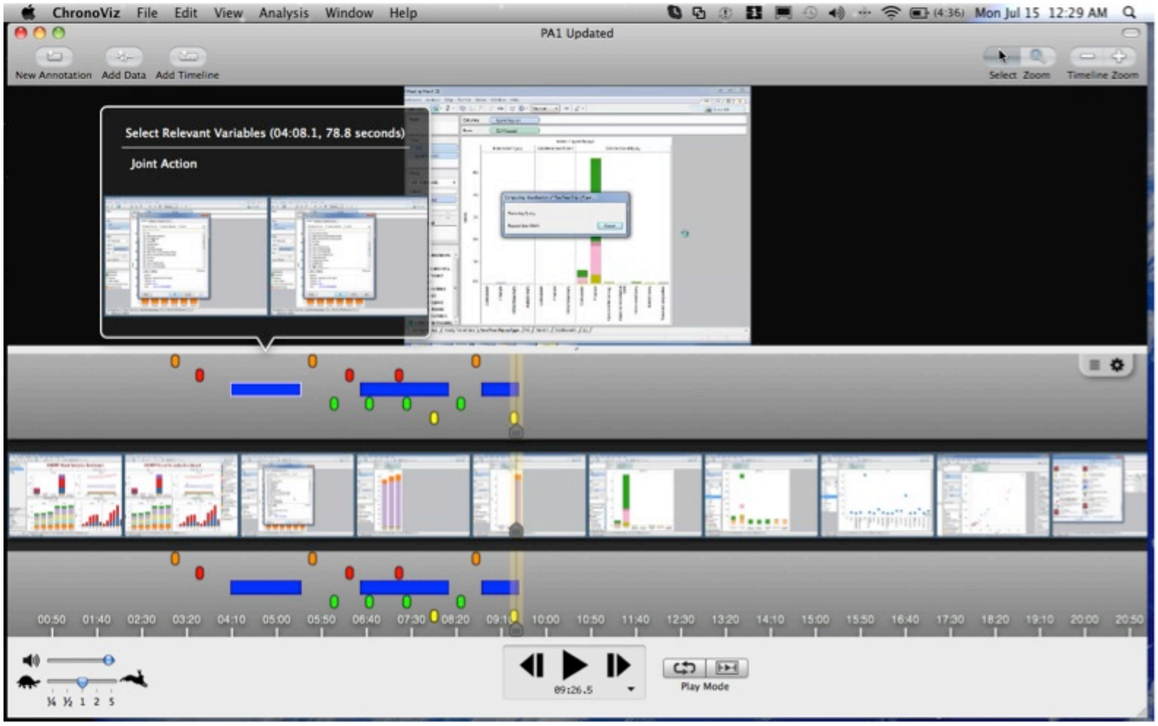


Figure 7.7. Chronoviz: Applying Visualization Drill.

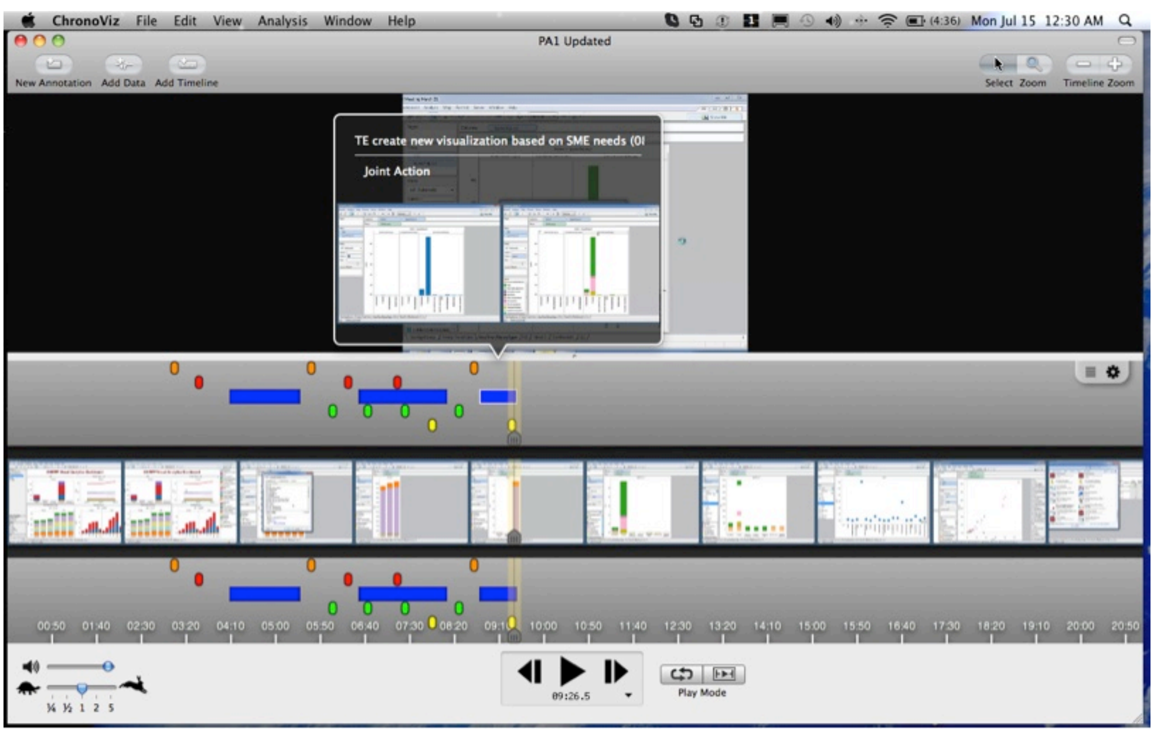
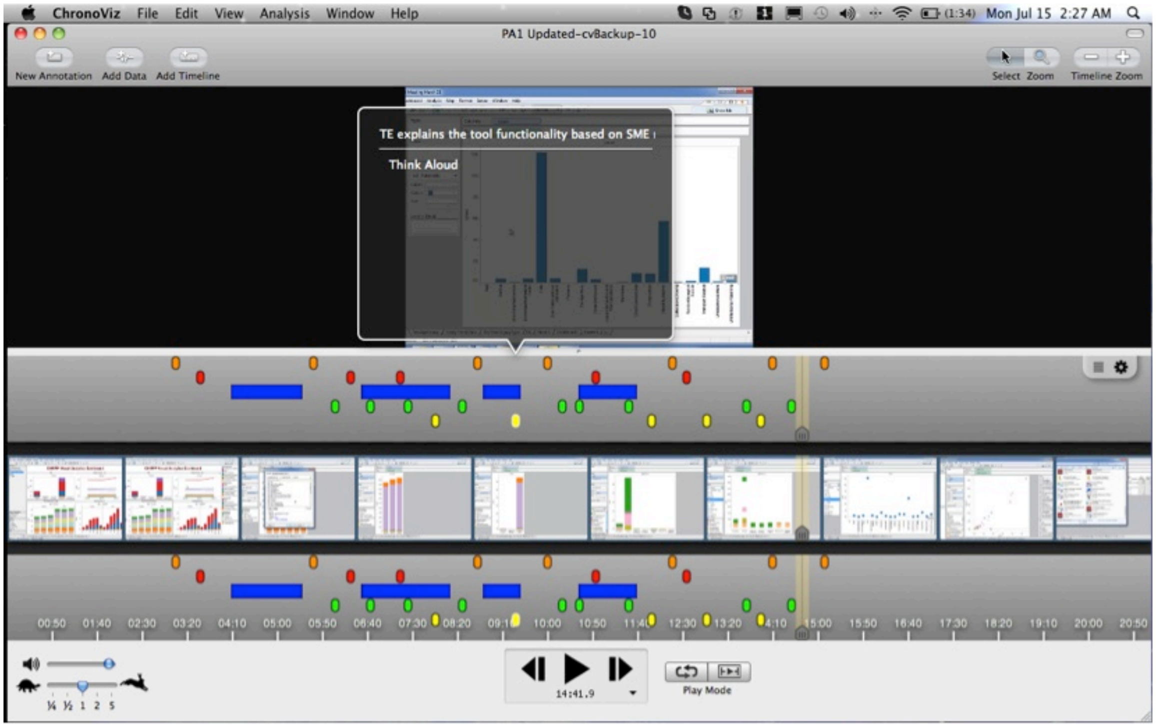


Figure 7.8. Chronoviz: Final Visualization Further Analysis.



5. Collaborate to Decide (C2D)

Towards the end of the session, SMEs collaborated to finalize their findings and reach a consensus. Based on the literature, reaching a consensus can be achieved either by SMEs settling on a common solution to the analytical problem or by combining SMEs multiple viewpoints and perspectives into one solution [Fischer, 2002]. In this study, SMEs tend to discuss, argue and negotiate their various perspectives to agree on shared understanding of the issue and a Concluding *Common Ground* to decide on an optimal solution to the analytical health problem. As SMEs summarized the collaborative group session experience:

Example 1:

> SME 7: "I think it's always better to make decisions in a group. If you're making high-level decisions, you need to have multiple inputs".

Example 2:

> SME 3: "the group session, there were a lot of exchange knowledge and expertise that helped with the decision-making process, because with the group session you have people with different types of expertise that bring together their ideas so it becomes a joint kind of collaboration."

In an early study, Fisher [1970] proposed a four-phase model for a decision-making process in a task-oriented group. The author identified the first phase as the "*Clarification and Agreement"* phase, in which members of the group explore the task and the social setting while seeking harmony with other group members to facilitate their interactions and work performance. Fisher labeled the second phase as the "*Dispute*" phase, in which favourable and unfavourable opinions are presented and examined by members of the group. The third phase is portrayed as the "*Conflict and Argument"* phase where group members discuss and argue the different viewpoints in an attempt to reduce conflicts between polarized opinions. The last phase of the decision-making model is characterized by the "*Emergence and Reinforcement",* in which various decision proposals emerge in this phase and members of the group work on reinforcing the favourable proposals to reach a decision.

In our study, SMEs decision-making process followed similar pattern of approaching problem solving and decision-making. However, we noticed that integrating a visualization tool into the decision-making process enriched Fisher's proposed decision-making models as SMEs relied on the visual display as a common evidence to support their assumptions and claims. As a *Coordinated Device*, the visualization tool minimized the dispute time and helped to reduce conflicts in polarized opinions by supporting SME's viewpoints through data manipulation and visualization. Furthermore, the visualization acted as a piece of evidence that enhanced SMEs confidence in their final decisions.

In an early work, Endsley (1988) explained how decision-making is linked to situation awareness and information processing and understanding, within the context of air force mission. Endsley (1998) defined Situation Awareness (SA) as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future' [Endsley, 1988]. The author presented the Situation Awareness model and explained that aircraft pilots need to accurately perceive existing components of their surrounding environment to build comprehensive picture and awareness of the situation in order to make better decisions. The lack of a complete and accurate situation awareness can lead to misleading and wrong decisions. Within the context of public health “wicked” problem, it’s is vital for SMEs to be aware of context, the situation of the problem and the setting of the group session in order to decide on an optimal solution to the problem. The integration of the visualization dashboard enabled SMEs to use the visual display to support their arguments and claims through evidence of *Common Ground.* The visualization tool helped SMEs to monitor the injury situation and assess the current state of the injury problem and consequently support the decision-making process. SMEs manipulated the injury data, asks the data questions, refines the visual display and interactively explored the reduced data space to identify relevant information and build understanding of the overall situation.

Integrating SMEs cognitive and perceptual skills with the dashboard advanced visualization capabilities dramatically enhanced the data analysis and decision-making process. SMEs interacted with the *i*AID dashboard in a cooperative analytical loop to advance decision-making. This process emphasized the need for SMEs reasoning and judgment approach [Keim et al, 2011] to be incorporated into the analysis approach alongside with the visualization tool to decide on the best injury interventions that socially and environmentally resonate. SME’s cognitive and perceptual capabilities represent valuable assets in the cognitive decision-making process. Previous studies have reported the successful synergy between interactive visualization tools and human cognitive capabilities that can lead to improvements in hypothesis generation and decision-making process [Keim et al, 2008]. According to Keim (2010), analyst’s human factors including reasoning, judgment, cognition, perception, knowledge and creativity improve the outcome of the analysis and advance the decision-making process [Keim et al, 2010]. The following summarized excerpts supports our findings and illustrated the way SMEs integrated their knowledge and judgment to reason about their decision to ‘target skates and cycling groups’:

SME 8: yeah, So we decided that you know, to prevent the worst, what we think that other injuries we would target different kinds of skates and the group that are cycling, is that correct?

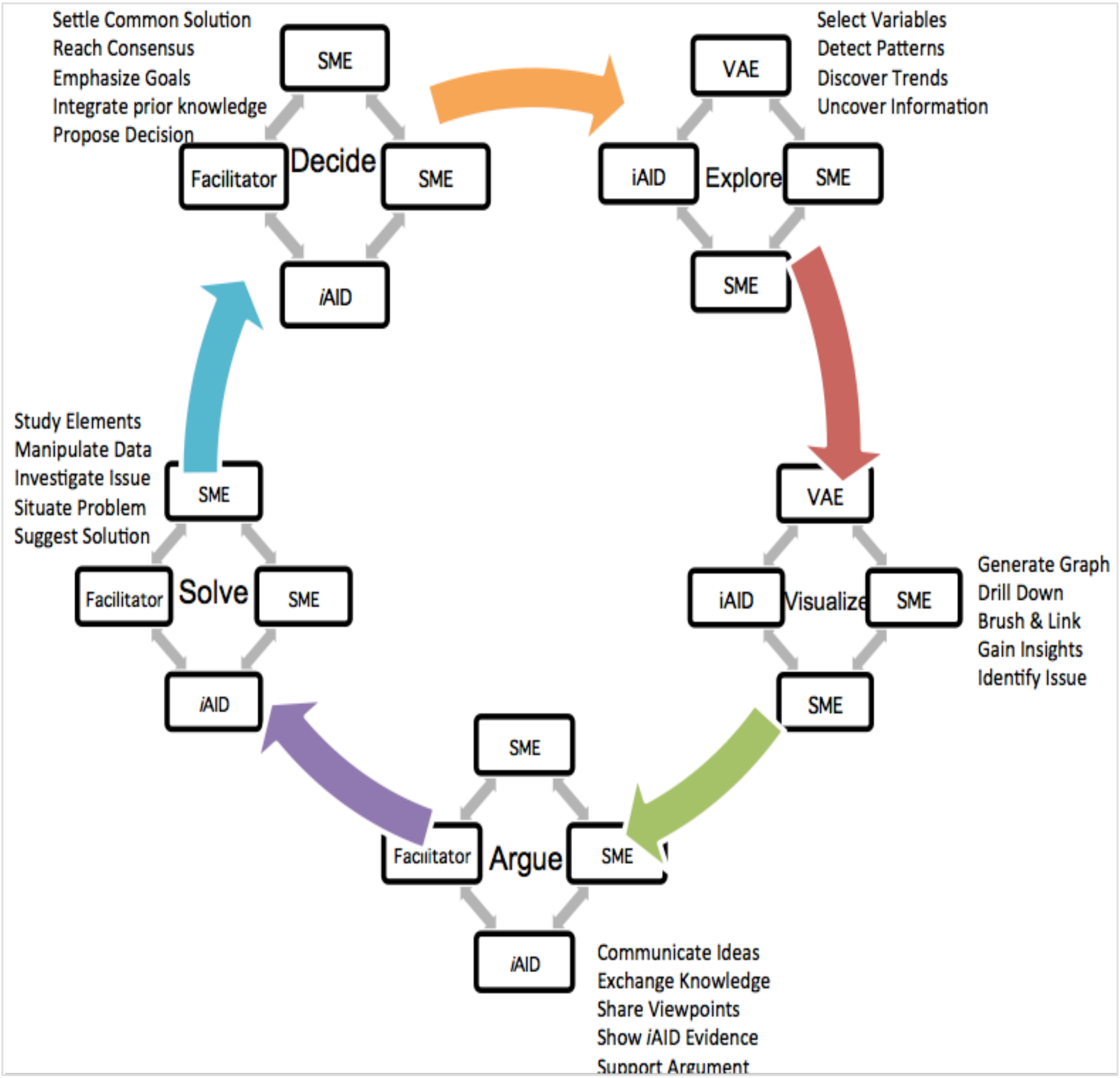
SME 3: yep, If you want wheel

SME 8: yeah, we would have to think about what you said, what's socially going to work? What with the policy and what the cultural around? That is going to be the story and an issue. But that's would be likely to target, I think.

SME 1: I think that's right. The protective nature of the helmet, where advocating for kids on small vehicles and cycles, right. So, Now having identified the target - where are they? And how do you market it and the policy and get it all in place?

This section presents various collaborative activities coordinated among multiple SMEs to explore the injury data, visualize and argue different perspective and ultimately solve the injury problem and make informed decision. We suggested a Collaborative Analytical Model that depicts the proposed collaborative activities among multiple SMEs taking place during the Group analysis sessions.

Figure 7.9. Collaborative Analytical Model



7.1.1.3. Interaction Styles

The definition and meaning of the term *interaction* varies based on the context and the field of study. In social sciences, *interaction* between individuals is defined as "the most elemental unit of social events, where people adapt their behaviour to each other, whether or not they follow mutual expectations or reject them. As coordinated action is not pre-programmed, a minimum of common meaning and linguistic understanding is necessary" [Kapmann, 1980]. However, *interactions* in a computer-mediated environment refer to “the actions of audience or recipients in relation to media content” [Jensen, 1998]. We synthesized both definitions to reflect the context of our study. We defined the term *interaction* as the social instances of communication and reflections of multiple individuals on the content of visualization tool. These interactive communications among SMEs serve to preserve and validate the established *Common Ground*, supported by the co-located computer-mediated environment.

We parsed the video files and captured instances of interactions among SMEs [Figs 5:8]. We focused our attention on the various interactions and communication channels established among SMEs throughout the session. Analysis of the videos from this perspective gave us insights into the nature and the various aspects of collaborative interactions among SMEs. Consequently, we identified and coded the following four types of interactions that took place during the Group analysis sessions:

1. All to Artefact (SMEs-Vis):

All SMEs focused their attention on the project single visual display and observed the content of the visual interface. VAE manipulated the injury data, built and refined the visualization based upon SMEs requests and needs. As shown in Fig 7.10, theses types of interactions varied based on the context of the analysis. We classified them into the following three main instances:

1. The first instance is when SMEs tested a scenario and wait for the created visualization to show up on the screen.
2. The second instance is when SMEs requested a refinement of existing visualization and anticipated a specific display. SMEs full attention is steered towards the visual dashboard to observe the refinement process, ensure that it matches their requests and anticipate the outcome.
3. The third instance is when the generated visualization is not what SMEs anticipated. SMEs pondered on the graph refinement and reflected on the findings.

Figure 7.10. GA Session: All SMEs to Artefact (SMEs-Vis).

2. All to One (SMEs-SME):

All SMEs focused their attention on one SME who was voicing an opinion or making a statement. Throughout the session, SMEs took turns reflecting on the outcome of the visual display based on their background knowledge and work experience. As shown in Figure 7.11, this type of interaction took place when SMEs focused their attention and listened to one SME who actively expressed a point of view, supported a claim or rejected other SME's viewpoint and proposed an alternative approach to problem solving. This exchange of knowledge through interactive and engaging conversations among SMEs played a substantial role in maintaining their Cumulative Common Ground and supporting their collaborative activities.

Figure 7.11. GA Session: All SMEs to One (SMEs-SME).

3. SME Pairs or Group, Rest to Artefact (SME-SME; SMEs-Vis):

SME interacted with other SME either in a One-on-One [Figures 7.12,7.13 and 7.14] or in a sub-group conversation [Fig 7.12] while the rest of SMEs focused and interacted with the visualization. These types of SMEs interaction style occurred when one SME shared minor observations about the visualization with nearby SME without engaging the whole group.

Figure 7.12. GA Session: SME Pair, Rest to Artefact (SME-SME; SMEs-Vis).

Figure 7.13. GA Session: SME Pairs, Rest to Artefact (SME-SME; SMEs-Vis).

Figure 7.14. GA Session: SMEs Group, Rest to Artefact (SME-SME; SMEs-Vis).

4. One-on-One (SMEs-SMEs):

SMEs interacted with each other in pairs or one-on-one (Figure 7.15). These types of interactions were essential to enable SMEs to discuss the various aspects of the problem solving, present their personal perspectives, share their background knowledge and convince each other in small groups before coming back and joining the whole group conversation.

Figure 7.15. GA Session: One-on-One (SMEs-SMEs).

On the one hand, some social psychologists argued that group interactions lead to a slow and less efficient process, which in turns prevent the group from achieving an optimal solution to the problem. On the other hand, other social psychologists argued that although interactions among group members imposes some delay in the collaboration process, it empowers group members with the ‘assembly effect bonuses’ that synthesizes group knowledge and inputs to improve the quality of the outcome and guarantee less errors in the results [Hackman & Morris, 1974]. In the case of this study, it was evident that the observed SMEs interactions with each other and with the tool in a modified Delphi structured setting contributed to the multifaceted dimensions of their collaborative analytics process and enabled them to efficiently and effectively solve the analytical task. One SME explained, “*that interaction between all of us, is what I think lead to better problem solving”.* We observed that SMEs interactions served to preserve and enhance their Cumulative *Common Ground* and consequently improve their coordination of activities. Social scientists Goodwin and Heritage emphasized the key role that interactions play in group communication and coordination of activities. The authors explained, “through processes of social interactions, shared meaning, mutual understanding and the coordination of human conducts are achieved” [Goodwin & Heritage, 1990]. This latter statement is applicable to this study. Throughout the sessions, we observed that SMEs interacted with other group members and verbally expressed their viewpoints and shared their understanding regarding the content of the visualizations. SMEs interactions were tightly linked to the collaborative activities intended to solve the analytical problem. As SMEs attended to a common task and shared mutual goals, they were engaged in collaborative activities facilitated by their various types of social interactions. These interactions structured SMEs collaborative activities and framed the way they shared knowledge and beliefs, communicated information and reflected on the content of the visualizations within the context of problem solving and decision-making.

The observed group interactions significantly influenced SMEs analytical task achievement and the advancement of the problem solving process. In a study investigating the relationship between student interactions in small group and high task achievement within an academic setting, the author concluded that interactions in small groups are correlated with high task achievement [Webb, 1982]. Webb synthesized findings from several studies and observations of students’ interactions while working on academic tasks and reported that students who were actively engaged in group interactions (i.e. explaining the task, exchanging information, providing and receiving help from other group members) exhibited higher task achievement. During the group session, SMEs interacted with each other and synthesized their multiple perspectives to present a comprehensive solution to the complex injury problem. One SME argued: "*I think that our group session was great because we sort of all everyone got some words in and they were able to work together on that".* This exchange of knowledge and expertise among multiple SMEs enabled them to solve the analytical task and see the solution from different perspectives. For instance, one SME commented:

> SME: "I thought the interaction and having the other experts there as well, people who have used the data differently, I thought that the interaction was really helpful",

Another SME added, when referring to the interaction with other group members:

> SME: "you see things that wouldn't have occurred to you to look for. And therefore that could be very helpful".

SMEs interactions not only helped them to solve the analytical task, but also to address the multiple aspects of the solution (i.e. "*what is actually actionable*", "*what socially resonate?*") by synthesizing the viewpoints of stakeholders with diverse background.

7.1.1.4. Role Awareness

The group analysis was a dynamic process that involved active conversations and role shifting among injury stakeholders or SMEs. Conversational analysts tend to emphasize participants' shifting of roles within conversation. Goodwin and Heritage, for example, argued that the activity of conversation in itself imposed distinguished roles and various positions on participating individuals [Goodwin & Heritage, 1990]. Our findings confirmed this latter statement and extended it to demonstrate that the different roles played by multiple stakeholders followed various patterns and changed constantly within a conversation as SMEs shifted from posing a question to providing an answer or comment to a question. The concept of role awareness presented a framework that influenced SMEs communication and collaboration. For instance, early in the sessions, SMEs did not assert their roles in the social setting, which limited their active contribution to the collaborative process. They were reluctant to share their ideas and viewpoints. They asserted the role of explorer to familiarize themselves with the task, the data as well as the social setting and their roles within this setting [Fisher, 1970]. As the session advanced, participants were actively engaged in collaborative activities. Participants interacted and communicated with each other, they switched roles frequently based on the sessions' setting, the context and the requirements of the collaborative task at hand.

We parsed the video files and examined participants' verbal and non-verbal behaviors to understand how role shifting influenced the way in which they collaborated and advanced the problem solving process. The roles SMEs and VAE assumed during their joint activities defined their responsibilities and determined their contributions to the joint activities. We observed and documented the roles played by VAE, SMEs and the facilitator within the context of collaborative problem solving and decision-making. Analyzing the data from the role shifting perspective gave us insights and clues into the importance of role awareness in collaborative activities. We anticipated that participants' role taking in the analytics sessions to be informative of the various aspects of collaboration between SMEs and VAE. Based on the observation of the video files and analysis of the participants' conversations, we identified the various roles played throughout the collaborative sessions and we classified them into the following two types of roles:

1. Fixed Roles

Fixed roles are well-defined roles played by participants (i.e. facilitator, SME or VAE) throughout the analytics session, regardless of the context of the analytical task.

a. The Facilitator:

The facilitator had a fixed role throughout the sessions. The facilitator was assigned the fixed role of a moderator. This role was well defined and perceived by VAE and participating SMEs. At the beginning of the each session, the facilitator introduced her role and presented stakeholders with a pre-set scenario to work on. Furthermore, the facilitator invoked rules about how the session needs to proceed, and what is expected from participants.

> Facilitator: "...my role as the facilitator is to provide you with the problem to solve as a group and to keep you on time. So you have around 20 to 25 to solve the problem. As well as to keep you on task, so if we find that stakeholders will go off to side conversations we'll ask you to come back"

After presenting the analytical problem, the facilitator role was to manage the session and steer the discussion. The facilitator encouraged all injury stakeholders to engage in conversations and participate in the discussion. She mainly steered SMEs work and guided them towards seeking support from VAE during the analysis process.

> Facilitator: "...we're hoping that you'll all participate. Likely to get started you'll need some information you need to know and that's where the Tool Expert will help you. So, when you feel ready, after you discussed it together, you can ask the Tool Expert to use the tool to find out the information that you need. Any questions about the process?"

The modified Delphi structured setting enabled the facilitator to organize the sessions and keep injury stakeholders within the bounds of the discussion as well as to eliminate opinion dominance. The facilitator role restricted her interference in the sessions' discussion in an attempt to foster a natural flow of conversation and argument to be carried out by SMEs. Throughout the analytical sessions, the facilitator ensured that SMEs stayed within the time limit for each session while steering the conversation towards reaching a consensus. As the multidimensional injury problem was complex and required the integration of multiple interventions, the facilitator guided SMEs towards reaching a consensus and deciding on an optimal solution. These two excerpts of interaction between SME and the facilitator explicitly show the role of the facilitator in steering the conversation towards a solution:

> Facilitator: "…I am going to ask you to be a little more concrete in getting to an answer".

> Facilitator: So for the sake of time, are you able to come to a …conclusion?
>
> SME: I think so

b. SME driver, VAE navigator:

Throughout the session, VAE had the fixed role of the visualization tool (*i*AID) navigator while SME was the tool driver. VAE was knowledgeable about the tool's functionality, and also expert in designing the data visualization and building the dashboard. VAE was in charge of manipulating the visualizations based upon SMEs needs and preferences. SMEs were knowledgeable about the injury data. They possess expertise and skills in the field of injury prevention and therefore they were in charged of taking turns to steer the analysis in order to advance the problem solving and decision-making process. SMEs discussed the problem under investigation, decided on a next analysis phase and requested VAE to refine the tool and retrieve essential information to support the problem solving process. The following excerpts show how VAE, as a navigator, executed SME's requests to refine the visualization and retrieve relevant information during the collaborative analytics session.

SMEs directly request information from VAE:

Example 1:

> SME1: "Give us concussion and head injuries" (l.7)

Example 2:

> SME5: "and then just keep "Head", exclude all others".

Example 3:

> SME 8: if you can see that the ones that are involving skates, what are the numbers in there? Can we see those 3 red bars?
>
> VAE: yes
>
> SME 8: just got to hover over the three red bars
>
> VAE: the red ones
>
> SME 8: in the graph, and what numbers are in here? How many?
>
> VAE: yeah (VAE hovered the mouse over the visualization to retrieve "Details-on-Demand" information)
>
> SME 8: 75…so that's a 125. And the other one is probably 60 or something

Example 4:

> SME 5: So if you could go back to the cause, I think you can put in Transport sub-cause.
>
> VAE: uhh, OK. Let me take the cause. We had a filter called, it was just "Falls". I'm just going to bring in "Transport"

SMEs request VAE to further refine the visualization and retrieve additional information:

Example 5:

SME 4: So these are all ages, all females and males.

VAE: that's right, yeah.

SME 4: so it would be nice to have the age group

SME 1: So let's drag the age group there

VAE: where are my age groups? Up here, there you go!

Example 6:

SME 4: but we want the off road and the bicycles, right?

SME 1: right

VAE: Uhh, so, I'm going to filter out this one.

SME 1: Uh, huhh.

VAE: the Pedestrians, you said.

SME 4: yeah, exclude

VAE: exclude…and…

SMEs request VAE to manipulate the visualization. Example 7:

SME 1:We want the type of injuries at the bottom. By…

VAE: By?

SME 1: Sex.

VAE: OK

2. Exchanged Roles

Exchange roles are different roles played by different participants (i.e. VAE, SME), based upon the requirements of the collaborative analytical work. SME and VAE exchanged roles from educator to learner and from speaker to addressee depending on the context of the task to be carried out. To facilitate the exchange of knowledge and support the learning process, VAE and SME adopted the "think aloud" approach throughout the sessions. The following excerpt shows how VAE explicitly expressed her thoughts and verbalized her reasoning approach to show SME the steps taken to manipulate the tool and refine the visualization:

> VAE: "I'm going to remove the "Causes" here…now I want to use the Sub-causes. Let me pull… they're going to be shown in here. And then, I'm going to stack the Sub-causes here".

SME and VAE exchanged roles during the analytics sessions when the emergence of both analysts' expertise and knowledge was needed to complete the task performance. VAE and SME took different roles each time that they attended to a common task that required one analyst (i.e. SME or VAE) to share her knowledge and expertise with the other analyst in order to be on the same page and advance the collaborative problem solving process. SME and VAE exchanged roles and verbally communicated tacit knowledge and skills to combine efforts and collaborate on the analytical task.

The excerpts below illustrate cues of exchanged roles that occurred between VAE and SME (i.e. educator and learner) and the impact this role exchange played on the knowledge discovery and transfer between VAE and SME.

a. **SME learner, VAE educator:**

Mastering the functionalities of the visualization tool enabled VAE to play the role of the educator. SMEs, lacking the technical knowledge, found the experience beneficial to explore the features of the tool and to learn about its functionalities. One SME reflected on his experience saying: *"I think watching somebody doing it, after a certain while it becomes intuitive. You don't think too much about it, which is good. It will take a while for some people, but it definitely helps to have somebody show you how to do it. I think you'll understand a lot more about how to organize the data as well. You realize how you can tabularize it and cross tab it, which isn't the way you think about it all the time".* The following excerpts illustrate how SMEs addressed a series of questions and information requests to VAE in an attempt to learn about the various features and functionalities of the visualization tool.

Example 1:

SME: "just explain this"…"so by putting it up here, you end up doing the…"

VAE: "yeah, another division on the columns"

SME: "Columns, right…and by putting it…this is the sub…"

VAE: "sub-division"

SME: "Sub-division of the column right here"

VAE: "This is the filtering technique of that category"

SME: "yes, yes…and that's very neat, make sense" (l. 141-150)

Example 2:

SME 8: So, is that all the causes of "Fractures", is that correct?

VAE: So, I'm just going to keep the "Fractures"

SME1: Keep the Fractures.

VAE: and then I'm going to add the causes.

SME1: and the causes go up there and that should stack it up

SME 2: Oh Look, it's "Fall"

In the following example, SME is learning, through repetition, about the terminology "stacked Bar" to refer to a new type of visualization:

Example 3:

SME 8: Can you do that in a bar form, or is it …Can you do that? That would be nice

VAE: A stacked bar? Yes.

SME 1: yeah. We wanted stacked, yeah

SME 4: Humm…. yeah…useful

Other examples of SMEs requests to learn about the visualization tool features and functionalities:

Example 4:

SME 8: Can you annotate the graph?"…"Can you draw an arrow and say…"

SME6: "Can you cut and paste this somewhere in your power point" (l. 356)

SME 8: "Can you show me an example" (l. 275)

SME 8: what does it look like, can you go to your desktop and show me how it actually looks" (372-373)

Example 5:

SME 6: Can you do that with this visualization?

VAE: well in this visualization, you can see different injuries and in each of the injuries you can see the different types of injuries

b. **SME Educator, VAE Learner:**

VAE was familiar with the injury datasets, however she lacked the contextual knowledge related to injury prevention. In some instances, the SME helped the VAE to understand the visualization and to accurately interpret the display from a public health injury perspective. For example, in the following excerpt, SME tried to explain to VAE the difference between "suicide and attempted suicide" as well as why the display was showing high numbers of female " attempted Suicide" compared to low numbers for males:

Example 1:

SME3: if you notice Females are higher than Males…

VAE: Oh

SME3: In actual suicide, Males are much higher than Females

Observation: Oh! in the death...mortalities

SME3: Yes, in the death. About 4 to 6 times. Yeah, so Females more attempts, Males far more completion.

Observer: Oh, wow...

Example 2:

SME 5: the body part might give you the head injuries

VAE: Uh, huhh… body parts, then let's get the body part instead of the causes.

7.1.1.5. Gesture Awareness

Gestures constitute an essential component of the conversational interactions among individuals [Quek et al.; 2002]. From hand gestures (e.g. finger pointing, refer to a person or a graph), to facial expressions (e.g. gazing, shifting sights), to body language (e.g. head nodding), all these communicative movements are intended to convey messages and information to other participants in a co-located collaborative environment. The field of cognitive science and developmental psychology addressed the notions of physical gestures and their impact on individuals' interactions and communications with others. In a study conducted by Iverson and Thelen (1999), the authors explored the interplay between gestures and speech and concluded that gestures were tightly associated with speech to support the expression of thoughts and ideas throughout the interactive communication process [Iverson & Thelen, 1999]. Hand gestures were equally relevant for collaboration and effective task achievement. In a previous study, Clark et al. explained that individuals attending to a particular task establish their dialogue based upon visual monitoring of each other's voice, facial expressions and hand gestures in order to reduce errors and improve the task completion time [Clark et al., 2004]. These previous studies inspired our data analysis and encouraged us to acknowledge and observe SMEs gestures in relation to their verbal communication within the contextual framework of the interactive collaborative process.

We analyzed the video files and documented SMEs various gestures that occurred throughout the interactive group sessions. We coded the gestures that were related to the collaborative interactions among SMEs using open coding techniques. A second coding pass was conducted using a coding scheme derived from Bekker et al. [1995]. We coded non-verbal gestures to emphasize the role that they played in various instances of the collaborative analytics session. We parsed the video sessions and took note of the various gestures that contributed to the phenomena under study. In a second round, we parsed the video sessions to code the main non-verbal gestures and classify them into two main categories. The third round was to capture images that support our main codes and enable us to visually position our coding scheme. We classified the retrieved codes into two main categories:

1. Hand Gestures

The "Pointing" gesture was the main hand gesture movement observed in the videos, every time SMEs referred to the visual representation or part of it. Pointing helped SMEs to focus their attention on the common location and the piece of evidence to improve communication of ideas and information [Bekker et al. 1995]. We noticed that throughout the sessions, SMEs finger pointed to refer to the visualization as a focal point and to orient SMEs attention to a particular space on the screen [Fig. 7.15.]. Being physically distant form the projected visualization, SMEs hand and finger gestures were accompanied with verbal explanation regarding the precise location on the projected screen. The following excerpt illustrates the use of hand gestures to locate a specific point at the screen:

> SME 8: what is the light blue (addressing the question to the VAE)
>
> VAE: this light blue…or that light blue? Which one? (Using the mouse to point at the screen)
>
> SME 8: that one (finger pointing at the projected screen)
>
> SME 1: "Fall from a high level"

These hand gestures were mainly "tool gestures". They guided SMEs cognitive attention to a specific visual display on the dashboard in order to either gain insights into the injury data or to support SMEs viewpoints with evidence from the visualization. As a result, these gestures played a substantial role in facilitating the communication of thoughts and ideas and consequently advancing the problem solving process while reducing SMEs information processing time.

Other types of hand gestures were observed during the collaborative sessions including SMEs "Raising Hands" to signal their contribution of a new idea or communication of a viewpoint or opinion. This gesture was efficient in structuring and organizing the interactions and flow of conversation among SMEs and consequently led to more efficient and productive collaboration. The last type of hand gestures identified during the collaborative setting was "Explaining with Hands". SMEs gestured with their hands to explain a new point of view or to show patterns in the data. For instance, one SME used her hands to show how the injury data was trending upward or downwards in the projected visualization [Figure 7.19.]. This gesture was efficient in gaining SMEs attention and encouraging them to attend to SME's viewpoint. It also played a substantial role in conveying effective information and exchanging knowledge about the data in an attempt to approach and advance the problem solving process.

2. Body Posture

Body postures supplemented SMEs hand gestures to enhance the interactions and communication among participants. As we parsed the analytics sessions, we identified several types of body gestures accompanying SMEs verbal interactions. These body gestures include "Turning towards the Screen" to focus eye gaze on the visual display, "Crossing arms" and "Hands on Cheeks" to show SMEs concentration on the activity [Figure 7.16.], “Head Nodding” to express agreement with proposed assumptions, as well as “Leaning forward” [Figure 7.16.] to attend to SME’s viewpoint or to closely examine the visualization.

Figure 7.16. SMEs Focus on Visualization: Crossing Arms / Hands on Cheeks.

Figure 7.17. SMEs Communication: Body Posture/Hand Gesture

Figure 7.18. SMEs Communication: Finger Pointing to Visualization.

Figure 7.19. SME Communication: Hand Gesture.

We further identified a combination of multiple communicative movements. For instance, SMEs exploited combined gestures like “Leaning Forward” with “Finger Pointing” to expedite the problem solving process and advance their joint activities. Moreover, we observed a combination of head nodding gestures accompanied by SMEs verbal utterances such as “*Right*”, “*Sure*”, “*Yeah*”, “*That’s true*”, “*Absolutely*”, etc. These utterances act as project markers that implicitly acknowledge addressee’s attendance to speakers’ remarks as well as to express SMEs agreement with other SMEs statements or problem solving approach. The gestures of head nodding that accompany the project markers served as horizontal transitions to affirm the flow of dialogue and conversation among SMEs and to align SMEs coordination of activities. [Bangerter & Clark, 2003]. It further showed engagement from the part of the addressee and assured the speaker that his/her message was assimilated and embraced by the addressee.

Hand gestures and body language were essential to help stakeholders interpret and direct communicative activities in collaborative analytics situations. As explained earlier, different gestures accompanied different interaction patterns. For instance, we observed a correlation between SMEs hand gestures and the various activities related to the interaction and manipulation of the visual display. As VAE manoeuvred the visualization, SMEs pointed at the visualization to request further information or to suggest additional refinement of the graph. Other gestures like head nodding interlinked with activities related to discussion and argumentation showed understanding and approval of the declared statement.

It is important to acknowledge that in this computer-mediated environment, SMEs attention was directed to the visual display. Therefore, many gestures may have gone unnoticed as SMEs attention was divided across multiple communication channels (i.e. other SMEs gestures vs. the visual display projected on the screen).

7.1.1.6. Dialogue and Verbal Communication

The use of language and verbal communication constitute substantial components of SMEs and VAE' collaboration with regard to joint activities. The collected audio data were analyzed to examine participants' utterances, use of language and discourse in order to derive meaning from their communication, discussion and argumentation. Analyzing the verbal communication among participants through the lens of the Joint Activity Theory enables us to capture participants' use of language and dialogue established to coordinate their actions and to solve the analytical task. We noticed that throughout the analytics sessions, SMEs interactions' relied heavily on conversation and verbal communication of ideas and viewpoints. Clark, in his book *"Using Language"*, studied the concept of language use in a collaborative setting [Clark, 1996]. He discussed the linguistic approach adopted by individuals to establish a *Common Ground* in a one-on-one basis and explained, "language use is really a form of joint action" [Clark, p.23 1996]. This research study extends Clark's framework to integrate multiple participants using dialogue and verbal communication to interact, reason and solve a complex analytical task in a collaborative analytics setting. Studying

SME-VAE interactions through the lens of language use enabled us to further understand the social and cognitive aspects of their collaborative analytics process. Analysis of the transcripts revealed that SME and VAE's use of language significantly contributed to SMEs knowledge building process and consequently the advancement of their collaborative activities. Language use was fundamental for SMEs to explicitly express their reasoning approach, their perspectives and opinions on this approach, their tool refinement suggestions as well as all that is happening in SMEs minds. We observed SMEs uttering a series of "*Uh, huhh*" or "*yeah*", "*that's good*", "*Make sense*" responses as VAE's manipulated the visualization and filtered out irrelevant variables and refined the visualization. We interpreted these utterances as agreement and approval to move on to the next step in the approach to problem solving. Additionally, SMEs used verbal expressions such as "*I know*" and "*I see*" to explicitly express their knowledge construction process, when interacting with the visualization with the assistance of the VAE. The following three example illustrate the process:

SME: "So, and now **I know** that "Falls" and "Struck by" are the big ones" (l. 1504-1507).

VAE: Uh, huhh

SME: Then I want to **know** Umm, OK… for the "Falls" and the "Struck by", what is the trend by year? What is the Age group?

VAE: those are Sex by Age group.

SME: Oh, by Age group, **I see**, right

*SME: Yeah, so **I see** here, from 2-4, from 5-9 and 10-14 those are the Falls and then the Struck are most in the 10-14, some are from 5-9, then you know, it would be interesting **to see** what type of Fall this is. Like what are they falling from? What are they struck by?*

VAE: Uh, huhh

SME: So, then you'll need sub-cause, right?

VAE: Yes

Bakhtin, a literary theorist, explored all aspects of language use. In his study, we focused on Bakhtin's notion of "Social language" to further explore the exchange of knowledge between VAE and SME through language use and verbal communication. "Social language" as defined by Bakhtin, refers to the "professional, social, generational, and gender 'stratifications' of language" [Koschmann, 1999 quoting Bakhtin]. Based on Bakhtin's definition, we argue that the use of "social language" and the integration of specific terminologies in SME-VAE dialogue enhanced the exchange of knowledge between SME and VAE in their joint activity environment. Throughout the sessions, SME and VAE conversation and dialogue encompassed many technical languages that enriched their communication and collaboration experience. The following examples show the use of specific 'social language" related to the visualization tool during the analytics sessions.

> SME: you could just **collapse** all this together, **removing** "Intent".
>
> SME: So let's **drag** the age group **there**".
>
> VAE: "but I don't want to **divide** them, I want to **stack them**".
>
> SME: "So if you say: "Well I'm interested in Cut", you can go in and you can then **Drill Down** on the causes".

We argue that the social setting imposed constant interactions and "think aloud" communications between VAE and SMEs to fill in the void or silence. Social co-presence fosters the flow of conversation and the "think aloud" approach through the various phases of the cognitive reasoning and problem solving process [Arias-Hernandez et al, 2011]. One SME described her experience saying: "I often think aloud and so just being able to talk to someone and thinking aloud and getting their opinion, like your (VAE's) opinion of what I'm doing and some possible ways of representing the data is very helpful". The proximity of SMEs co-presence significantly induced SMEs coordination of actions and enhanced their collaboration on the analytical task. In a study conducted by Hiltz et al. (1986) to compare computerized conference to face-to-face setting, the authors concluded that face-to-face interactions promoted more communication among participants and increased the group's potential to reach a consensus [Hiltz, Johnson & Turoff, 1986]. Being present in the same setting and working within the social context, presented a unique environment of awareness among participants and the need to attend to each other's viewpoints in order to coordinate actions and collaborate their activities to reach a consensus.

In addition to the social co-presence, the perceptual co-presence of the visual dashboard influenced the coordination of joint actions between VAE and SMEs. As VAE and SMEs attended to the same visual representation, it was easier for SMEs to align their communication of viewpoints and ideas to advance the problem solving process. Referring to the same artefact by using words such as “*this*”, “*These ones*”, “*up there*”, “the blue bar”, is classified by Clark as “gestural indications” [Clark p. 113]. These indications played a pivotal role in orienting SMEs gaze and focused their attention on the same piece of evidence as a *Common Ground* to enhance their communication and collaboration.

Furthermore, we explored the dialogue and conversation occurring between SMEs (SME-SME) during the problem solving process using the Chronoviz tool. The aspect that we analyzed and highlighted in SMEs verbal communication was the temporality aspect.

Temporality in conversation and turn taking

The nature of the verbal communication and interaction between SMEs impacted the way in which they coordinated their activities to advance the problem solving process, reach consensus and make decision. Throughout the analytics sessions, the flow of conversation between SMEs was evident and suggested a gradual turn taking and an ongoing approach to jointly solve the problem through rounds of argumentation and discussion. Stakeholders’ conversation and turn taking within the interactive and situational context represented a fundamental basis to mediate SMEs collaboration and establishment of common understanding [Schegloff, 1991]. During the analytics sessions, we noticed that SMEs conversation, discussion and argumentation represented a substantial component of their joint actions. Analysis of the analytics sessions revealed that SMEs were engaged in the interactive conversation and turn taking. Stakeholders’ use of dialogue and language represented the foundation of co-located cognitive and social collaborative activities that lead to the advancement in the analysis process [Clark, 1996]. Throughout the analytics sessions, SMEs took turns in the conversation; they evenly contributed to the ongoing discussion and carried out dialogue. We noticed a harmonized dialogue with few overlapping sentences. The following excerpt shows contributions from all SMEs as VAE manipulated the graph, to select relevant variables and refine the visualization to match the requirement of the analytical task:

SME 1: "Suffocation" and "Chocking"? There shouldn't be any of those here.

VAE: Should I exclude this one?

SME 1: yeah

SME 4: yeah

SME 3: Suicide

SME 4: Exclude that…Keep that (refereeing to another variable)

SME 1:Keep that

SME 3: It's interesting…that categories too.

SME 4: well yeah

SME 1: The "Poisonous" can go

SME 7: you're probably talking about very small… to begin with

SME 5: yeah

SME 4: yeah

SME 2: yeah.

SME 4: yeah, it will be very small number

SME 3: the teens are generally very…

SME 5: it has…

SME 4: the 17 years and above go to VGH, so it's only 16 and under that come here, yeah.

SME 1: so there is the sort of…

SME 8: Can we see what "Struck by/against"? Whether it is bicycle or what? Can you tell us more about that?

Temporality of Pauses: During the course of the Group analysis sessions, SMEs produced a series of utterances or processed utterances produced by other SMEs. The two processes were separated by pauses or wait times that we explored using Chronoviz. We argued that existing pauses between SMEs conversations enhanced knowledge construction. An early study conducted by Tobin in educational researched explored the role that 'wait times' play in higher cognitive achievement. The author examined 'wait time' or 'pauses' in the classroom learning environment and concluded that 'wait time' occurring in interactive conversation was associated with an increase in the use of evidence to support inferences as well as a higher level of cognitive information processing [Tobin, 1987]. Our study supports these previous findings and looked at SMEs pauses in conversations as chronological progress of information processing and knowledge building by injury stakeholders or SMEs. The fluency in the conversation among SMEs integrated pauses that we interpreted as means to internalize new information uttered by other SMEs or generated by the refined visualization. Observing the chronological pauses between SMEs utterances suggested that pauses and wait times gave SMEs the opportunity to understand the data and thoughtfully interpret the visual representations created by the VAE. It also helped them to cognitively assimilate other SMEs verbal communication as well as improve their cognitive capabilities to efficiently solve the analytical problem

7.1.1.7. Cognition Distribution

Analysis of the video files and screen captures revealed that at each phase of the problem solving process, SMEs relied on the tool to solve the task at hand. The visualization tool acted as a cognitive tool to constitute the 'things that make us smart' [Norman, 1993]. The iAID visualization tool helped to support SMEs reasoning approach and to advance their cognitive and analytical process. Based on the distribution cognition framework, Hutchins (1995) demonstrated that interacting with a cognitive tool enabled analysts to develop superior cognitive capabilities, compared to analyst conducting analysis without tool support. He postulated, "tools permit us to transform difficult tasks into ones that can be done by pattern matching, by the manipulation of simple physical systems" [Hutchins, p.170]. Being part of a distributed cognition system enhances analysts' cognitive capabilities to support the performance of analytical tasks. Visualization experts, Heer et al. explored the integration of visualization tool in collaborative group environment. The authors concluded that incorporating visual analytics tools and technology into collaborative group work advances the group cognitive process [Heer et al, 2011]. In this study, we argued that integrating the *i*AID dashboard into the collaborative analytical task supported the analytical process by acting as a *Coordination Device*. This *Coordination Device* served to offload SMEs cognitive process to more interactions with the dashboard [Clark, 1996]. SMEs asked the data question and VAE generated visualization upon SMEs needs and requests. VAE was knowledgeable about the tool manipulation and SMEs were knowledgeable about the data, the collaboration between SMEs and VAE served to exploit the potential of the visualization tool in order to expedite the problem-solving process while enhancing the accuracy of the analysis outcome. The nature of the VAE-SME collaboration synthesized both experts' knowledge to exchange viewpoints, propose and refine the visualizations to build a comprehensive picture about the injury situation. One SME explained his/her interaction with the tool to retrieve information, saying, *"what could we learned from the data that would tell us who is falling? Why are they falling? And what can we do to stop them from falling?".*

The nature of analytical problem and the diversity of injury stakeholders required the adoption of collaborative Visual Analytics approach that can support SMEs cognitive reasoning and advance the problem solving process. From a cognition science perspective, we concluded that Hutchins' distributed cognition concept was observed in the group analysis process in the form of two different types of cognitive processes.

Firstly, we observed socially distributed cognition process through social interactions between SMEs and the VAE. These interactions were exploited to manipulate the injury data, create the visualizations, refine the visualisation and finally to interpret and process the outcome of the visualization and use it to approach the problem solving and decision-making in the socially collaborative setting. SMEs interactively expressed their viewpoints and voiced their opinions simultaneously with each refinement of the visualization. SMEs socially interacted with each other and explicitly express their ideas and perspectives about the data interpretations based on their prior experience as well as proposed various approaches to problem solving. SMEs' thought expression, in turn, elicited prompt responses from other SMEs and consequently accelerated the establishment of Common Ground that was essential to expedite the process of problem solving.

Secondly, we observed the artefact distribution of cognition process that was illustrated through interactions and interchange of information with the physical artefact (i.e *i*AID dashboard) present in SMEs computer mediated environment. The *i*AID dashboard acted as a cognitive tool that served to amplify SMEs cognitive capabilities to support their analytical problem solving process. We argued that after observing data visualizations, SMEs formulated and answered new questions about the injury data and tried to argue and discuss the results with other group members. Concurrent interactions with the visualization tool along with the flow of conversation and verbal communication among SMEs within the social environment helped to mediate the group coordination of activities. The visualization tool expanded SMEs cognitive capabilities by answering their questions within the context of the analytical task. The process of manipulating and refining the visualization throughout the interactive sessions conveyed information that was essential to build cumulative knowledge and understanding about the injury data, otherwise not easily retrieved from the final visualization. SMEs were able to use the iAID dashboard as coordinated devices to support their claims and to explicitly present evidence that advances the problem solving process. As one SME stated: *"you see things that wouldn't have occurred to you to look for. And therefore that could be very helpful"*.

7.1.2. Qualitative Analysis of Paired Sessions

To evaluate the usability and usefulness of the *i*AID dashboard, we conducted a series of seven Paired analysis sessions. At the beginning of the session, a brief introduction to the dashboard and its features was presented to participating injury stakeholders. Following the brief introduction, an exploratory SME introductory session was conducted first with all SMEs before the beginning of the PA sessions. The objective of this introductory session was to explore SMEs interests, goals and tool expectations as well as to explore their domain task performance and the data they normally use to retrieve information and solve injury problems. The introductory session was structured as follow:

- Introduction and job title/description (clinical or research).
- Domain task performance.
- Currently addressed Injury problem.
- Goals and tool expectations to complete tasks on injury prevention

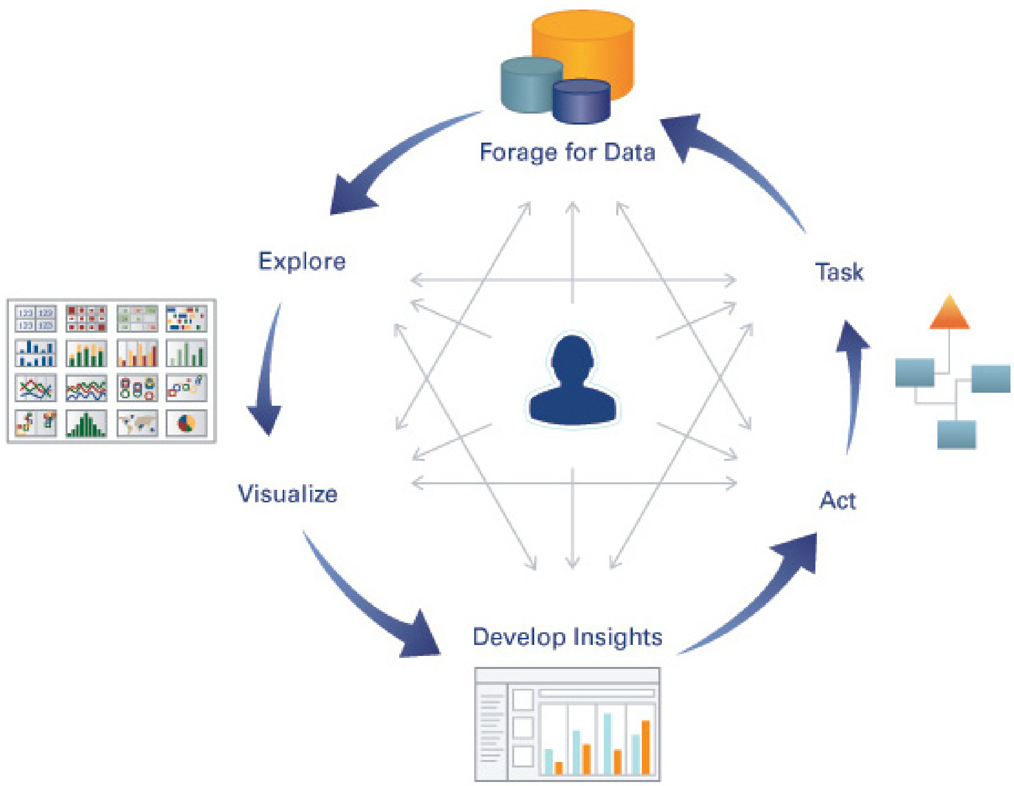
7.1.2.1 Analytical Task and Data Exploration

During the Paired analysis sessions, we decided not to assign a specific analytical task for injury stakeholders or SME to work on during the Paired analysis sessions, instead we asked SMEs to choose a scenario that was particularly relevant to their current domain work. Our rationale for selecting to conduct this open-scenario approach was that SMEs have diverse expertise and breadth of understanding and choosing their domain relevant analytical tasks to work on during the paired sessions would provide us with the information that we needed as to whether the *i*AID visual dashboard was a valuable aid to SMEs problem solving and decision making process. As expected, the majority of SMEs picked an analytical problem related to their current work. They felt engaged and motivated to explore their individual task using the tool and to seek answers to their questions.

Throughout the PA sessions, injury stakeholders interacted with the *i*AID depending upon their needs and goals. VAE and SME worked together in one-one one paired setting to solve the problem and retrieved needed information from the dashboard to make a decision. The VAE ensured that SME could understand the visualizations and parse them accurately. Throughout the sessions, we observed and made note of the injury stakeholders' interactions with the new version of the *i*AID dashboard.

Card, Mackinlay, & Shneiderman (1999) presented the visualization exploration model as part of users' data analysis process. This model shown in Figure 7.20 (retrieved from [Card et al. 1999]) emphasized the main functions related to 'visualization transformation' including: Forage for Data, Explore & Visualize, Develop insights, Act & Task.

Figure 7.20. Visualization Exploration Model



To solve the analytical task, Injury stakeholders or SMEs followed this visualization exploration model as they needed to forge for injury data, explore and visualize the various aspects of the data in order to gain insights into the problem solving process. Examples of the visualization exploration model is highlighted in the following SMEs activities:

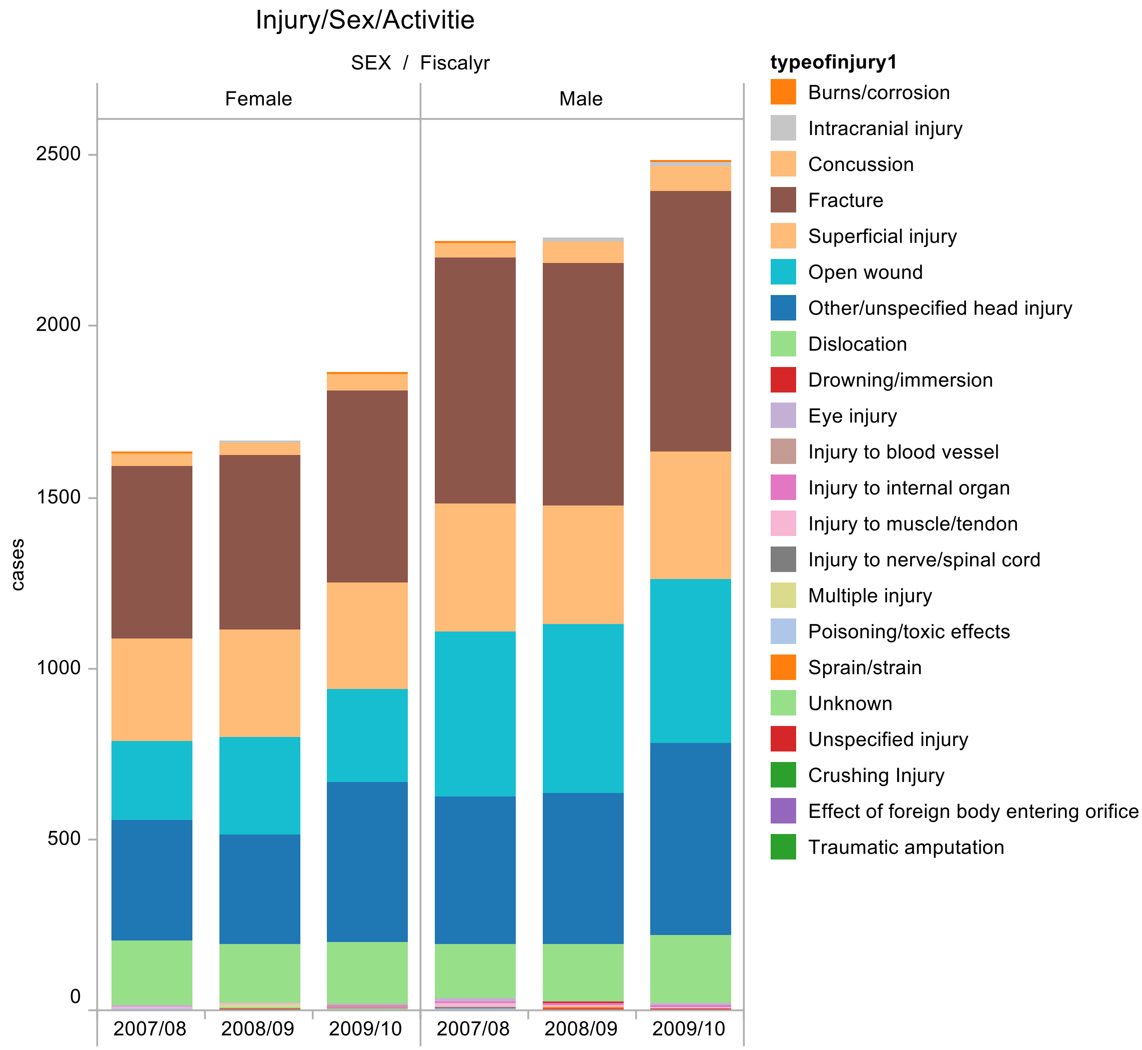
- **Forge for data:** Injury stakeholders investigated the injury data. They mapped the data on relevant dimensions and forged for data by looking for pattern variation in injury cases across spatial and temporal dimensions.
- **Explore and Visualize:** Injury stakeholders explored the data using the dashboard visualizations and observed patterns and unusual aggregation of injury cases. They looked and identified jumps in injury data as well as spotted outliers and tried to detect general trends across multiple data dimensions, regions, age and sex. They analyzed quantitatively the patterns that they see using bare charts, pie charts and trend lines. They asked sub-sequent questions and shift between various types of visualizations to seek answers.

- **Develop Insights:** Injury stakeholders gained insights into the injury data from the generated visualizations or from the hypothesis confirmation. They tried to describe the patterns in the data and classify them into categories including: a. Clusters for unusual aggregation of injury cases. B. Jump for a rapid change, increase or decrease of injury occurrences. C. Variation and changing for patterns of injury occurrences (i.e. seasonal patterns example 'window Falls' peak in spring and early summer).
- **Act and Task:** Injury stakeholders tried to explain these patterns in an attempt to model them and predict their variations and changes, using the retrieved information in order to efficiently address the injury problem.

The following section gives examples to illustrate how Injury stakeholders examined various suggested analytical problems using iAID multiple visualizations. Injury stakeholders or SMEs visualized solutions and approached the explored issues differently based upon their background knowledge and current needs. The landing page of the iAID dashboard gave health stakeholders a comprehensive overview of the injury situation as a whole while enabling them to drill down for further details-on-demand, providing additional levels of granularity. Each window provided an analytical aspect related to the performance of the main injury indicators. Injury stakeholders hovered the mouse and selected one visualization window for further investigation and in-depth analysis of a particular injury indicator and its relevant underpinning factors. One SME exp*lained: "I could see if I were to drill down on the dashboard, how the data would look and it would come up and that was important to me cause those are the types things that I would look at."*

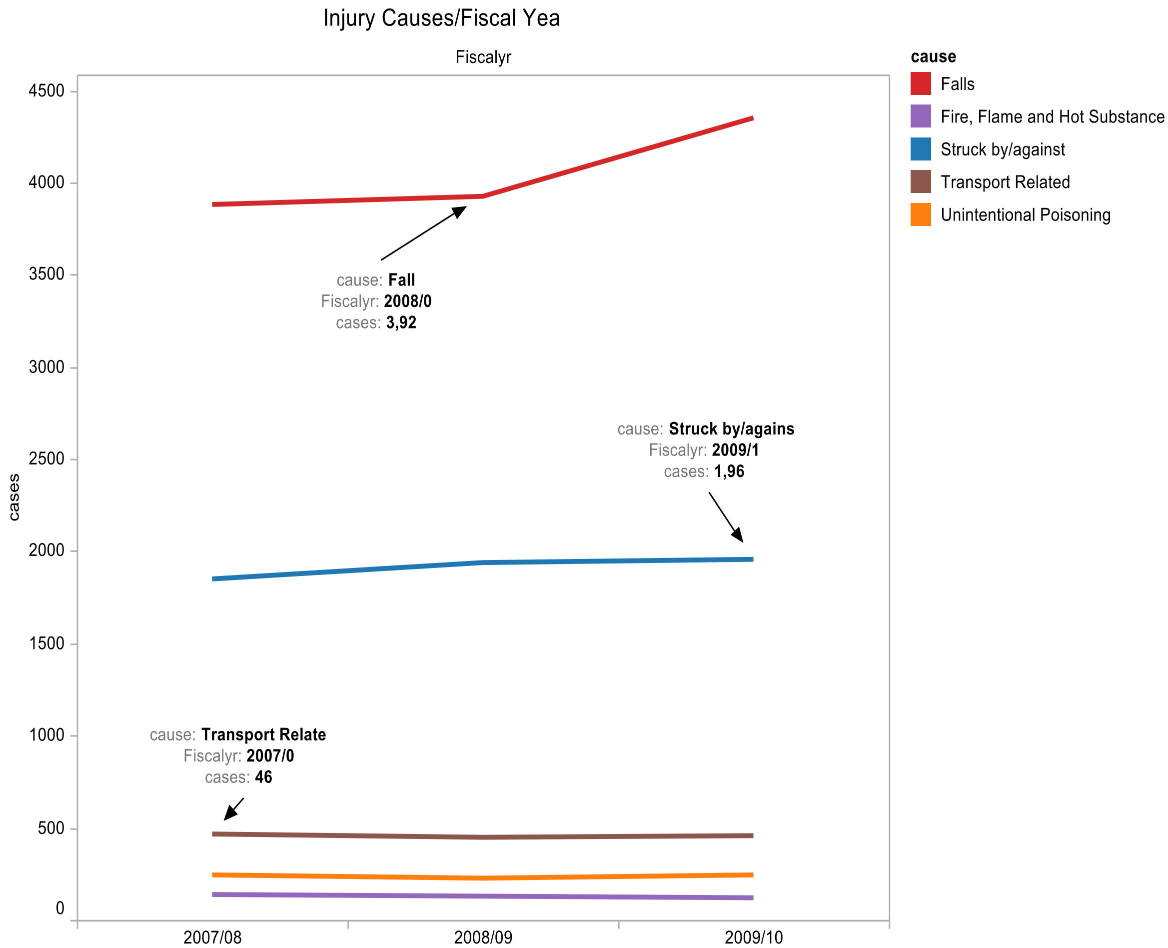
For instance, some SMEs were interested in exploring and learning more about the distribution of injuries by fiscal year and types of injuries [Figure 7.20]. They dragged and dropped new dimensions and variables into the display to customize their visualizations and explore how different data elements influenced the outcome of the analysis.

Figure 7.21. Dashboard Visualization Drill Down: Injury Causes/Fiscal Year/Activity Type.



In another instance, some SMEs were interested in examining the leading injury causes (e.g. Fall, Struck by/against, Transport Related, Fire/Flame, and Unintentional injuries) [Figure 7.21] and how they trended over time from 2007 to 2010. SMEs used the *i*AID feature "Annotate Graph" to include notes referring to trend values to further provide details about relevant trends. As shown in figure 6, the "Fall" injury cause consistently and considerably trended high compared to other injury causes that remained relatively flat.

Figure 7.22. Dashboard Visualization Time Trend: Injury Causes/Fiscal Year.



7.1.2.2. Task Taxonomy

Analysis of the Paired Analysis sessions video-, audio-recordings and screen captures were conducted to characterize the SMEs interactions with the *i*AID dashboard and the specific domain task related to injury problems. Based upon analysis of the injury stakeholders individual interactions with the iAID dashboard, we categorized their tasks and classified them into the following six task taxonomies [Table 7.1]:

1. **Answer Research Questions:** some injury stakeholders accessed with the *i*AID dashboard with the incentive to answer a pre-defined research question related to their current work. One SME noted: “Looking for data that can answer my pre-set research question”.

2. **Explore Available Data:** Other injury stakeholders prefer to explore the injury data in general without any specific research question in mind. They explained that they want to access the dashboard to explore the data, examine the leading causes that require further investigation as well as observe how the data trends and patterns. As one SME explained, "*Looking for trends and patterns in the data",* another added*, "Observing how the data is trending over time".*
3. **Identify leading injury causes:** Injury stakeholders need to identify the leading causes of injury that represent the highest burden on the health care system.
4. **Interact and understand:** SMEs want to interact with the visual display and investigate specific areas and dimensions of the health issues. Drill down by different variables (Age group, Sex, Causes, Sub-causes and Regions, time trends). One SME clarified: "*To get as complete a picture as possible with available data*".
5. **Modify and Customize:** SMEs want to be able to drag and drop different dimensions into the graph in order to test various scenarios and to customize the visualization to better fit their needs.
6. **Share and Collaborate:** Many injury stakeholders want to access the *i*AID dashboard with the intention to build knowledge and transfer knowledge by sharing relevant evidence to generate reports or support their published papers. They need supporting graphs to communicate their findings and make analysis results accessible to colleagues and the public.

Table 7.1. Injury Stakeholders: Task Taxonomy.

Task Taxonomy	Description
Answer Research Question	Look for available data to answer SME's pre-set research question.
Explore Available Data	Examine and identify leading causes of injuries.
Identify Leading Injury Causes	Identify the leading causes of injury that represent the highest burden on the health care system.
Interact and Understand	Investigate specific datasets and build refined visualization based on needs.
Modify and Customize	Apply analytics visualization capabilities to test various scenarios and to customize the visualization
Share and Collaborate	Exchange visual representations and findings with other stakeholders.

These task taxonomies were used to inform the design of the *i*AID dashboard to integrate domain analytical tasks. Following the Paired sessions, SMEs were asked to complete a questionnaire and reflect on their experience manipulating the injury data using the *i*AID dashboard.

7.2. Quantitative Results and Design Implications

We adopted a methodological triangulation of qualitative and quantitative methods in order to comprehensively examine and investigate the research problem [Morse, 1991]. Collecting data from multiple sources enabled us to investigate the studied concepts in sufficient detail. The following section present the study quantitative findings followed by design implications.

7.2.1. Empirical Findings

We analyzed the questionnaire data to assess the dashboard based on ten metrics divided into two main categories: 1. Functionality metrics, and 2. Interface metrics. The functionality metrics evaluated the dashboard potential to stimulate discussions, brainstorm ideas and facilitate the problem solving and decision-making process. The Interface metrics assessed the dashboard in terms of intuitiveness and ease of use to support task performance. The metrics evaluated users perception and beliefs that the *i*AID dashboard supports their problem solving and decision-making to address public health wicked problems.

Analysis of the PA sessions mainly focused on testing the usability of the iAID dashboard to support injury stakeholder's domain tasks. We compiled and analyzed the self-reported questionnaire data. The response rate of the questionnaire was 87%. Participants rated the *i*AID dashboard in terms of the following four characteristics (Table 7.2):

- *i*AID dashboard visualization helped injury stakeholders to convert data into useful information.
- *i*AID dashboard stimulated discussions and helped injury stakeholders to brainstorm new ideas.

- *i*AID dashboard enabled injury stakeholders to efficiently and effectively complete the assigned analytical task.
- *i*AID dashboard helped injury stakeholders share their ideas with other stakeholders.

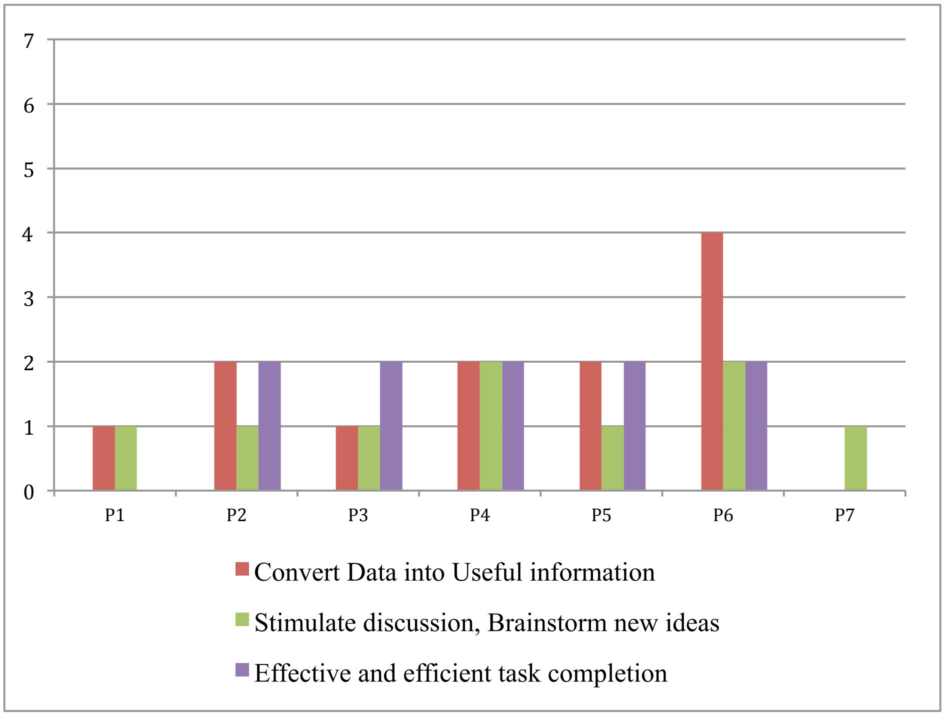
Table 7.2. Questionnaire Compiled Data Metrics: SMEs Interaction with *i*AID. Useful Information & Task Completion.

Metrics	Strongly Agree	Agree	Somehow Agree	No Comments
Useful Information	28.5%	42.8%	14.2%	14.2%
Discussion Stimulating	71.4%	28.6%	-	
Task Completion	-	71.4%	-	28.6%
Ideas Sharing	42.8%	28.5%	14.2%	14.2%

Based on the data compiled from the self-reported questionnaire, Figure 7.2 highlights the study findings and illustrates injury stakeholders' high ranking of the *i*AID dashboard in terms of converting data into useful information, stimulating group discussion and facilitating the completion of the given analytical task.

Furthermore, Figure 7.22 quantitatively reveals SMEs rating of the *i*AID dashboard's usability. As shown, the majority of the participants ranked the *i*AID dashboard high in terms of assisting them in converting the complex injury data into useful information that could help them to gain insights into the injury data as well as to understand the injury situation and complete the assigned analytical task.

Figure 7.23. SMEs Ranking *i*AID dashboard: Information Sharing and Task Completion Support (1-Strongly Agree, 7-Strongly Disagree).



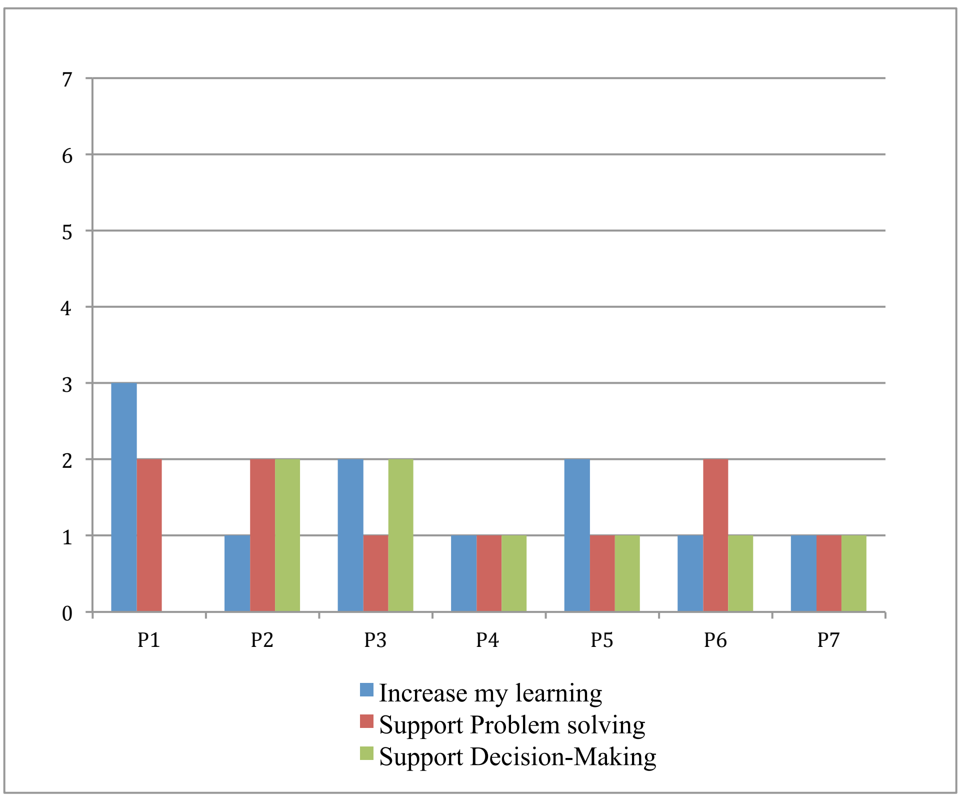
Using a 7 Likert scale responses (1- strongly Agree and 7- Strongly Disagree), SMEs rated the iAID dashboard's usefulness and efficiency on average with the following: Convert data into useful information average= 2, Stimulate discussion average= 1.2, and Task Completion average= 2. During the collaborative PA sessions, SMEs manipulated the iAID visual display and customized the visualizations according to SMEs needs and task requirements. With the assistance of VAE, SMEs interacted with the dashboard to refine the visual representations in a way that enhanced their understanding of the multidimensional injury data and empowered them with the best approach to address the injury problem at hand, converge to a solution and reach a consensus. We surveyed the impact of the *i*AID dashboard on increasing SMEs learning and building knowledge. We also examined the implications of using the *i*AID dashboard to advance stakeholders' problem solving process and support their decision-making in a face-to-face collaborative setting. Table 7.3 depicts the results of the data compiled from the questionnaire.

Table 7.3. Questionnaire Compiled Data Metrics: SMEs Interaction with *i*AID, Problem Solving & Decision-Making.

Variables	Strongly Agree	Agree	Somehow Agree	No Comments
Increase Learning	57.1%	28.5%	14.4%	
Support Problem Solving	57.1%	42.9%	-	
Support Decision-Making	57.1%	28.5%	-	14.4%

The results were graphed in Figure 7.23 to illustrate how stakeholders' perceived the *i*AID dashboard functionalities and ranked them in terms of increasing learning and supporting problem solving and decision-making using a 7 Likert scale responses (1-strongly Agree and 7- Strongly Disagree). On average, SMEs rated the *i*AID dashboard as follows: Increase learning average = 1.5, Support Problem Solving average = 1.4 and Support Decision Making average = 1.3.

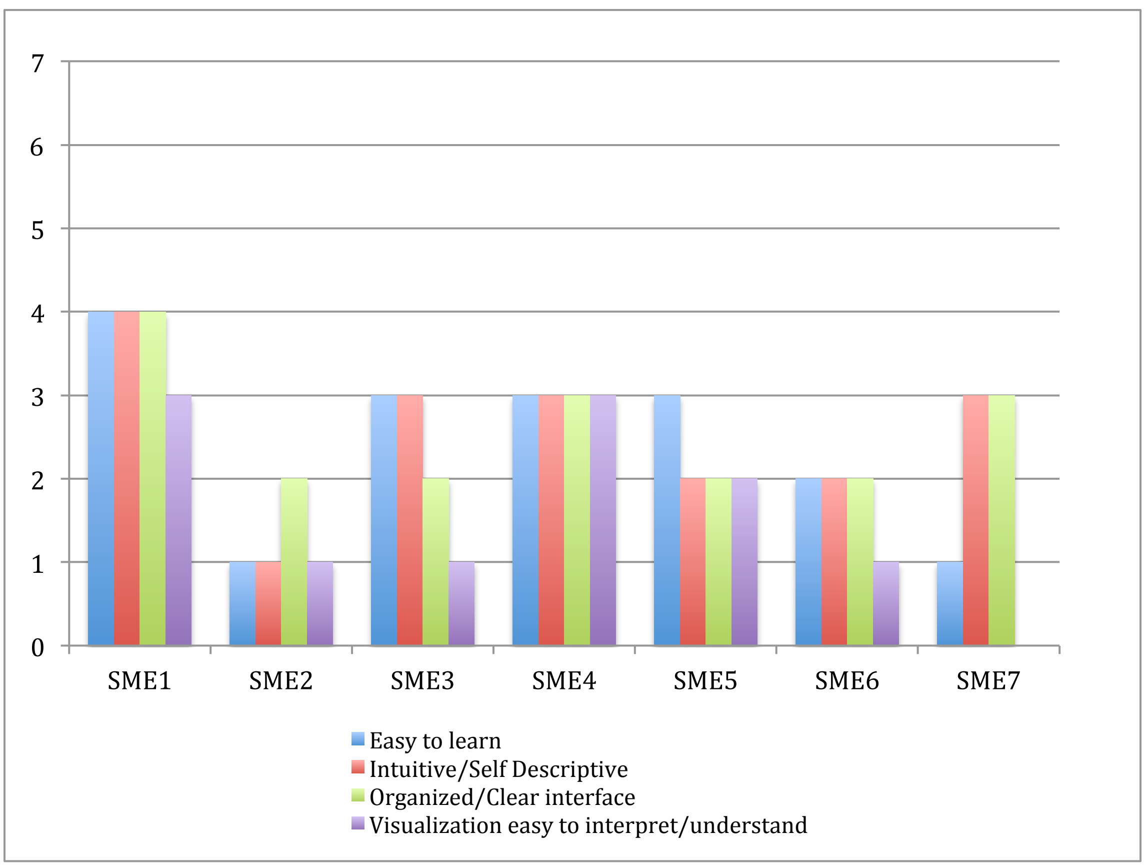
Figure 7.24. SMEs Ranking *i*AID dashboard: Problem Solving & Decision-Making (1-Strongly Agree, 7-Strongly Disagree).



The results indicated that the analysis sessions fostered a collaborative environment for VAE and SMEs to exchange knowledge and expertise to solve the analytical problem under investigation. During the analysis sessions, VAE assisted SMEs in exploring the data using the *i*AID dashboard. SMEs and VAE worked with the visual dashboard to understand the injury data, identify trends and patterns as well as recognize communities at risks.

Furthermore, analysis of the questionnaire data revealed that the majority of injury stakeholders perceived the *i*AID dashboard as intuitive and easy to learn. The *i*AID dashboard presented SMEs with information related to injury data patterns, data variations, comparisons, trends and outliers. Furthermore, the results illustrated in Figure 7.24 indicate that SMEs ranked the dashboard high in terms of its clear interface and ease of visual interpretation.

Figure 7.25. SMEs Ranking *i*AID dashboard Interface: Ease of Use, Intuitiveness, Clarity(1-Strongly Agree, 7-Strongly Disagree).



The results of the both qualitative and quantitative data converged to indicate that interacting with the *i*AID dashboard enabled injury stakeholders to view the overall injury situations at a glance, examine key performance of injury indicators, as well as visualize serious injury causes to build knowledge and solve the wicked injury problem. With the support of VAE, SMEs were able to use the *i*AID dashboard to test and manipulate injury data in order to understand the underlying causes of injuries, identify areas of particular concern in injury, and quickly acquire knowledge that was fundamental to guide timely decision-making and drive appropriate actions.

Results from our PA sessions and questionnaire analysis confirmed early findings by Few [2007] and showed that visual representations of relevant injury information empowered stakeholders with the ability to "convert slow reasoning tasks into fast perception tasks by virtue of making them visually salient" [Few, 2007]. The *i*AID dashboard offered visual displays of relevant variables and parameters within each injury indicator and represented them in a way that was easy to understand and interpret. One *SME confirmed: "(Visual representations) highlight the different variations. So, if there is a change over time, you can see it so easily in the visual representation. Similarly, if there is a big difference for example between regions, you could see that visually very quickly."*

Injury stakeholders were able to quickly identify leading causes of injuries and the ones requiring immediate actions. Interacting with the visualizations oriented injury stakeholders' attention towards areas with an urgent need for interventions. One SME confirmed our statement and explained, *"they (visual representations) provide a great deal of information very quickly and allow me to understand trends and variation in the injury data."* Moreover, the dashboard provides context to situate the injury problem and accurately judge the injury situation. One SME commented: "*it (visual representation) helps to present the story",* another SME added: *"it allows you to ask the data questions based on what you're looking for".*

The *i*AID dashboard served as an effective problem solving support tool. The *i*AID helped to translate the complex and multidimensional injury data into information and knowledge, which were vital to make subsequent decisions and initiate appropriate actions in timely fashion. SMEs interacted with the *i*AID dashboard while integrating their background knowledge to enrich the data analysis process and integrate additional perspectives, viewpoints and dimensions into the data analysis process. As one SME explained: "*it (the visual representation) allows me to do my own interpretations of what is going on… it will just open up different ideas.*"

7.2.2. Design Implications

Based on our findings, we illustrate some design guidelines and recommendations to refine our *i*AID dashboard as well as to inform the design of innovative analytical dashboards. Compiled data from the analysis sessions as well as the questionnaires revealed five design features that we identified as essential components for designing and developing effective dashboards with advanced Visual Analytical features and functionalities to support decision-making within the public health care sector.

7.2.2.1. Important Information First

Effective dashboards should limit the visual display to relevant metrics and key information that are essential to accomplish the objective of the developed dashboard. All pertinent aspects of these metrics should be displayed on the dashboard main page. The dashboard single landing display page should show different analytical views depicting the multidimensional aspects of the health data and offering a comprehensive picture of the overall key health performance. One efficient way to display them is by using multiple coordinated visualizations placed side-by-side [North & Shneiderman, 2000] to facilitate knowledge translation at a glance. According to Ware, when examining and comparing side-by-side objects, eye movements are 10 times faster compared to objects on sequential display pages [Ware, 2008]. Hence, it is more efficient for the human working memory to compare two entities and pick up a chunk of information in a side-by-side display.

Consequently, the design of dashboard should take into consideration the metrics that are significant to the analysts' work and worth gaining a spot on the limited space of the dashboard page. These selected metrics should be prearranged and displayed on a one-page visual representation that encompasses multiple coordinated visualizations (i.e. geospatial map, time trends) to maximize injury data interpretation while reducing injury stakehodlers' cognitive efforts [Carr, 1999].

7.2.2.2.Intuitive User Interface

Dashboards with self-explanatory and easy to use interfaces require the least cognitive effort to manipulate the data and understand its underpinning variables [Moore, 2008]. Public health professional are faced with information overload in time pressured public health event settings. Hence, effective visual dashboards should be intuitive to help injury stakeholders rapidly unravel hidden patterns and trends in the visualized health data and expedite the analysis and decision-making process. Visualizations embedded into a dashboard should be easy to use and operate by injury stakeholders, providing readily accessible information and offering layers of analysis of the injury data that can be triggered based on SMEs' level of technical expertise as well as the need to explore root causes of investigated injury issues. The easy-to-understand visual representations act as a shared reference framework to enhance injury stakeholders' group performance and teamwork and ultimately improve their cooperation. Intuitive and easy-to-use interfaces facilitate injury stakeholders' interaction with the visualization tool to test various scenarios and understand the different perspectives of the analytical problem. Furthermore, aesthetically pleasing interfaces should be considered when designing a dashboard as it elicits users' intention to interact with the dashboard and retrieve salient information.

7.2.2.3. Leverage Human Perceptual Capabilities

Dashboard interfaces should be designed to leverage human perceptual capabilities and facilitate the brain's cognitive ability to process a chunk of data at one time. As Ware explained that a "*good design optimizes the visual thinking process*" [Ware, 2008]. Successful Visual representations of large datasets trigger human's eyes and exploit human's visual pattern detector capabilities to compare datasets and reveal hidden trends and patterns as well as spot outliers [Ware, 2008]. When designing a dashboard interface, it is essential to use differentiator elements such as color (hue, darkness/lightness contrast), shape (size, elongation, orientation), motion, and spatial grouping to leverage visual perception and improve human's visual queries when searching for relevant information in a graphical display [Ware, 2007]. Designating key injury indicators, outliers, high trends, comparative values, and alerting health locations using color-coded icons supports injury stakeholders' visual working memory with external visual aids and amplify their cognitive capabilities to process a chunk of information at a glance [Ware, 2008].

7.2.2.4. Interactivity and Customization

Interactivity constitutes a vital component of an analytical dashboard. Incorporating interactivity functions into the design of analytical dashboard is essential to tailor the visual displays to fit injury stakeholders' goals and needs in order to ultimately support their decision-making process [Keim et al., 2010]. Interactive visualizations provide injury stakeholders with a flexible platform to establish an analytical discourse with the data, testing various injury scenarios and examining the underpinning claims of each carried argument. Compared to pre-built visualizations, interactivity offers injury stakeholders the ability to customize the visualizations based on their operational needs and preferences. For instance, injury stakeholders who are mainly interested in 'head injuries' can customize the dashboard visual display to reflect their needs and gain advanced analytical capabilities. It enables injury stakeholders to experiment and examine diverse injury situations and collaboratively assess the pros and cons of any injury problem under investigation. Moreover, interactive visualizations play a pivotal role in enhancing the analytical thinking process as a result of the interplay between internal mental models and external visual representation of data [Liu et al., 2010], thus enabling injury stakeholders to externalize the patterns and trends in complex injury data. Furthermore, interactivity facilitates the evaluation and assessment of injury initiatives and interventions programs and their impacts on reducing and preventing injury problems.

7.2.2.5. Dissemination and Collaboration

Disseminating health information in a readable and understandable format is fundamental to initiate appropriate actions in a timely manner [Teutsch & Churchill, 2000]. When designing an analytical dashboard, it is essential to incorporate visual dissemination functionalities to enhance communication and collaboration among analysts. Analytical dashboard should help injury stakeholders to synthesize meaningful information from complex data and disseminate extractions to health professionals and policy makers to improve timely interventions. Effective visual dashboards should enable injury stakeholders to generate graphical reports and produce results that can be shared and communicated among them. Reports and findings should be formatted and disseminated in a readable and comprehensible format to convey the analysis results and improve the collaborative decision-making process.

7.2.2.6. Distributed Cognition

Visualization dashboards should be designed with an eye towards amplifying health professionals' analytical reasoning and cognitive skills with external visualization aids that are essential for enhancing the distributed cognition process and improving data analysis. Norman (1993), emphasized in his research the significance of amplifying humans' cognitive capabilities to get insights through the use of external aids during the analytical reasoning process. He explained, 'the power of unaided mind is highly overrated. Without external aids, memory, thoughts and reasoning are all constrained. The real powers come from devising external aids that enhance cognitive activities. How have we increase memory, thought and reasoning? By the invention of external aids: it is things that make us smart' [Norman, 1993].

Furthermore, the socially communicative nature of analysis processes should be considered and embedded into the design of dashboard interactive interfaces. As postulated in the book illuminating the path, '*"The analytical reasoning must be a richly collaborative process"* [Cook & Thomas, 2005]. For many applications, analysis is a collaborative argumentative process that involves the integration of multiple operations and generated policies. To facilitate collaborative analytics, a collaborative analysis dashboard should be designed to emphasize the distribution of cognition processes among multiple analysts in order to support the synthesis and the coordination among analysts, subject matter experts and decision makers to amplify the cognitive process and address wicked health problems. Based on this study's empirical findings, the distributed cognition process was identified and documented in various setting including: a) Smart seeing and projecting; b) Extended/Distributed interactive cognition; and c) Socially distributed cognition. These three distributed cognition process were manifested and therefore each has the potential to significantly contribute to different design patterns, actions and guidelines.

Within the context of public health, effective visual dashboard should bridge analysis and argumentation to enable health professionals to annotate the visual representation, for example, with multiple annotations that highlights the integration of health intervention strategies or health policies through time. Future research studies should focus on the design of new methodologies and collaborative interactive visualization tools and techniques that can be integrated into the public health sector to enhance the collaborative reasoning process of health professionals, support their collaborative analysis and ultimately facilitate the decision making process.

7.2.2.7 Common Ground and Coordination Devices

Given the results of this research, we argued that *Common Ground* constitutes a theoretically rich indicator that impacts the group analysis process and subsequently determines and predicts the success and failure of the Group analysis process. Understanding group established and maintained *Common Ground* are key elements that improved group collaborative process. As a result, designing visualization dashboards that support the establishment of Common Ground among multiple analysts is fundamental to support the Group analysis process. As a result, we suggest the use of *Common Ground* as a metric to evaluate the group analysis process as well as to inform the design of visualization dashboard technology that supports group analysis as it can provide consistency, accuracy and rigor to the group analysis process.

Furthermore, coordinated devices play a substantial role in facilitating group discussion, argumentation and collaboration among multiple injury stakeholders. Coordination devices represent explicit agreements that support injury stakeholders Common Ground and help them to converge towards a ‘Joint Activity’ [Clark, 1996]. Therefore, visual dashboards should be designed to act like coordination devices that help injury stakeholders to coordinate their activities and collaborate on task analysis.

7.3 Study Limitations and Delimitations

This research study offers insights into the integration of an interactive visualization tool –*i*AID into the public health injury sector in order to support collaborative group problem solving and decision-making. This study incorporated a number of limitations and delimitations that we divide into two main categories: Study Limitations and Delimitations, and Tool Limitations and Delimitations. We acknowledge both categories in the following section.

7.3.1 Study Limitations and Delimitations

Firstly, we acknowledge that our current study encounters a relatively small sample size. Being relatively small, the sample size may limit the generalizability of the study and its applicability on a larger injury stakeholders' population and the broader public health community. This restriction is imposed by patient information privacy policies that allow only limited number of authorized stakeholders to access and interact with the available public health data. As stated earlier, to address the issue of relatively small number of participating SMEs, each SME was purposely selected because of their strong knowledge and expertise in injury prevention and also their credibility and position to represent constituent peers.

Secondly, This study investigated a hypothetical injury issue and therefore injury stakeholders were not making actual decisions. However, it was essential to acknowledge and take into consideration the challenges and obstacles that might face the collaborative decision-making process, during the course of the Group analysis session, including:

1. Ineffective communication and lack of group dynamic: communication and interaction between SMEs is essential to influence each other's viewpoints and settle on an optimal solution that accommodates collective opinions and thoughts. Therefore, we designed the Group session in a way that supported communication and collaboration among SMEs and consequently fostered collective intelligence. I addition, the facilitator played a major role in promoting collaboration among stakeholders and guiding the group analytical session toward a solution, consensus or optimal decisions.

2. Dominance by few group members: A study conducted by Dubrovsky et al. [1991] about the impact of social status on group decision-making. The authors explained that group members with high-social status tend to dominate group discussions and influence the outcome of the decision making process. Therefore, to ensure that all the voices in the room are heard and that everybody's opinions and thoughts are incorporated into the group, we introduced a skilled facilitator that helped to manage the group session. The facilitator invoked rules on how the discussion should

be carried out. The facilitator plays a key role in preventing dominance by steering the session discussion and guiding the argument while giving equal share of conversation to group members.

3. Discussion in the group session is limited to the general: in the group session, discussion tend to be restricted by the general knowledge, ideas and information that are known and common to the majority of group members, rather than reaching detailed and specific thoughts shared by few individuals. To address this issue, we designed the analytical task to be precise and specific with a definite injury problem.

4. Authority and Social pressure: in the face-to-face co-located session, members are reluctant to share their personal opinions within this social co-presence. Furthermore, members of a group can be privileged with higher-ranking authority, which might influence the flow of conversation and the equal weight on shared opinions. Therefore, we need to emphasize the need to have a trained facilitator to steer and manage the group analytical process. The facilitator encouraged all SMEs to equally participate and contribute to the problem solving process.

Thirdly, considerations for patients' privacy and confidentiality must be taken into account when designing analytical dashboards to visually depict health data. Protecting patients' privacy and confidentiality is of paramount importance within the healthcare sector. In order to maintain confidentiality and privacy standards and avoid pinpointing patients based on their geographic locations, the analytical dashboard must be developed and managed so as not to display injury classes with fewer than five cases. Data must be anonymous, removed of any personal identifiers and aggregated at the regional level so that patient identity and privacy is always protected. Moreover, data in small numbers are not reported in order to preserve the confidentiality and the privacy of patients' identities.

One of the study's delimitation is the single coding process as the code was conducted by one researcher. We acknowledge the potential delimitations of a single coder. However, as previously discussed, coding this particular types of data was not a common task, it required unique skills and knowledge in various fields to generate reliable and efficient coding schemes. As a researcher in the field of Visual Analytics with background expertise in health information management, I possessed the contextual knowledge to examine and code the collaborative Visual Analytics phenomena that occurred among multiple health professionals dealing with complex health problem. However, we acknowledge existing research biases derived from the researcher' conceptual lenses and own perspectives, prior knowledge and beliefs that might affect the coding process and the interpretation of the data. To prevent researcher' possible biases, we recognize that we wanted a second coder to conduct an additional coding or refine the coding system. However, it was challenging to find a second coder who possesses the appropriate contextual knowledge to conduct an efficient coding process. Furthermore, due to the lack of time and funding, we were restricted from selecting appropriate coders to conduct the second coding process. Hence, as the primary researcher and coder of this study's data, I tried to reduce the biases and minimize the different factors influencing the outcome of the data analysis by:

1. Using SMEs own words to code the textual files.
2. Using multiple data sources (i.e. the Paired and Group analysis data, the questionnaire data and the interviews data) to enhance the reliability and validity of the results as well as to support the coding process with evidence retrieved from SMEs quotations.
3. Using detailed descriptions of SMEs collaborative activities and interactions in order to make the findings more generalizable and applicable to other contexts. I also kept a research journal reflecting on the data, every time I read the transcripts.
4. As a researcher in the field of VA, I was careful when interpreting the qualitative data and tried to avoid my voice from getting into the data interpretation. Therefore, I mainly looked at what SMEs actually experienced in the PA and GA sessions and what they're trying to explain to me in the questionnaires and follow up interviews.
5. To ensure a rigorous analysis and study, research findings were presented to knowledgeable colleagues at the SCIENCE lab as well as peer reviewed conferences (Please refer to Appendix F).

7.3.2 Tool Limitations and Delimitations

The proposed *i*AID dashboard has its limitations. The dashboard encompasses various types of visualizations created to depict the injury data. These visual displays should be carefully built in order to accurately and honestly tell the story behind the injury data without distorting them. Weak visualization or poor data representations may mislead the analysis process, as the graphical display can be open to many interpretations. Therefore, we acknowledge the constraint imposed by the introduction of a new visualization technology into the public health sector and the need for users to be able to design and organize the dashboard visualizations in a meaningful way as well as to accurately interpret the generated visualization. In the follow up interviews, SMEs expressed their concern about this issue:

> SME6: "I wonder if the results are only as good as the person who is actually minding the data and coordinating things…I wonder if I would have the same results or as good a results as if the tool expert did it.
>
> SME4: "I think the biggest limitations would be on the users side, knowing how to organize it in the right way so that it is meaningful.

One of the key elements of generating accurate and reliable visualizations of the health data derives from two main components: 1) Understanding of the health data 2) Possessing adequate technical skills to design and manage the visualization tool. To generate meaningful visualizations, the researcher needed to gain the required knowledge and understanding of concepts related to population health, health promotion and injury prevention. Therefore, the researcher attempted to master the new field knowledge and terminologies in a short period of time by registering for a number of graduate level public health courses at the University of British Columbia prior to working on this project and designing the visualizations. Moreover, the researcher was trained on various visualization tools in order to exploit the software features and functionalities to generate the most appropriate visualizations that best depict available health data. To address health professionals' concern about the effective use of the *i*AID dashboard, we understand the need for adequate training to help health stakeholders to comprehend and accurately interpret the injury data visualizations. Thus, we suggest the design of a training manual or documentation tool that provide suitable training and technical support for novice VA users to gain a comprehensive understanding on how to effectively manipulate the data and create accurate visualizations using the visual dashboard.

Fourthly, the injury surveillance data should be valid and reliable to ensure that the generated visualizations and analysis of the information precisely reflects the current injury situation. Injury data uploaded into the *i*AID dashboard may not always be current and up-to-date and therefore might not reflect current injury situations. For instance, in the case of the CHIRPP data, there is a gap of 2 years between current data and available data uploaded into the *i*AID pilot dashboard. Hence, interpretation of the information generated by the dashboard should be cautiously examined to ensure successful health interventions. Initiating actions based on the current dashboard information should be studied closely to make sure that prompted actions are relevant to current injury situations. However, while CHIRPP data is not necessarily current to the day, trends in the types and causes of injury have remained fairly constant over many decades. Therefore, the value of the *i*AID dashboard is to provide injury stakeholders with the ability to monitor the data and to observe the effects of injury prevention interventions over time.

Despite these limitations and delimitations, the study findings clearly reveal the advantages of integrating analytical dashboard as a decision-support tool to synthesize information from multidimensional and dynamic health data. The study's empirical findings constitute relevant and valuable resources that contribute to the understanding of collaborative Visual Analytics and its impact of problem solving and decision-making within the health care sector.

Chapter 8. Conclusions and Future Work

Our approach to this thesis was an issue-based approach, where we started with a defined research question and investigated, explored the various methods that can be used to answer the proposed research question. We adopted the Paired Analytics and the Group Analytics methodologies to conduct the data collection procedure including participants' observations, video and audio recordings, as well as screen captures. We triangulated the data by examining the transcripts, observing the video recordings and listening to the audio recordings to enhance validity of collected data. We further triangulated the qualitative data with numerical measures through a designed questionnaire that assessed injury stakeholders' interactions with the designed *i*AID dashboard and with other stakeholders to approach problem solving and support decision-making within the context of addressing wicked health problem. Analyzing the data was grounded in theories from the Joint Action theory and the distributed cognition framework. We focused on evaluating the collaborative Visual Analytics related themes and concepts grounded in dialogues and conversation during the paired analysis and group analysis sessions. This chapter summarizes the main findings of this empirical study. It highlights the thesis contribution, presents reflections and implications of the research methodology as well as offers a glimpse at potential future research work.

8.1 Research Summary

The following key points summarized the study's general results and synthesized its main contributions:

- Visual Analytics tools and techniques were successfully integrated into the public health care sector to provide additional practical application of the VA to address complex and wicked health problems.

- Design guidelines and principles of visualizations along with advanced visualization techniques were used to design, prototype and develop the *i*AID dashboard as a proof-of-concept Visual Analytics tool.

- Inspired by the Delphi method, we designed and evaluated the Group Analytics Methodology that integrates multiple stakeholders working together using a Visual Analytics tool to address a wicked problem with the support of a Visual Analytics Expert and a facilitator.

- The Group Analytics methodology empirically evaluated and assessed the impact of collaborative Visual Analytics on problem solving and decision-making process within the context of public health wicked problems. The analytical sessions helped us to capture stakeholders' reasoning process in a real world setting. Pooling multiple stakeholders' ideas and inputs fosters a collective intelligence environment that helps to address the analytical problem and solve it using the designed *i*AID dashboard.

- The modified Delphi method represents a structured approach to inform the design of the Group analysis sessions. The sessions serve to collect data about the metrics and the characteristics of an effective collaboration that aim at assisting multiple injury stakeholders in their problem solving and decision making process. The modified Delphi method represents a rigorous method to capture stakeholders' verbal and non-verbal communication in a natural setting.

- Engaging with the right stakeholders in a real-world setting presents an exceptional opportunity to assess collaborative Visual Analytics to address wicked health problems. The proposed analytical tasks were realistic and valid, and the selected CHIRPP dataset was efficiently used to develop useful hypotheses and solve the tasks.

- Multiple injury stakeholders were observed during the collaborative social environment to understand how they interacted, established a *Common Ground*, coordinated their *joint activities* to solve the wicked problem. We further observed how injury stakeholders or SMEs build, preserve and validate their Common Ground to enhance their coordination of activities and collaboration.

- The *i*AID visual display pushed stakeholders to move forward based on the gained knowledge from the shared visual representation (*Coordinated Device*). SMEs discussed, exchanged knowledge with other stakeholders and reasoned about the injury problem using the Visual Analytics dashboard. The common visual display not only served to refer injury stakeholders or SMEs to one reference and evidence, it also amplifies SMEs cognitive capabilities.

- Advancing the problem solving process relies on the interactions between SMEs and the communication with VAE to refine the visual display and reflect their needs and preferences. During the group sessions, multiple SMEs exchanged knowledge and expertise with VAE to explore the various data dimensions, manipulated variables and observed the corresponding visualization in different views of the dashboard. Collaboratively, VAE and SMEs tried to understand the data and noted the visualization preferences for each set of data types.

- The Joint Activity Theory and Distributed Cognition framework presented a powerful technique to analyze the collected qualitative data.

- Iterative process of Joint Activities was adopted by SMEs to move forward in the problem solving approach until they assumed a 'Concluding Common' Ground as the right platform to reach a consensus and a decision. Comprehensive decisions represent the emergent product of the interaction and joint activities performed by multiple stakeholders.

- This study integrated theories and methods from the cognitive and social science (i.e. the modified Delphi method, the Joint Action Theory and the Distributed cognition framework) to analyze and understand the SMEs thoughts processing, perceptions and reasoning when interacting with visualization tools. This analysis will consequently inform the design of innovative tools that facilitate problem solving and support better decision-making. Bridging these theories and approaches from various disciplines and empirically evaluated them will certainly lead us to acquire richer understanding of the phenomenon and establish deeper theories.

- Data collected from the analytics sessions, the questionnaires and the follow up interviews were compiled and thoroughly analyzed to provide us with in-depth and rich understanding of the collaborative analytics process carried out by multiple SMEs that engaged with each other to establish and enhance their *Common Ground* in order to reach a consensus, solve the analytical task and make a decision.

- The Collaborative Analytics Model represents the iterative process that we synthesized based on the observed patterns that SMEs adapted throughout the analytics session to reach a consensus and make a decision about the problem.

- Lessons learned from Group Analytics methodology will inform the design of analytical sessions within organizational setting.

- Resources and hindrances retrieved from the analysis of the collaborative sessions represent a valuable source of knowledge that suggests design considerations to integrate this study's findings into the design of visualization tools.

8.2 Contributions and Reflections

Within the field of public health, health professionals and policy makers suffer from the challenging task of analysing and interpreting heterogeneous and complex health data in order to make time-critical decisions. Dynamic problems, such as those experienced in public health, in general and injury prevention in particular, have many of the characteristics of Horst Rittel's 'Wicked Problems' [Rittel & Webber, 1973]. These characteristics include: 1) The lack of an agreed-upon definition of the problem, 2) The lack of a "stopping rule" for its solution, 3) Evaluation of solutions is value-based, not true-or-false 4) Each wicked problem is unique in some senses, 5) Wicked problems cannot be adequately solved by applying a simple rule. We classified the injury problem as a wicked problem because Injuries result from interconnected and interdependent problems that combine various health elements causing them to be difficult to unravel and resolve. Preventing injury is a multifaceted health problem, considered to be a wicked health problem due to the complexity and multidimensional aspects involved.

Rittel & Webber (1973) emphasized the importance of a solution whose implementation will be judged to be effective. As public health and injury prevention problems are ill-structured 'wicked problems', they are challenging to solve using conventional problem solving approaches. In response to the special nature of these problems, a number of techniques have been created. The best-known technique is the "Delphi Method", first developed by Norman Dalkey of the RAND Corporation in the 1950's for a U.S. sponsored military project [Dalkey et al. 1969]. The Delphi method is a consensus based decision-making technique that enables a panel of experts to share and exchange observations and views about a complex problem under investigation in order to reach a solution. Participating experts pool their knowledge, expertise, and ideas into a group discussion focused on solving the problem and agreeing on a solution. The generated solution synthesizes the opinions, perspectives and judgments of involved experts. Integrating multiple injury stakeholders with diverse backgrounds, expertise and different interests leads to broader analysis of the wicked health problem, improved judgment of the underpinning contributing factors and better assessment of the proposed solutions. The resulted outcome is a multidimensional solution that integrates a mixture of resolutions including 1) the integration of public health services, 2) the provision of training to health professionals, 3) the improvement of research, and 4) the development and implementation of new or improved policies.

We adapted the modified Delphi method by adding real-time interactive visualization of complex health data by multiple injury stakeholders to facilitate experts problem solving and support their decision-making. The integration of an interactive visualization tool proved to afford injury stakeholders the right platform to investigate the injury data, effectively discuss retrieved information and share perspectives about the analytical injury problem. The use of a Visual Analytics tool is a novel approach to address complex public health and injury problems and assist health professionals and policy makers in resolving wicked problems and making informed decisions. This research study adapted Visual Analytics methods and management science techniques to generate a novel approach to deal with multidimensional health data in order to help health professionals and policy makers to address wicked and ill-structured health problems. Proposed solutions to public health problems must be consistent with a rational analysis of the available health data, but also must take into account the values and beliefs of multiple stakeholders in the community. Thus, we argued that data analysis must take place in a context of a modified Delphi structured approach to collaborative Visual Analytics in order to facilitate problem solving and support decision-making.

The wicked nature of public health problems entails the integration of Visual Analytics methods to deal with the multi-sources and multi-dimensional health data retrieved from multiple sources. From the perspective of public health, The emerging science of Visual Analytics seeks to provide theories and empirical methods that will enable application designers to apply information visualization techniques and computational analysis methods within the context of human decision-making to better design visualization tool that deals with complex data [Thomas & Cook, 2005]. The Visual Analytics approach argued that for complex and ill-structured problems, there is a need for human analytical reasoning capabilities and background knowledge to be incorporated along with the computational capabilities of information systems to support the analysis process [Keim at al, 2011]. As the present study indicates, the integration of human cognitive and perceptual skills with computer capabilities is seen as fundamental efforts to advance the analytical process and improve decision-making

This study bridged the Visual Analytics approach and modified Delphi structured collaborative decision-making methods to solve wicked health problems. The collaborative use of interactive visualization in the context of group decision-making required us to evaluate the performance of both the information visualization tool and the decision-making process as a distributed cognitive system [Hutchins, 1998] where multiple human agents collaborate on sensemaking, argumentation, and decision-making process as a joint activity. We based our analysis of the group performance on Clark's Joint Activity Theory (JAT) [Clark, 1996]. Within the context of problem solving and decision-making, the Joint Activity Theory provided a powerful method and a practical theoretical framework to analyze multiple individuals' verbal and non-verbal communication and to study their collaboration in a cooperative face-to-face computer-mediated environment to solve the analytical problem.

The main contributions of this study are twofold: First, it applied principles of visualization and design guidelines to prototype and develop the *i*AID dashboard as a proof-of-concept interactive decision-support tool that was used to help health professionals and policy makers visually explore, quickly comprehend and effectively interpret complex injury data. Second, it provided an in-depth understanding of the collaborative Visual Analytics process and its impact on problem solving and decision-making within the context of public health injury sector.

We interviewed injury stakeholders to understand and characterize domain task requirements. Based on the gathered interview data, we classified domain tasks into six main task taxonomies including: 1) Answer Research Question 2) Explore available injury data 3) Identify leading injury causes 4) Interact and understand data 5) Modify and Customize visualizations 6) Share and Collaborate. These taxonomies suggested the unique needs of injury stakeholders and helped to inform the design of the visualization tool's main components and functionalities. Based on the classification of the domain experts' task taxonomies, we presented design implications and the application of Visual Analytics principles and methods to inform the design of a Visual Analytics tool that supports domain analytical tasks. Through an interactive process, we prototyped and developed a proof-of-concept interactive visualization tool- the *interactive* Injury Analytical Dashboard (*i*AID). The main purpose of the *i*AID dashboard is to facilitate data understanding and interpretation as well as to support injury stakeholders' cognitive and analytical tasks. The *i*AID visual dashboard served to communicate key injury information in order to show the health system's overall performance in terms of major injury indicators that impact the health and wellbeing of the population. Displaying relevant health performances metrics in easy-to-understand visual representations helped to generate insights into the multidimensional injury data, which in turns helped to investigate and understand the causes of injuries which can dramatically increase the possibilities of reducing preventable deaths caused by predictable injuries [Pike, 2013]. The *i*AID visual dashboard offered analysts two key functionalities: Visualization and Interactivity. On the one hand, data visualization was important to amplify SMEs cognitive capabilities as well as to facilitate problem solving by making the solution to the health problem salient or prominent. On the other hand, interactivity provided SMEs with a platform to establish an *Analytic Discourse* [Thomas & Cook, 2005] between the SMEs and the data in order to support data analysis by asking the injury data questions, seeking answers, generating hypotheses and testing scenarios.

The *i*AID dashboard and the visual displays were equally relevant to individuals and group task performance. The positive comments and feedback provided by SMEs about their experience interacting with the visualization tool illustrated the importance of integrating the visualization tool as a useful decision-support tool to visually explore and interpret injury data, facilitate problem solving and support decision-making:

SME: "they (visual representations) provide a great deal of information very quickly and allow me to understand trends and variation in the injury data."

SME: "it (visual dashboard) helps to present the story"

SME: "it helps to think about the data in different way. It's kind of different ways to slice the pie to get the creativity going in terms of what the data are actually telling us and possible directions for preventions."

SME: "It's pretty impressive how the (dashboard) laid this out. I mean you can see a lot"

SME: "that interactivity is there, and that's the beauty of it...you can sit at your own PC, work on it in the cloud and produce whatever it is according to the questions you have"

SME: "The visual representations of the data for me are key in understanding what I'm looking at."

SME: "I trust what I see"

Another main contribution of this thesis is the design and the evaluation of a new methodology termed 'Group Analytics' (GA). The Group Analytics methodology enabled us to capture and understand the collaborative Visual Analytics process among multiple individuals and to observe how this process influenced group problem solving and decision-making. The proposed Group Analytics (GA) methodology builds upon the modified Delphi method to advance the Paired Analytics (PA) methodology [Arias-Hernandez et al., 2011]. The Group Analytics methodology extends the Paired Analytics methodology to incorporate multiple Subject Matter Experts (SMEs) that interact with each other and with the Visual Analytics Expert (VAE) in a co-located social setting to solve a given analytical task using the designed *i*AID dashboard as a Visual Analytics tool. The study showed that the proposed 'Group Analytics' methodology was effective in enabling us to study the collaborative and social aspects of Visual Analytics and their impact on facilitating problem solving and supporting decision-making of multiple stakeholders within the context of wicked injury problems.

The exploratory nature of the study's research question entails the collection of qualitative data (i.e. interviews, participants observations, video and audio recording and screen captures) and quantitative data (i.e. questionnaire) to gain in-depth understanding of the collaborative Visual Analytics process and its impact on problem solving and decision-making. The novelty of this research is that is the application of the Paired Analytics and the Group Analytics methodologies to solve real life public health injury problem with real national expert injury stakeholders and using real - anonymous - injury data retrieved from the database of the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP). SMEs are real health professionals making real life decisions about saving people's life, so their reflections on the usability and effectiveness of the *i*AID dashboard is a true reflection on the ability of the dashboard to fulfill their task requirements needs, that will be later on adapted by the ministry of health (PHAC). The Paired Analytics methodology served to test the usability of the *i*AID dashboard to support injury stakeholders' data analysis process. It also served to capture SMEs problem solving process in order to create relevant and effective analytical models and decide on the best analytical tools and methodologies to integrate within the healthcare sector. Results from the analysis of the quantitative data revealed that SMEs rated the *i*AID dashboard's visualizations high in terms of converting data into useful information, stimulating group discussion and facilitating the completion of the given analytical task, increasing learning, facilitating problem solving as well as supporting decision-making. The rating indicated that the majority of SMEs perceived the *i*AID dashboard as a useful problem solving and decision support tool. The *i*AID dashboard enabled health professionals to communicate and discuss findings in order to align their goals and work objectives. Moreover, the *i*AID dashboard provided a holistic way of looking at the injury data and gaining insight into the overall injury situation. It empowered health professionals with accurate and reliable information to monitor and evaluate the impacts of injury prevention initiatives.

To complement the quantitative evaluation, The qualitative analysis of the Group analysis sessions provided us with in-depth understanding of the impact of SMEs collaborative interactions with the visualization tool- *i*AID, on facilitating SMEs problem solving and supporting their decision-making process in a modified Delphi structured social setting. The Group Analytics methodology revealed the positive effect of collaborative Visual Analytics on the process of group problem solving and decision-making. Another principal contribution of this study is the real-word domain application of Clark's Joint Activity Theory, specifically the concept of Common Ground that was highlighted in the Group analysis collaborative process. From a cognitive science perspective, Clark's studied the concept of Common Ground between two individuals attempting to perform a given task [Clark, 1996]. Clark argued that establishing a Common Ground is fundamental to human communication and interaction. Inspired by Clark's concept of Common Ground, this study examined Clark's concept of Common Ground, and extended it to evaluate the emergence of Common Ground among multiple individuals attempting to perform a specific analytical task or solve an analytical problem in a computer mediated social environment. Throughout the GA session, injury stakeholders or SMEs interacted with each other and communicated their shared knowledge, interest, intent and goals to build their initial Common Ground. SMEs shared their prior knowledge, emphasized their common interests and goals to support the emergence of the opening *Common Ground* among them. Socially distributed cognition was manifested in SMEs verbal and non-verbal communication as well as social interactions to retrieved tacit knowledge and share it with other SMEs through language use. From a D-cog perspective, SMEs social interactions with each and with their surrounding enhanced their cognitive capabilities and enabled them to better address the wicked health problem. SMEs communications helped to maintain and enhance the initial *Common Ground* throughout the Group analysis process. Once SMEs have shared and established their common understanding of the data, they were able to validate and exploit this *Common Ground* in order move to the next phase of the modified Delphi process, which is the collaborative activities that advanced the problem solving and decision-making. As Clark stated '*Common Ground* is prerequisite for coordination- for joint actions' [Clark, p. 66]. Throughout the session, we noted that SMEs Cumulative Common Ground was explicit and constituted the foundation upon which relies the group coordination of joint activities and collaboration. Contrary to Clark's unstructured environment, we adopted a modified Delphi approach to structure SMEs collaborative setting and supplemented it with a visualization tool – the *i*AID dashboard to support SMEs communication and interactions. The *i*AID visual interface was prototyped and developed to reflect SMEs preferences and analytical task requirements. Throughout the group analysis sessions, we argued that the *i*AID dashboard interface constituted parts of SMEs shared environment and *Common Ground*. SMEs exploited the *i*AID dashboard to supplement additional pieces to the established *Common Ground*. The iAID dashboard served as a cognitive amplifier to expand SMEs cognitive capabilities to perform superior cognitive analysis. SMEs exploited the *i*AID cognitive tool and used it as a Coordination Device to maintain and improve SMEs *Common Ground* so as to ensure their effective collaboration and coordination of activities. This study indicated that *Common Ground* constitutes the scaffold that supports the collaborative joint activities among SMEs. Towards the end of the Group analysis process, the established *Common Ground* was ubiquitous and SMEs assumed it and referred to it to advance their analytical task performance. SMEs referred to their *Common Ground* to guide their collaboration and advance their joint problem solving and decision-making. We further argued that the Group Analytics methodology provided us with a unique opportunity to document how SMEs *Established, Preserved, Maintained, Validated and Exploited* their *Common Ground* through an iterative and consistent process during the Group analysis sessions, in order to increase their ability to coordinate their joint activities.

Based on the qualitative and quantitative evaluations, we argued that collaboration among multiple SMEs and interactions with the *i*AID dashboard were key components to enhance SMEs ability to understand the injury data and construct knowledge about the injury situation and consequently facilitated SMEs problem solving and decision-making. The qualitative and quantitate analysis of the data were helpful to assess injury stakeholders' perception of the *i*AID dashboard usability and functionalities. They further offered us invaluable insights into SMEs established *Common Ground*, their collaboration of activities, their interactions as well as their roles and gesture awareness within the context of collaborative problem solving and decision-making.

8.4 Recommendations and Future Work

Integrating advanced Visual Analytics tool can amplify group members' cognitive and perceptual capabilities and consequently expedite their collaborative task performance. However, in addition to supporting SMEs cognitive and perceptual capabilities, we argued that based on the study empirical findings, structuring the group process is vital to establish a Common Ground among SMEs in order to promote their coordination of activities and to enhance their communication and collaboration. Many factors contribute to the success of Group collaborations including the modified Delphi approach, which is seen as fundamental to foster a structured collaboration among group members. Another factor is the established and maintained *Common Ground,* which proved to be vital to support the modified Delphi structured Group analysis process and to ensure its success.

Collected paired analysis and group analysis data provide invaluable and resourceful information to researchers in the field of Visual Analytics to learn from real-world application of Visual Analytics. The Group Analytics methodology designed and introduced in this thesis provides a novel contribution to the field of Visual Analytics, including laying the groundwork for future research in co-located collaborative Visual

Analytics and its impact on facilitating problem solving and supporting decision-making across various disciplines.

Given what we learned from this study, we anticipate that this study will move forward in several directions. From a design perspective, we concluded through this research that the design and functionality using PA and GA test scenarios efficiently support SMEs in addressing wicked injury problem and effectively enable them to make decisions about what interventions to introduce within the injury prevention sector. This study will have implications on the design of innovative collaborative Visual Analytics tools based on the JAT and D-Cog theoretical framework. Furthermore, we identified emerging challenges with the *i*AID dashboard that could provide opportunities to improve the current version of the visualization tool to accommodate the needs of injury stakeholders. The study's implications can inform the design of future innovative visualization tools that synthesize the collaborative aspects of Visual Analytics including Common Ground and coordination devices as key components to enhance group knowledge construction and optimize decision-making.

From the public health perspective, enhanced group collaboration is vital to generate superior and timely decisions within the injury prevention sector. Pooling diverse perspectives and combining collective intelligence to address a wicked health problem is essential to reach well-informed decisions and initiate appropriate actions that could dramatically save lives and improve the well being of individuals and communities. As the current study indicates, the integration of collaborative Visual Analytics proved to be a novel and effective approach to address wicked injury problems characterized by complex and multidimensional data. Future research studies should focus on the design of new methodologies and innovative collaborative Visual Analytics tools and techniques that can be integrated into the public health sector to enhance the communication and collaboration among multiple health professionals, to support their collaborative analysis and ultimately to facilitate their problem solving and decision-making. Future work should conduct further heuristic evaluations of the introduction of Visual Analytics tools into analytical activities of health professionals to improve the quality of health problem solving and decision-making (i.e. inform injury prevention strategies and programs, introduce new injury regulations and policies, initiate appropriate injury prevention actions). Given the nature of how injury data flows, future research design should include a longitudinal study to assess and measure the impact of using the Visual Analytics tools on reducing or preventing injuries. Future research should be conducted to investigate the practical applications of the *i*AID dashboard in situ and to empirically evaluate the incorporation of Visual analytics into the public health injury prevention decision-making to investigate its impact on reducing the frequency and severity of child and youth injuries across Canada. A randomized control trial, a case study or a field study can be designed as future research studies, where the unit measure would be selected to be a health unit that will get the dashboard randomly, compared to a matched case control health unit that doesn't integrate the *i*AID dashboard for the purpose of comparing the outcome in terms of the frequency, severity of child and youth injuries. Using a set of metrics, the study would help to assess how well the injury data was manipulated, how the decisions were reached, how satisfied were SMEs using the interactive visualization dashboard as well as what is observed in terms of the reduction in injuries in the child and youth population, deaths, hospital separations and emergency room visits.

Future work should include the duplication of this successful study to guide the effective integration of Visual Analytics techniques and tools into various health care systems as well as the application of Visual Analytics to other domains and areas within the healthcare sector, including Trauma Registry data and Emergency Patients data in order to leverage research and consequently deal with health issues, generate new evidence based knowledge and address population needs.

References

Adler, M., & Ziglio, E. (1996). Gazing into the oracle: the Delphi method and its application to social policy and public health. Jessica Kingsley Publishers.

Agee, J. (2009). Developing qualitative research questions: a reflective process. *International Journal of Qualitative Studies in Education*, *22*(4), 431–447.

Aliaga, M., & Gunderson, B. (1999). *Interactive statistics*. Prentice Hall.

Andrienko, G., Andrienko, N., & Wrobel, S. (2007). Visual analytics tools for analysis of movement data. *ACM SIGKDD Explorations Newsletter*, *9*(2), 38–46.

Andrienko, G., Andrienko, N., Demsar, U., Dransch, D., Dykes, J., Fabrikant, S. I., … Tominski, C. (2010). Space, time and visual analytics. *International Journal of Geographical Information Science*, *24*(10), 1577–1600.

Andrienko, G., Andrienko, N., Jankowski, P., Keim, D., Kraak, M.-J., MacEachren, A., & Wrobel, S. (2007). Geovisual analytics for spatial decision support: Setting the research agenda. *International Journal of Geographical Information Science*, *21*(8), 839–857.

Arias-Hernandez, R., Kaastra, L. T., & Fisher, B. (2011). Joint action theory and pair analytics: In-vivo studies of cognition and social interaction in collaborative visual analytics. In Proceedings of the 33rd Annual Conference of the Cognitive Science Society (pp. 3244–3249).

Arias-Hernandez, R., Kaastra, L. T., Green, T. M., & Fisher, B. (2011). Pair Analytics: Capturing Reasoning Processes in Collaborative Visual Analytics. In (HICSS), 2011 44th Hawaii International Conference On System Sciences (pp. 1–10).

Basit, T. (2003). Manual or electronic? The role of coding in qualitative data analysis. *Educational Research*, *45*(2), 143–154.

Bekker, M. M., Olson, J. S., & Olson, G. M. (1995). Analysis of gestures in face-to-face design teams provides guidance for how to use groupware in design. In Proceedings of the 1st conference on Designing interactive systems: processes, practices, methods, & techniques (pp. 157–166).

Belland, B. R. (2011). Distributed Cognition as a Lens to Understand the Effects of Scaffolds: The Role of Transfer of Responsibility. Educational Psychology Review, 23(4), 577–600.

Borkin, M., Gajos, K., Peters, A., Mitsouras, D., Melchionna, S., Rybicki, F., … Pfister, H. (2011). Evaluation of artery visualizations for heart disease diagnosis. *Visualization and Computer Graphics, IEEE Transactions on*, *17*(12), 2479–2488.

Boulos, M. N. K., Viangteeravat, T., Anyanwu, M. N., Nagisetty, V. R., & Kuscu, E. (2011). Web GIS in practice IX: a demonstration of geospatial visual analytics using Microsoft Live Labs Pivot technology and WHO mortality data. *Int. J. Health Geogr*, *10*(19).

Bradley, E. H., Curry, L. A., & Devers, K. J. (2007). Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Health Services Research*, *42*(4), 1758–1772.

Brennan, S. E., Mueller, K., Zelinsky, G., Ramakrishnan, I., Warren, D. S., & Kaufman, A. (2006). Toward a multi-analyst, collaborative framework for visual analytics. In Visual Analytics Science And Technology, 2006 IEEE Symposium On (pp. 129–136).

Brink, P. J., & Wood, M. J. (1989). Descriptive designs. *Advanced Design in Nursing Research*, 123–140.

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues*, *8*(2), 5–21.

Burns, N., & Grove, S. K. (1997). Selecting a research design. *The Practice of Nursing Research: Conduct, Critique, & Utilization*, *3*, 249–291.

Card, S. K., Mackinlay, J. D., & Shneiderman, B. (1999). *Readings in information visualization: using vision to think*. Morgan Kaufmann.

Carr, D. A. (1999). Guidelines for designing information visualization applications. Proceedings of ECUE, 99, 1–3.

CHIRPP (2009). The Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP), Public Health Agency of Canada.

Clark, H. H. (1996). Using language (Vol. 4). Cambridge University Press Cambridge.

COFFEY, A. A., & Atkinson, P. (1996). *Making sense of qualitative data: Complementary research strategies*. Sage.

Cook, K. A., & Thomas, J. J. (2005). Illuminating the path: the research and development agenda for visual analytics. Pacific Northwest National Laboratory (PNNL), Richland, WA (US).

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. Qualitative sociology, 13(1), 3–21.

Corbin, J., & Strauss, A. (2008). Basics of qualitative research: Techniques and procedures for developing grounded theory. Sage.

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches. Sage Publications, Incorporated.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and conducting mixed methods research*. Wiley Online Library.

Dalkey, N. C., Brown, B. B., & Cochran, S. (1969). The method: An experimental study of group opinion (Vol. 3). Rand Corporation Santa Monica, CA.

Delbecq, A. L., Van de Ven, A. H., & Gustafson, D. H. (1975). Group techniques for program planning. Glenview, IL: Scott, Foresman, and Co.

Denzin, N. K., & Lincoln, Y. S. (2005). *The Sage handbook of qualitative research*. Sage.

Dillenbourg, P. (1999). What do you mean by collaborative learning? *Collaborative-Learning: Cognitive and Computational Approaches.*, 1–19.

Dubrovsky, V. J., Kiesler, S., & Sethna, B. N. (1991). The equalization phenomenon: Status effects in computer-mediated and face-to-face decision-making groups. Human-Computer Interaction, 6(2), 119–146.

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 32, pp. 97–101). SAGE Publications.

Few S. Dashboard Confusion Revisited. Perceptual Edge. 2007.

Few. S. (2007). Improve Your Vision and Expand Your Mind with Visual Analytics.

Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (2002). Fostering collaborative knowledge construction with visualization tools. Learning and Instruction, 12(2), 213–232.

Fisher, B. A. (1970). Decision emergence: Phases in group decision-making. Communications Monographs, 37(1), 53–66.

Gesteland, P. H., Livnat, Y., Galli, N., Samore, M. H., & Gundlapalli, A. V. (2012). The EpiCanvas infectious disease weather map: an interactive visual exploration of temporal and spatial correlations. *Journal of the American Medical Informatics Association*, *19*(6), 954–959.

Goodwin, C., & Heritage, J. (1990). Conversation analysis. Annual review of anthropology, 19, 283–307.

Gordon, T. J. (1994). The Delphi method. Futures research methodology, 6.

Guo, D. (2007). Visual analytics of spatial interaction patterns for pandemic decision support. *International Journal of Geographical Information Science*, *21*(8), 859–877.

Guo, D. (2007). Visual analytics of spatial interaction patterns for pandemic decision support. *International Journal of Geographical Information Science*, *21*(8), 859–877.

H.A. Simon. The Sciences of the Artificial. MIT Press, 1996.

Hackman, J. R., & Morris, C. G. (1974). Group tasks, group interaction process, and group performance effectiveness: A review and proposed integration. Defense Technical Information Center.

Hackos, J. T., & Redish, J. (1998). User and task analysis for interface design.

Halverson, C. A. (1994). Distributed Cognition as a theoretical framework for HCI: Don't throw the Baby out with the bathwater-the importance of the cursor in Air Traffic Control. Cognitive Science Department, UCSD. Report, 9403.

Hanrahan, P., Stolte, C., Mackinlay, J., & Director, V. A. (2009). Selecting a Visual Analytics Application.

Heer, J., & Agrawala, M. (2008). Design considerations for collaborative visual analytics. *Information Visualization*, *7*(1), 49–62

Heer, J., Viégas, F. B., & Wattenberg, M. (2009). Voyagers and voyeurs: Supporting asynchronous collaborative visualization. *Communications of the ACM*, *52*(1), 87–97.]

Heuer Jr, R. J. (1999). *Psychology of intelligence analysis*. Lulu. com.

Hiltz, S. R., Johnson, K., & Turoff, M. (1986). Experiments in Group Decision Making Communication Process and Outcome in Face-to-Face Versus Computerized Conferences. Human communication research, 13(2), 225–252.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. ACM Transactions on Computer-Human Interaction (TOCHI), 7(2), 174–196.

Hsu, C.-C., & Sandford, B. A. (2007). The Delphi technique: making sense of consensus. Practical Assessment, Research & Evaluation, 12(10), 1–8.

Hutchins, E. (1995). *Cognition in the Wild* (Vol. 262082314). MIT press Cambridge, MA.

Isenberg, P., & Fisher, D. (2009). Collaborative Brushing and Linking for Co-located Visual Analytics of Document Collections. In *Computer Graphics Forum* (Vol. 28, pp. 1031–1038).

Iverson, J. M., & Thelen, E. (1999). Hand, mouth and brain. The dynamic emergence of speech and gesture. Journal of Consciousness Studies, 6(11-12), 11–12.

Jensen, J. F. (1998). Interactivity. Tracking a new concept in media and communication studies. Nordicom Review, 19(1), 185–204.

Kaastra, L. T., Arias-Hernandez, R., & Fisher, B. (2012). Evaluating analytic performance. In Proceedings of the 2012 BELIV Workshop: Beyond Time and Errors-Novel Evaluation Methods for Visualization (p. 14).

Keim, D. A. (2002). Information visualization and visual data mining. *Visualization and Computer Graphics, IEEE Transactions on*, *8*(1), 1–8.

Keim, D. A., Mansmann, F., & Thomas, J. (2010). Visual analytics: how much visualization and how much analytics? *ACM SIGKDD Explorations Newsletter*, *11*(2), 5–8.

Keim, D. A., Mansmann, F., Schneidewind, J., & Ziegler, H. (2006). Challenges in visual data analysis. *Information Visualization, 2006. IV 2006. Tenth International Conference on* (pp. 9–16).

Keim, D., & Zhang, L. (2011). Solving problems with visual analytics: challenges and applications. Proceedings of the 11th International Conference on Knowledge Management and Knowledge Technologies (p. 1).

Keim, D., Andrienko, G., Fekete, J. D., Görg, C., Kohlhammer, J., & Melançon, G. (2008). Visual analytics: Definition, process, and challenges. *Information Visualization*, 154–175.

Kezar, A. (2000). The importance of pilot studies: Beginning the hermeneutic circle. *Research in Higher Education*, *41*(3), 385–400.

Kezar, A. (2000). The importance of pilot studies: Beginning the hermeneutic circle. *Research in Higher Education*, *41*(3), 385–400.

Kirschner, P. A., Shum, S. J. B., & Carr, C. S. (2003). *Visualizing argumentation: Software tools for collaborative and educational sense-making*. Springer-Verlag New York Inc.

Koschmann, T. (1999). Toward a dialogic theory of learning: Bakhtin's contribution to understanding learning in settings of collaboration.

Kruger, R., Carpendale, S., Scott, S. D., & Greenberg, S. (2003). How people use orientation on tables: comprehension, coordination and communication. In *Proceedings of the 2003 international ACM SIGGROUP conference on Supporting group work* (pp. 369–378).

Langley, J., & Brenner, R. (2004). What is an injury? *Injury Prevention*, *10*(2), 69–71.

Linstone, H. A., & Turoff, M. (2002). The Delphi Method: Techniques and Applications. Addison-Wesley Reading, MA.

Liu, Z., & Stasko, J. T. (2010). Mental models, visual reasoning and interaction in information visualization: A top-down perspective. *Visualization and Computer Graphics, IEEE Transactions on*, *16*(6), 999–1008.

Liu, Z., Nersessian, N., & Stasko, J. (2008). Distributed cognition as a theoretical framework for information visualization. Visualization and Computer Graphics, IEEE Transactions on, 14(6), 1173–1180.

MacEachren, A. M., Brewer, I., & Steiner, E. (2001). Geovisualization to mediate collaborative work: Tools to support different-place knowledge construction and decision-making. *20th International cartographic conference* (pp. 6–10).

MacEachren, A. M., Brewer, I., Cai, G., & Chen, J. (2003). Visually enabled geocollaboration to support data exploration and decision-making. Proceedings of the 21st International Cartographic Conference, Durban, South Africa (pp. 10–16).

MacEachren, A. M., Gahegan, M., Pike, W., Brewer, I., Cai, G., Lengerich, E., & Hardistry, F. (2004). Geovisualization for knowledge construction and decision support. *Computer Graphics and Applications, IEEE*, *24*(1), 13–17.

Maciejewski, R., Rudolph, S., Hafen, R., Abusalah, A., Yakout, M., Ouzzani, M., Cleveland, W. S., et al. (2010). A visual analytics approach to understanding spatiotemporal hotspots. *Visualization and Computer Graphics, IEEE Transactions on*, *16*(2), 205–220.

MacQueen, K. M., McLellan, E., Kay, K., & Milstein, B. (1998). Codebook development for team-based qualitative analysis. *Cultural Anthropology Methods*, *10*(2), 31–36.

Marsh, K. L., Richardson, M. J., & Schmidt, R. C. (2009). Social connection through joint action and interpersonal coordination. Topics in Cognitive Science, 1(2), 320–339.

Marshall, C., & Rossman, G. B. (2006). *Design qualitative research*. Thousand Oaks: Sage Publications.

Merriam, S. B. (2002). Qualitative research in practice: Examples for discussion and analysis.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological review*, *63*(2), 81

Moore, K., Edge, G., & Kurc, A. (2008). Visualization techniques and graphical user interfaces in syndromic surveillance systems. Summary from the Disease Surveillance Workshop, Sept. 11–12, 2007; Bangkok, Thailand. BMC proceedings (Vol. 2, p. S6)

Morris, M. R., & Teevan, J. (2009). Understanding groups' properties as a means of improving collaborative search systems. *arXiv Preprint arXiv:0908.0586*.

Norman, D. A. (1993). *Things that make us smart: Defending human attributes in the age of the machine*. Basic Books.

North, C., & Shneiderman, B. (2000). Snap-together visualization: can users construct and operate coordinated visualizations? International Journal of Human-Computer Studies, 53(5), 715–739.

Nova, N., Sangin, M., & Dillenbourg, P. (2008). Reconsidering Clark's Theory in CSCW. In 8th International Conference on the Design of Cooperative Systems (COOP'08).

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: an example, design considerations and applications. Information & Management, 42(1), 15–29.

Pike, I. et al. (2010). Measuring Injury Matters: Injury Indicators for Children and Youth in Canada. Vancouver, BC: UBC.

Pike, W. A., May, R., Baddeley, B., Riensche, R., Bruce, J., & Younkin, K. (2007). Scalable visual reasoning: supporting collaboration through distributed analysis. In Collaborative Technologies and Systems, 2007. CTS 2007. International Symposium on (pp. 24–32).

Pirolli, P., & Card, S. (2005). The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis. In *Proceedings of International Conference on Intelligence Analysis* (Vol. 5, pp. 2–4).

Plaisant, C., Heller, D., Li, J., Shneiderman, B., Mushlin, R., & Karat, J. (1998). Visualizing medical records with LifeLines. In *CHI 98 Conference Summary on Human Factors in Computing Systems* (pp. 28–29). ACM.

Polit, D. F., Beck, C. T., & Hungler, B. (n.d.). *Essentials of nursing research, 2001*. Lippincott Williams & Wilkins, Philadelphia, USA.

Quek, F., McNeill, D., Bryll, R., Duncan, S., Ma, X.-F., Kirbas, C., … Ansari, R. (2002). Multimodal human discourse: gesture and speech. ACM Transactions on Computer-Human Interaction (TOCHI), 9(3), 171–193.

Rittel, H. W., & Webber, M. M. (1973). 2.3 Planning Problems are Wicked. *Polity*, *4*, 155–69

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169.

Robertson, S. I. (2003). *Problem solving*. Psychology Press.

Rogers, Y. (1997). A brief introduction to distributed cognition. Retrieved July, 24, 1997.

Rogers, Y., & Ellis, J. (1994). Distributed cognition: an alternative framework for analysing and explaining collaborative working. Journal of information technology, 9, 119–119.

Rudolph, S., Savikhin, A., & Ebert, D. S. (2009). FinVis: Applied visual analytics for personal financial planning. In *Visual Analytics Science and Technology, 2009. VAST 2009. IEEE Symposium on* (pp. 195–202). IEEE.

S. K. Card, J. D. Mackinlay, and B. Shneiderman. Readings in information visualization: using vision to think, chapter 1, pages 1–34. Morgan Kaufmann Publishers Inc, 25 January 1999.

Saldaña, J. (2012). *The coding manual for qualitative researchers*. Sage.

Scaife, M., & Rogers, Y. (1996). External cognition: how do graphical representations work? *International Journal of Human-Computer Studies*, *45*(2), 185–213.

Schegloff, E. A. (1991). Conversation analysis and socially shared cognition.

Scott, S. D., Sheelagh, M., Carpendale, T., & Inkpen, K. M. (2004). Territoriality in collaborative tabletop workspaces. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work* (pp. 294–303).

Scott, S. D., Sheelagh, M., Carpendale, T., & Inkpen, K. M. (2004). Territoriality in collaborative tabletop workspaces. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work* (pp. 294–303).

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: bodies and minds moving together. Trends in cognitive sciences, 10(2), 70–76.

Shneiderman, B. (1996). The eyes have it: A task by data type taxonomy for information visualizations. In *Visual Languages, 1996. Proceedings., IEEE Symposium on* (pp. 336–343). IEEE.

Shneiderman, B., Plaisant, C., & Hesse, B. (2013). Improving health and healthcare with interactive visualization methods.

Shrinivasan, Y. B., & van Wijk, J. J. (2008). Supporting the analytical reasoning process in information visualization. *Proceedings of the twenty-sixth annual SIGCHI conference on Human factors in computing systems* (pp. 1237–1246).

Smith, R. G., & Davis, R. (1981). Frameworks for cooperation in distributed problem solving. *Systems, Man and Cybernetics, IEEE Transactions on*, *11*(1), 61–70.

Stahl, G. (2000). A model of collaborative knowledge-building. In *Proceedings of the fourth international conference of the learning sciences* (pp. 70–77).

Stasko, J., Görg, C., & Liu, Z. (2008). Jigsaw: supporting investigative analysis through interactive visualization. *Information Visualization*, *7*(2), 118–132.

Stenning, K., & Van Lambalgen, M. (2008). *Human reasoning and cognitive science*. The MIT Press.

Strauss, A. & Juliet Corbin. (1998). Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory (2nd Ed.).

Tang, A., Tory, M., Po, B., Neumann, P., & Carpendale, S. (2006). Collaborative coupling over tabletop displays. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 1181–1190).

Tang, J. C. (1991). Findings from observational studies of collaborative work. International Journal of Man-machine studies, 34(2), 143–160.

Tashakkori, A., & Creswell, J. W. (2007). Editorial: The new era of mixed methods. *Journal of Mixed Methods Research*, *1*(1), 3–7.

Teddlie, C. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage Publications Inc.

Teutsch, S. M., & Churchill, R. E. (2000). *Principles and practice of public health surveillance*. Oxford University Press, USA.

Thomas, J., & Kielman, J. (2009). Challenges for visual analytics. *Information Visualization*, *8*(4), 309–314.

Tobin, K. (1987). The role of wait time in higher cognitive level learning. Review of educational research, 57(1), 69–95.

Tomaszewski, B. M., & MacEachren, A. M. (2006). A distributed spatiotemporal cognition approach to visualization in support of coordinated group activity. In *Proceedings of the 3rd International ISCRAM Conference* (pp. 347–35). Newark,(NJ)(USA).

Toulmin, S. (1958) The Uses of Argument. Cambridge University Press. Cambridge, UK.

Tufte, E. R. (n.d.). Visual explanations. 1997. *Graphics Press*, *200*, 79.

Tufte, E. R., & Weise Moeller, E. (1997). *Visual explanations: images and quantities, evidence and narrative* (Vol. 107). Graphics Press Cheshire, CT.

Van Teijlingen, E., & Hundley,V. (2002). The importance of pilot studies. *Nursing Standard*, *16*(40), 33–36.

Wang Baldonado, M. Q., Woodruff, A., & Kuchinsky, A. (2000). Guidelines for using multiple views in information visualization. *Proceedings of the working conference on Advanced visual interfaces* (pp. 110–119).

Wang, T. D., Plaisant, C., Quinn, A. J., Stanchak, R., Murphy, S., & Shneiderman, B. (2008). Aligning temporal data by sentinel events: discovering patterns in electronic health records. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 457–466). ACM.

Wang, T. D., Wongsuphasawat, K., Plaisant, C., & Shneiderman, B. (2011). Extracting insights from electronic health records: case studies, a visual analytics process model, and design recommendations. *Journal of Medical Systems*, *35*(5), 1135–1152.

Wang, X., Jeong, D. H., Dou, W., Lee, S., Ribarsky, W., & Chang, R. (2009). Defining and applying knowledge conversion processes to a visual analytics system. *Computers & Graphics*, *33*(5), 616–623.

Ware, C. (2008). *Visual thinking for design*. Morgan Kaufmann Pub.

Webb, N. M. (1982). Student interaction and learning in small groups. *Review of Educational Research*, *52*(3), 421–445.

Wooldridge, M., & Jennings, N. R. (1996). Towards a theory of cooperative problem solving. In Distributed Software Agents and Applications (pp. 40–53). Springe.

Appendix A.

Visual Analytics Dashboard System: Questionnaire

This questionnaire is designed to solicit stakeholders' reactions to the proposed Injury Indicator Dashboard system using emergency department data from the BC Children's Hospital. Your feedback will enable us to understand various aspects of collaborative Visual Analytics and its effect on problem solving and decision-making process.

PART I: DEMOGRAPHIC INFORMATION

GOAL: The main objective of this section is to collect participants' demographic information.

1. Gender

↑ Male

↑ Female

2. Age Group

↑ 25 – 34

↑ 35 – 44

↑ 45 – 54

↑ 55 – 64

↑ 65 or older

3. Job Description

↑ Injury Prevention Practitioner

↑ Policy Maker

↑ Other, please specify: ______________________________

4. Academic Degree

↑ Diploma

↑ Bachelor

↑ Masters

↑ PhD

↑ Other, please specify: ______________________________

PART II: SYSTEM EVALUATION

GOAL: The main objective of this section is to assess the usability, feasibility, and ease of use of the Dashboard system.

Please consider the tasks you have accomplished using the system and indicate how strongly you agree or disagree with the following statements.

Look and Feel

1. The Dashboard system is easy to learn

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

2. The Dashboard system is intuitive and self descriptive

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

3. The Dashboard interface was organized and clear

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

<u>Content</u>

4. The visualizations/charts are easy to understand and interpret

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

5. The visualizations convert data into useful information

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

PART III: COLLABORATION

GOAL: The main objective of this section is to assess the role of collaboration and its impact on the problem solving and decision-making process.

After completing a scenario using the Dashboard system, please circle the rating of your choice for the following statements:

Dashboard

1. The Dashboard helps me share my ideas with other injury stakeholders

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

2. The dashboard stimulated discussion, brainstorming new ideas

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

Collaborative Analytic Sessions

1. In my opinion, group collaboration increased my learning

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

:

2. In my opinion, group collaboration supported the problem solving process

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

:

3. In my opinion, group collaboration supported the decision-making process

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

4. What other factors (e.g. stakeholders' authority, trust) contributed to problem solving and decision-making?

____

____

____

PART IV: SCENARIO ANALYSIS

GOAL: The objective of this section is to analyze how the Dashboard assisted injury stakeholders with problem solving while working with a VA tool expert.

After completing a scenario using the Dashboard system, please circle the rating of your choice for the following statements. Please write your comments and suggestions to elaborate on your answers.

1. Overall, I'm satisfied with the amount of time it took me to complete the task

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

2. I effectively and efficiently completed the task using the Dashboard

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

Paired Analytic Sessions

3. In my opinion, engaging with the VA tool expert enhanced my ability to understand the Dashboard

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

4. In my opinion, engaging with the VA tool expert supported the problem solving process

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

5. In my opinion, engaging with the VA tool expert supported the decision-making process

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

COMMENTS:

Other

6. What features should the Visual Analytics Dashboard incorporate to facilitate problem solving?

7. What features should the Visual Analytics Dashboard incorporate to support decision-making?

8. What other features would you like to see in the updated version of the Visual Analytics Dashboard?

Thank you for participating in this study. Your feedback is very important to us. Your answers will be kept strictly confidential. We appreciate your time.

Appendix B.

Look, Feel and Functionality of an Injury Indicators Dashboard

Meeting Participants & Goals

The meeting goal was to solicit input on what is meaningful to injury prevention practitioners and stakeholders with regards to the design and functionality – *Look and Feel* – of the Dashboard as well as to inform the development and design of the *Canadian Child and Youth Injury Dashboard* in terms of visual appeal, specific features, utility of the information, and the perceived functionality. Participants included injury prevention researchers, policy/decision makers, and representatives from national injury prevention organizations, and injury practitioners such as health nurses, health authority representatives, and Coroner's Service representatives joined the meeting. Each group provided ideas on the look, feel and functionality of an injury indicators dashboard. Their ideas are summarized in the table below:

Indicators Dashboard	Points made
Look	1) On the front page, have the most severe outcomes displayed, across indicators 2) Drill down is very important (customizability) 3) Current dashboard model is too busy – need separation of information and graphics 4) Could have a hospital with windows – each window represents a different injury and related information 5) 3D 6) Click on indicators list, then go directly to map to choose region 7) Have an 'indicator of the day' section to tell people what they are most at risk for (age, activity, current weather, location) 8) Be able to see what interventions worked in other communities 9) National death clock across the top 10) Should look like a dashboard 11) Ability to click on provinces across the bottom 12) Map of Canada you can click on 13) Boxes you can click on for specific information (e.g. mechanism of injury, indicators, specifications, outputs such as tables or graphs, map overlays 14) Upcoming events 15) Use of icons 16) Source of information available 17) Injury clock to count injuries over passage of time 18) Indicators displayed by age, sex, SES, urban/rural (incorporate images and icons to display information in best way possible) 19) Show only 1 chart/graph at a time with ability to click on others 20) Link to "what can I do about this"

Indicators Dashboard	Points made
Feel	21) Cost should be minor or negligible 22) List clearly available, levels easily accessible 23) Plain language 24) Different languages for new Canadians 25) Community Accounts is awesome website with existing dashboards 26) Need pull down screens that are not too overwhelming 27) User-friendly 28) Consider terminology; we need to know right away how you have defined the potential indicators before we can proceed; we need further explanation in each indicator on the dashboard remembering that each person may not be familiar with medical terminology 29) If we want youth engagement in injury prevention, then how do we make a system like this more youth friendly so that youth can use this in program development; policy development/advocacy? 30) Interactive 31) User friendly/easy 32) Customizable on desktop 33) Keep it simple 34) Intuitive drop-down menus
Function	35) Want to layer and compare factors in /between indicators and statistical comparisons (in one interface) 36) Ability to cross tabulate the data 37) Ability to search by type of injury or cause of injury (e.g. falls OR brain injury) 38) Flexibility to adapt/add to locally (e.g. map out liquor stores, schools, hospitals) 39) Like to see national and provincial data 40) Ability to view all provinces/jurisdictions 41) Need definitions for injury codes 42) Security and confidentiality of data is important 43) Must link with CIHI who have portal system software with dashboard capability 44) GIS connection 45) Urban, rural, remote comparisons 46) Policy comparisons and links to the policies in each jurisdiction 47) Search function 48) Customizable dashboards to make relevant to own work 49) Local level data that would ‘pop’/stand out when it was time to take action 50) Compendium of best practices 51) Link to Cochrane reviews to access gold standard 52) Ability to click on provinces across the bottom, then click again to regional level data 53) Continuity of information between levels 54) Interactive rolling window discussion forum 55) Comparability by region and to National

Indicators Dashboard	Points made
	56) Cost calculator 57) Option to lift out charts/data for reports/publications 58) Address social determinants 59) Ability to compare 60) Audience – practitioners, policy-makers, researchers 61) Functions – overall injury summary; landing page state of the nation 62) Pyramid with related charts, costs, etc. 63) Indicator icons leading to detailed info on each 64) Main topics for each? 65) Similar views 66) Charts to be presented: 67) One larger icon, with others in smaller icons 68) Ability to enlarge 69) Maybe slideshow of slides 70) Information over time (e.g. gapminder) 71) Trends over time 72) Relate to other HC issues 73) Trends over geography (and time) 74) Links to what to do

Appendix C. Striving to Go Live: The Canadian Child and Youth Injury Dashboard

This meeting was entitled '*Striving to Go Live: The Canadian Child and Youth Injury Dashboard'.* It took place March 2011, in Ottawa and discussed the Injury Indicators Overview as well as the *online Canadian Child and Youth Injury Dashboard*. (Arc, The Hotel, Ottawa March 30, 2011)

Summary of Advice for Building an Injury Dashboard

Be aware of data that changes or gets updated (WIRA, TC)

Need to let users know that data may change (i.e. WIRA)

Be wary of double-counting in databases

Need to reconcile NCDB reporting differences from different police bodies

Need to provide rider to dashboard users about data accuracy

Watch for coding using '0' as it can mean an age of less than 1 yr old OR can mean age unknown.

Desire to have dashboard in English and French

NOTES

1. Introductions

2. Injury Indicators Overview (Powerpoint presented by Ian)

3. Discussion

- How will we deal with data sources that provide data on different years (calendar vs. fiscal OR different start dates for data across provinces)
- Definition of data is important
- Categories for excel columns is important
- Dashboard should provide link to specification table
- Need to decide where data will be housed
- How do we uphold federal, provincial, municipal legislation for data?
- How small is community level data? We don't want it so small that ** show up in all queries. Likely, we will keep data at health authority level to address this.

· Could we present data in a way that allows future population projections to be made? (i.e. If we keep going as we are, this is the # of falls we will have in 2020)

· Discussed ability to project future impact (i.e. If we take these injury prevention actions, this is what the impact could be). We decided that there is no reliable way to do this at this time

· Need to decide on regions/clusters geographically

· Need to make data relevant to policy makers and community members

· Clarified that this dashboard is intended for practitioners and policy makers

· Clarified that aggregated, summary level data will be used rather than raw, individual level data

4. Data currently available ·

PHAC has CHIRPP data from all pediatric emergency departments

Health statistics from Canadian Coroners Medical Examiners data (CCME) exists and is being tested by PHAC and will be released (at least internally)

Comes from Vital Statistics ·

Lifesaving Society uses Water Incident Research Alliance (WIRA) - drowning data from 1999-2009 for all of Canada except Ontario ('99-'07)

Data includes unintentional, water-related fatalities ○ Data is complete, detailed, rich, but not current

WIRA receives records from Coroners once files are closed

CIHI has a products and services guide with all CIHI data holdings available on their website

Central site for ON Trauma Registry

CIHI gathers the ON death dataset, but only release when complete (most recent complete year is 2006)

Validates death dataset using Vital Stats to ensure completeness ○ CIHI has all hospitalizations, all hospital data cut from Discharge Abstract Database

(minimal dataset)

Minimal Dataset is missing poisonings

Comprehensive dataset from recognized hospitals (ISS 12 or greater)

Comprehensive dataset in ON very rich (more codes), other provinces have rich data registries, but CIHI only receives a cut of that data

There are 65 hospitals in Quebec and 35 hospitals in the rest of Canada

NACRS held by CIHI (emergency dept visits) is good for ON and AB, still building in the rest of Canada

There are several other groups starting to gather data: Traumatic brain injury group, neurotrauma group, Rick Hanson Foundation, Spinal cord injury group

RIW Costing database available – report to be released by May 21 on the cost of drinking related injuries such as drinking and driving, drinking and boating, etc.

REHAB database (NRS) is building – currently collecting in-hospital rehab

CIHI data using ICD-10-CA codes, adheres to international standard

CIHI has 2 divisions: 1)Research and analysis & 2)Programs – annual reports produced on health indicators bring datasets from 2 divisions together

·

· SMARTRISK

Hold Intelehealth record level data

Have produced the Economic Burden of Injury Report using ERAT for calculations

15 injury categories for 36 health authorities

·Transport Canada

TRAID collision database has been replaced by National Collision Database (NCDB)

Provinces provide their own data, TC need agreement from each province to share data

NCDB contains national data or data provided and agreed upon by each province

Fatality Database contains drivers/pedestrians killed in alcohol/drug related incidents and can be broken down by region

Cost of Collision Study has been conducted using a different model than SMARTRISK

Reporting comes from RCMP, OPP, municipal police,etc.

There is sometimes a problem with agreement on data from different sources – need to reconcile reporting differences if presenting data on a dashboard.

Public insurers such as ICBC only exist in 3 provinces

·Canadian Red Cross

Also uses WIRA data

Need to provide a rider to dashboard users about data accuracy e.g. If someone dies from drowning in a ditch after a vehicle crash, data may not be entered accurately in the database resulting in missed cases

Data may only give the primary cause of death without ability to obtain secondary ·Statistics Canada

The Canadian Community Health Survey is collected every 2 years for children

CCHS contains self report of: injuries requiring medical treatment, circumstances, what was injured, use of carseats, risk factors

CCHS could provide regional breakdowns

Aboriginal Children's Survey conducted in 2006

Stats Can holds a copy of Discharge Abstract Database from CIHI for 2005/2006

Stats Can holds Vital Stats up to 2007 at the health region level (will soon receive 2008)

Canadian Mortality Database used for record linkage – especially used for updated files
- CENSUS data (provides denominators)

Postal code conversion file converts postal codes to geographic identifiers useful for StatsCan geography, can relate to socio-economic status by assigning postal code to income quintile of the local health area, possibly DA level

Stats Can has Inuit data because of work on Naasautit with Inuit Tapiriit Kanatami (http://www.inuitknowledge.ca/naasautit)

·Health Canada has database of illicit drugs – they also have results of self-reported National drug & alcohol survey

Discussion

Which datasets collect risk factors? Drowning dataset, CHIRPP, and CCHS ·Is data available on ethnicity'

· How can we visualize data and indicators working together? ·Discussion of reporting ratios

· Discussion of cell sizes less than 5 and how to portray them on the dashboard in a useful way

6. Demonstration of Patient Costing Measures (Pierre Leveille, CIHI)

· Explained case mix group, case costing & RIW, and cost per weighted case

· Costs from 49 out of 700 hospitals in Canada

· CIHI patient cost estimator can export results into Excel or ACCISS, from CIHI website under Quicklinks, click Interactive Tools/Databases, then click Patient Costing Measures

7. Demonstration of CDC's Wonder Database, contact Julie Gilchrist at CDC in Atlanta for more information

8. Obtaining Data: Privacy, Confidentiality and Data Security

· CIHI options are: 1) Receive an annual data drop by signing a data sharing agreement OR 2)Make an annual data request

It was agreed that data sharing agreement was best option

To have a data sharing agreement, need to demonstrate that we can protect data

(firewalls)

Also need legitimate institution, Chief Data Officer, secure place to house data

Need to discuss what is wanted and how to deal with Quebec data

Claire-Marie will assist with application for data sharing agreement and data request

· WIRA – data sharing agreement makes sense, need to clear confidentiality with Coroners Office

· It was agreed that ethics certificates are helpful in obtaining data sharing agreements

· Transport Canada- need to make a standing request for collision data (married up with Coroners data)

Can try to obtain data through TC's online tool

We need to tell TC what we want, they will send abstracts

· Statistics Canada

Can request aggregate data

May be able to get health region level, though may need to be rolled up in to several years to avoid small cell sizes

9. Further Discussion of Dashboard

· Desire to provide dashboard in both English and French

· Could house the dashboard at the Child and Family Research Institute

· Do we need a mirror site – could be Windsor

· Desire to build a pilot dashboard in BC ·Need detailed information in excel column headers

dashboard

· Mo Green in Nova Scotia is willing to assist in building a 'youth skin' to 'youthanize' the dashboard

· Timeline: Hope to accomplish by end of STAIR Child & Youth Team Grant in 2015

Appendix D:
Summary of Analytics Sessions

Via email:

Dear All,

Thank you for accepting our invitation to be involved in the Injury Dashboard research study. As explained during the Dashboard Workshop held in March at the BC Children's Hospital, Samar Al-Hajj, PhD student needs to conduct follow up phone interviews with injury prevention stakeholders who attended the March meeting in order to complete the last part of data collection required for her PhD research study. The consent form you signed prior to the March 21, 2013 meeting includes this step in the research. Your participation is still voluntary and your decision to participate or not is confidential. Your interview answers will be kept confidential.

The pre-established interview questions will help Samar to emphasize phenomena and reinforce main concepts gathered from the reflections on the first round of data collected during the Pair Analytics (PA) sessions. The following paragraph highlights some of the major findings from the initial analysis of the PA sessions:

• Subject Matter Experts (SMEs) follow similar approaches to analytical problem solving (look for patterns in data, drill down by "age group, sex, causes, sub-causes and regions" for further level of details, observe how data trend over time) • SMEs share findings/results of the analysis (reports or papers) •During the PA sessions, SME had positive experience interacting with the Visual Analytics Expert (VAE) and with the visual analytic Dashboard tool.

• SME and TE communicated effectively in terms of exchanging knowledge and expertise and customizing/refining the visual display to reflect SMEs needs at the different stages of the problem solving process.

• Some SMEs discussed the limitations of the data in terms of the categorization and the definition of various terms in the original database, which makes it challenging for them to understand the variables without referring back to the "narrative field".

• Many SMEs were impressed with the tool's advanced functionalities and features, which they perceive as useful and directly applicable to their current work.

Please take a few moments to think about the following questions:

Q1: In your opinion, how do external visual representations of injury data support you in your problem solving process?

Q2: In your opinion, how does the communication and interaction between SME and TE during the Paired session affect the advancement of the problem solving and decision-making process?

Q3: In your opinion, how does collaboration and the exchange of knowledge and expertise influence the decision making process in the Group Session compared to the Paired Session?

Q4: In your opinion, how valid, reliable, trustworthy are the results produced by the Dashboard?

Q5: Finally, from your personal position and involvement in injury prevention, please provide any further information that you would like to share about this Dashboard and the way it can be used to assist in your job.

We will arrange to solicit your comments and answers to these questions in a scheduled phone call interview. Please inform us about your availability and convenience during the coming 2 weeks.

Your feedback is very important to us. We appreciate your time.

Sincerely,

Samar

Appendix E.

Follow Up Interview Questions

- Q1: In your opinion, how do external visual representations of injury data support you in your problem solving process?
- Q2: In your opinion, how does the communication and interaction between SME and TE during the Paired session affect the advancement of the problem solving and decision- making process?
- Q3: In your opinion, how does collaboration and the exchange of knowledge and expertise influence the decision making process in the Group Session compared to the Paired Session?
- Q4: In your opinion, how valid, reliable, trustworthy are the results produced by the Dashboard?
- Q5: Finally, from your personal position and involvement in injury prevention, please provide any further information that you would like to share about this Dashboard and the way it can be used to assist in your job.

Appendix F.

BC Injury Dashboard Meeting Agenda

The Injury Dashboard Meeting was held March 21, 2013.at the BC Children's Hospital, 4480 Oak Street, Vancouver, *Room K0-155 (basement of Ambulatory Care Bld*). The Meeting Agenda was as follows:

Time	Activity	Speakers
10:30 – 10:45 am	Welcome and Project Review and purpose of the Day	Dr. Ian Pike
10:45 – 11:00 am	Presentation of Dashboard (mock-up) Explain the Day Activities/Expectations	Samar Al-Hajj
11:00 – 11:30 am	Group Analytics Session I (Scenario based)	Shannon Piedt- facilitator Samar Al-Hajj – Visual Analytics Expert
11:30 – noon	Group Analytics Session II (Scenario based)	Shannon Piedt- facilitator Samar Al-Hajj – Visual Analytics Expert
Noon – 1:30 pm	Lunch and Paired Analysis Sessions 7 participants will be invited to engage in a 15-20 minute paired analysis session These will take place during and after lunch	Samar Al-Hajj
1:30 – 2:00 pm	Questionnaire Participants are welcome to depart once they have completed the paired analysis session and the questionnaire	Samar Al-Hajj

Appendix G.

Published Papers

1. Al-Hajj, S. Pike, I. and. Fisher. B., "Interactive Dashboards: Using Visual Analytics for Knowledge Discovery and Transfer". Visual Analytics in HealthCare. Proceedings of the American Medical Informatics Association, AMIA 2013. Washington, DC, USA (2013).

2. Al-Hajj, S. Pike, I., Fisher, B., "Visual Analytics dashboard: Decision-Making Support for Health Informatics". Proceedings of IEEE Visual Analytics in HealthCare Workshop 2013: Public Health's Wicked Problems: Can InfoVis Save Lives? In Conjunction with IEEE VisWeek 2013. Atlanta, GA, USA (2013)**.**

3. Al-Hajj, S. Pike, I., Riecke, B. E. and Fisher B., "Visual Analytics in Public Health: Supporting Knowledge Construction and Decision-Making" Proceedings of the Hawaii International Conference on System Sciences (HICSS 48). Maui, Hawaii. (2013): IEEE Computer Society Press (2013), pp. 2416-2423.

4. Al-Hajj, S. Pike I, and Fisher B., "Visual Analytics to Support Medical Decision Making Process". Short communication, 24th International Conference of the European Federation for Medical Informatics: Quality of Life through Quality of Information. Medical Informatics Europe (MIE) 2012, Pisa, ITALY.

5. Al-Hajj, S., Fortuno III, E. S., & Fisher, B. (2011). Data Visualization of Immunological Competence of HIV Exposed but Uninfected (HEU) infants. *IEEE Visual Analytics for Science and Technology (VAST)*. **Best Student Submission Award (IEEE VAST 2011, Discovery Exhibition)**.

6. Al-Hajj, S., Arias-Hernandez R., and Fisher B., (2011). Interactive Visualization for Analyzing and Understanding immunological data. IEEE Visual Analytics in Health Care Workshop 2011: Understanding the Physician Perspective, pp.45-48.

Appendix H:
Coding Strategies

This appendix includes list the codes retrieved from the analysis of the Group Analysis sessions using Atlas.ti.

Following the ethics requirement, copies of the raw data and video data are available and covered by Ethics UBC through Dr. Fisher (bfisher@sfu.ca) at Simon Fraser University and Dr. Pike (ipike@cw.bc.ca) at the BC Injury and Research Prevention Unit.

Group Analytics Session II

Code-Filter: All

HU: Group Analytics Session TWO NEW October 25 Atlas.ti

File:[G:\Group Analytics Session TWO NEW October 25 Atlas ti.hpr7]

Edited by: Super

SME-SME Agreement

SME-Reference to the Visualization

SME-Data Manipulation Suggestion

SME-SME Answer Question about Database

SME-SME attend to viewpoint

SME-Interpretation of Visualization

SME-Positive Experience

SME-Explain Viewpoint

SME-Suggests Visualization Refinement

SME-SME attend to information

SME-VAE Agreement

VAE- Execute SME's Request

SME-Support Opinion

SME-SME Ask Question

SME- Request Further Visualization Drill Down

SME-SME Answer Question

SME Personal Experience

SME-SME Ask Question about Database

VAE-Think Aloud

SME-SME Disagreement

SME-Explain Tool Capabilities

SME Problem Solving Approach

Database Limitations

VAE-Request Clarification

SME-Positive Experience with Visualization

SME-SME Common Goal Emphasis

VAE-SME Agreement

SME-VAE Request Data Manipulation

SME-Request more Info to Build Knowledge

SME- Database Information

SME Different Perspective of Problem Solving Approach

VAE Interpret Visualization

SME Knowledge Building

SME-Inquiry about the Visualization

SME-Acknowledge Multidimensional Problem Solving Approach

SME-Present Alternative Opinion

VAE-Support

SME-Suggest Solution

VAE-Explain Tool Capabilities

VAE- Request Clarification

SME-Approach to Decision-Making

SME-Visualization Preferences

SME-Question about the tool

SME-Decision about Interventions

SME-VAE Refocus on Task

VAE Suggest Visualization Refinement

SME-Acknowledge Multidimensional Decision-Making Approach

SME positive Experience

SME-Propose Decision

Need for Analyst Reasoning Approach

SME-Omit Alternative Viewpoints

SME-Explain Multidimensional Problem Solving Approach

SME-Inquiry about the Database

SME Observing Visualization

SME-Suggest Data Manipulation

SME-Facilitator Attend to Information

SME Inquire Information about Database

SME-Facilitator Agreement

Facilitator Agreement

Facilitator-Task Orientation

Database Limitations

Facilitator-Session Expectation

VAE Think Aloud

SME-VAE Request Data Manipulation

Facilitator Session Guidance

SME-Explain Problem Multidimensional Problem Solving Approach

SME-Summary of Findings

SME Inquire Information about Database

Group Analytics Session II

Code-Filter: All

HU: Group Analytics Session TWO NEW October 25

File: [C:\Users\Samar\Desktop\Atlas Folder\Group Analytics Session TWO NEW October 25.hpr7]

Edited by: Super

Database Limitations

Database Limitations

Facilitator-Session Expectation

Facilitator-Task Orientation

Facilitator Agreement

Facilitator Session Guidance

SME- Database Information

SME- Request Further Visualization Drill Down

SME-Acknowledge Multidimensional Problem Solving Approach

SME-Data Manipulation Suggestion

SME-Explain Multidimensional Problem Solving Approach

SME-Explain Problem Multidimensional Problem Solving Approach

SME-Explain Tool Capabilities

SME-Explain Viewpoint

SME-Facilitator Agreement

SME-Facilitator Attend to Information

SME-Inquiry about the Database

SME-Inquiry about the Visualization

SME-Interpretation of Visualization

SME-Omit Alternative Viewpoints

SME-Positive Experience

SME-Positive Experience with Visualization

SME-Present Alternative Opinion

SME-Propose Decision

SME-Question about the tool

SME-Reference to the Visualization

SME-Request more Info to Build Knowledge

SME-SME Agreement

SME-SME Answer Question

SME-SME Answer Question about Database

SME-SME Ask Question

SME-SME Ask Question about Database

SME-SME attend to information

SME-SME attend to viewpoint

SME-SME Common Goal Emphasis

SME-SME Disagreement

SME-Suggest Data Manipulation

SME-Suggest Solution

SME-Suggests Visualization Refinement

SME-Summary of Findings

SME-Support Opinion

SME-VAE Agreement

SME-VAE Refocus on Task

SME-VAE Request Data Manipulation

SME-VAE Request Data Manipulation

SME-Visualization Preferences

SME Different Perspective of Problem Solving Approach

SME Inquire Information about Database

SME Inquire Information about Database

SME Knowledge Building

SME Observing Visualization

SME Personal Experience

SME positive Experience

SME Problem Solving Approach

VAE- Execute SME's Request

VAE- Request Clarification

VAE-Explain Tool Capabilities

VAE-Request Clarification

VAE-SME Agreement

VAE-Support

VAE-Think Aloud

VAE Interpret Visualization

VAE Suggest Visualization Refinement

VAE Think Aloud

Group Analytics I

Code-Filter: All

HU: Atlas.ti Group Analytics Session NEW October 20

File: [C:\Users\Samar\Desktop\Atlas Folder\Atlas.ti Group Analytics Session NEW October 20.hpr7]

Edited by: Super

Building Common Ground

Confirm Understanding

Database Limitations

Discussion Starting Point

Establish Process Rules

Extending Initial Knowledge

Facilitator Agreement

Facilitator Session Guidance

Knowledge from the Data

Need for Data

No Restrictions to Problem Solving Approach

Participation

Session Expectation

Shift in Problem Solving Approach

SME- attend to Visualization

SME- Request Further Visualization Drill Downs

SME- Suggests Visualization Refinement

SME- Visualization Preferences

SME-Explain Tool Capabilities

SME-Facilitator Agreement

SME-Positive Experience

SME-Positive Experience with the Visualization

SME-Question about the Tool

SME-Refocus on Task

SME-Request more Info to Build Knowledge

SME-SME Answer Question

SME-SME Ask Question

SME-SME attend to information

SME-SME attend to viewpoint

SME-SME Common Goal Emphasis

SME-SME Disagreement

SME-SME Point Clarification

SME-SME Response Agreement

SME-SME Response to Viewpoint

SME-Suggest New Idea

SME-Suggests Data Refinement

SME-Summary of Findings

SME-Think Aloud

SME-VAE Agreement

SME - Interpretation of Visualization

SME - Suggest Data Manipulation

SME Agreement

SME Data Manipulation Suggestion

SME Different Perspective of Problem Solving Approach

SME Inquire Information about Database

SME Insight

SME Knowledge Building

SME needs technical Support

SME Personal Experience

SME Problem Solving Approach

SME Reference to the Visualization

SME Response Agreement

Solving Analytical Task

Suggest Data Exploration

Support Data Exploration

Tool Support

VAE- Interpretation of Visualization

VAE- Response (Database)

VAE- Response about the Tool

VAE- Verify SME's Request

VAE- Visualization Further Refinement

VAE-Execute SME's Request

VAE-Think Aloud

VAE Interpret Visualization

VAE Suggest Visualization Refinement

VAE Support

Visualization-Common Ground

Visualization Tool Support

Appendix I:
Pair Analytics Transcripts

As the main researcher conducting this study, I was the observer of the sessions, sitting next to the VAE. My role as an observer was to mainly observe the pairing between the VAE and the SME as well as to take field notes to document the VAE-SME interaction with each other, and using the system, as well as the exchange of knowledge to solve the analytical task proposed by the SME. However in some cases the SME direct the question to me and ask me to for further assistance.

In the Pair Analytics sessions, we gave SME or injury stakeholders the choice to decide on the analytical task of their interest to make it more engaging for them to seek solution to the problem and follow it up till the end.

Session I

SME1: So what's the purpose here?

VAE: the purpose is...I'm going to let Samar (The Observer) do it. I'm the mouse.

SME1: (laugh)…the mouse!

VAE: yeah, I am the mouse

SME1: It's very good… It's very impressive

VAE: It's way more capable…I mean it has a lot of capabilities than we explored this morning.

SME1: Uh, huhh.

VAE: I guess we can dig a bit more into the details now.

SME1: sure!

Observer (me): Now we're just going on a Paired one on one. So maybe, it's going to be either you suggesting a scenario that we investigate or we would suggest a scenario that we'll go through it together using the visualization tool.

VAE: So I noticed, you had some questions this morning. You said …

Observer (me): Just… I'm sorry before we carry on. Usually when you deal with analytical task, do you have any specific analytical approach that you use…what's your usual approach to...

SME1: It kind depends from what angle you're looking at it. I'm not an injury prevention person, but I am trauma care person. We're trying to expand what we do, including injury prevention. So we're looking at causes that are significant morbidities and things like that. So trying to find out what the numbers are underneath the patients that go to hospital and we operate on, you know severe cases. How we do that, I guess, is very similar to our trauma registry. So we look for the deaths with the high probability and low probability of survival who die. So the potential for preventable deaths… And we try to focus back on what the causes are and what we could have prevented. My approach would be, I guess, to look for the outcomes. Start with the outcomes that we are the most concerned about.

VAE: Uh, huhh

SME1: In this case, it would be severe injuries, serious injuries. So I want to know from here, how we could find the most serious injuries?

VAE: Uh, huhh. OK

SME1: And I want to look back to getting as much information about them as I can

Observer: OK, perfect

VAE: So, I have here the top 5 types of injuries. Is that related to the questions that you were talking about?

SME1: So when you say, type of injuries? You're meaning location of injuries? Is this an anatomical type or is it a cause type?

VAE: Let me go to type of injuries? Actually, I have them in here, injury types

SME1: Fractures…

VAE: This is only the top 5, but I can show you all of them.

SME1: Is that the way I would figure what would be the most serious, and using that category type, is that correct?

Observer: yeah

VAE: We also have causes, if that informs you.

SME1: cause are mechanism of injuries, is that right?

VAE: yeah...

SME1: not so important. I'm more interested in the bad injuries. So, I would want to go to the ones that are

VAE: Then let's go in here. Here is where your expertise comes and you will have to tell me what you consider severe

SME1: yeah, that's right, I can use my choices, correct?

VAE: Correct. So I have all the types in here.

SME1: Let me just have a look down at them...Umm…drowning…injuries to internal organs…that would be the one

VAE: Let me just external organs…Fractures would be, I guess, SME1: Fractures, I guess, would be another. And head injury, I guess concussions …we're going to take them off after… Can you go down a bit? Spinal cord for sure…intracranial injuries…

VAE: Uh, huhh

SME1: yeah, traumatic amputation, I guess...and I guess, that would be a good one. So these would be the main ones. Multiple injuries in principle.

VAE: What is the most…

SME1: we could work with that group I guess, and we could say these are the injuries that all occur in all admissions and operations, you know, would be associated with that.

VAE: OK. So let's take a look at those. And we have fractures

SME1: That's a big part of it…Concussions is a big part of it. (Based on the generated visualization) multiple injuries…this is the group

VAE: Oh yes and we have the perspective here is that we have it categorized by sex and time-fiscal year. If you don't want any of those divisions, we're going to take them out…and put whatever dimensions are more essential.

SME1: you know, the sex doesn't matter to me, right after that anyway...May be later get it…

VAE: Yes, Uh huhh

SME1: and then…So, tell me again all the ways we can cross tabulate this

VAE: Uh, huhh

SME1: using mechanism or causes of injuries… right?

VAE: Uh, huhh.

SME1: what are the other things? Age…you got it in there.

VAE: They have the body parts. Well, if you want…causes and the sub-causes

Observer: intentional and unintentional

SME1: Can we try the …? Cause it's true, the intentional, unintentional is what we're…

Observer: Intent

VAE: yes

SME1: and every input is categorized intentional or unintentional, I guess, right?

Observer: that's right and some of them are undetermined.

SME1: right.

VAE: this is going to divide it

SME1: That's OK. So mainly we're dealing with unintentional injuries, right?

Observer: Unintentional, right?

SME1: Intentional! Do we know if there is suicide or no? Self-inflicted or…?

Observer: then you'll have to check sub-causes of that? What type of column in there? It's a year, It's by year…OK

VAE: Oh yeah, this is all by year.

SME1: You can put them all in there.

Observer: yeah, take the Year off and it's going to be aggregated

VAE: the problem here is that the data doesn't go further into any more details...If it's Intentional or unintentional? Was it suicide or not?

SME1: It doesn't tell us that?

VAE: It doesn't tell us that…we can show the causes and the sub-causes

SME1: yeah. It's a small group, so it's not that important. But I'm sort of thinking if we apply this to adult, it would look like….you know

VAE: Uh, huhh.

SME1: for this purpose I guess, a large group of fractures. The concussion. The head injuries groups, wasn't there? I thought concussions and intracranial injuries…were is that?

VAE: Intracranial injuries

SME1: It's there. OK…another head injuries

VAE: just take a look in here…just to the …

SME1: OK

VAE: head, just for a second

SME1: Yeah, unintentional concussion, I guess. And …we tried to look at the causes. Where is my choice of causes? If I want to see

VAE: Yes. So I'm going to bring in the causes here? Let me just do something. Do we want to stick to concussion and intracranial injuries?

SME1: Can we include… Can you go back to the whole list or does it become an unreal to do?

VAE: Yes.

SME1: OK, and then let's stick with this list

VAE: And then, bring the causes

SME1: That's going to make it spread like this…I guess, but that's OK

VAE: I was thinking maybe, we want to bring the type of injury in here and just bring the causes here… (dragging and dropping on dimensions and variables on the screen)

SME1: just explain this…you…So by putting it up here, you end up doing the…

VAE: yeah, another division on the columns

SME1: Columns, right.

Observer: Yeah.

SME1: and by putting it…this is the sub…

VAE: sub-division

SME1: sub-division of the column right here, pointing to the Tableau screen

Observer: this is the filtering technique of that category

SME1: yes, yes.

SME1: Ah, that's very neat. Make sense

VAE: Now we have our

SME1: You can yeah, we can also collapse…I can see based on "Intent", so you can collapse this, just for the space

Observer: that's right.

SME1: you could just collapse all this together, removing "Intent"

VAE: Just the "Unintentional"?

Observe: You have to remove "Intent" to

VAE: Uh, huhh

SME1: That could make it easier, cause I could tell

Observe: So you're getting the hang of the tool

SME1: No, it's good, it's good. It's very good actually.

Observer: (laugh)

SME1: I want you to come and the do the same thing for my trauma registry, can you do it?

Observer: yeah, sure (laugh)

SME1: I'm serious

Observer: Do you have good and clean data?

SME1: We have clean and good data, lots of it, just like this (CHIRPP injury data)

Observer: that's perfect

SME1: So that very…How long does it take to construct something like this for a dataset?

Observer: A day!

SME1: Are you serious!! (sigh)

Observer: yes (laugh)

VAE: Yes.

SME1: Using the software, I guess, right?

Observer: yeah. You just have to go through the training

SME1: but you have a confine? So as the data change, import related it to what's in here. Is it download?

Observer: You just connect to the live data, connect to extract of the data for the sake of patient privacy and confidentiality

VAE: What type of data do you have? Is it Excel files?

SME1: It can be, yeah

VAE: We can link it to an Excel file, and make it dynamic. So as the Excel file changes…

SME1: yeah, the software is Tableau

Observer: yes.

SME1: Must be an expensive software, though, is it?

VAE: It is…. Well, sometimes

Observer: sometimes, it's pay per click, so depending on the package that you choose. And this is the professional version that we're using right now.

SME1: right.

Observer: yeah, so it has all the functionalities

SME1: very very interesting…So what are we looking at in here? We're looking at … What else can I learn about? So those are fractures that are injury type

VAE: Now we are digging into the sub-causes

SME1: Falls, yeah. And is there any more break down…by age, by age Group, by year…

VAE: yep

SME1: I don't need to. But I'm just

VAE: We can

SME1: If we did that, you'll have to spread it out, I guess, right. You can only

VAE: We can

SME1: You can apply one subcategory in bar, you can't

VAE: No, we can apply multiple

SME1: Can you break this bar and show me by female or male

Observer: or within

SME1: yeah, you know what I mean

Observer: It's going to be side-by-side, right?

SME1: Sounds, you can only get one category. So I guess we'll get one category in

VAE: Exactly

Observer: you mean, one combining male and female but separate

SME1: yeah, yeah…Like you could take this bar and break this bar into…

Observer: than it's going to add more colors to that one

SME1: It's going to be more confused

Observer: yeah, it's going to be confusing

VAE: But what we could do is, Umm. Change it to…let me see. So if I use circle, let me do that

Observer: Or maybe try to use that area space…click on that (talking to the TE)

SME1: Ahh (observing the changes in the visualizations) different types of graphs. Oh, Interesting

VAE: So if I use circles, let me try this…

Observer: Or maybe try to move that area space…

SME1: Ahh, interesting… See that the circle graph… Can you make all these pie graphs to show break down..Is that doable…no?

Observer: well I did that for the Map. Just click on the Map, do you have a map in this one?

VAE: Yeah, but it's not loading.

Observer: yeah let me try this one… cause it (the Map) needs Internet connection. I've tried to do it for the other ones

SME1: yeah, that's it (when the Map display showed on the screen). That's it. Very interesting.

Observer: This is overlapping, laid over a Map.

VAE: Overlapping the Map

SME1: Oh, OK.

Observer: this is the provincial Map. So let's say you want to hover the mouse. Could you please hover the mouse over any of these one -pies (talking to the VAE) and you can see this is the Fall, in that specific location…

SME1: yes, yes.

Observer: and you can see this is the

SME1: yes, yes, that's very useful

Observer: yeah, very useful. This is for the geographic distribution

VAE: May be we can use…I just want to show you

SME1: If you just show the circles

Observer: If you want to use the other one, you just have to click on pie

SME1: pie

VAE: No

Observer: but I'm not sure of it has different dimensions to use

VAE: No, it has different dimension. I'm just trying to use the circle, and use the size…

SME1: Can you make these into pies graph for what is in that circle under the category?

VAE: Oh, no

Observer: Maybe

SME1: (laugh)…I'm getting fancy

Observer: you're challenging the system. (laugh)

VAE: laugh

SME1: I mean yeah, but there is no need for this is. It's just makes it all visual, right!

VAE: yeah, I'm just trying to sub-divide it.

Observer: I'm not sure if I need to mention that, but the last time, what I did animated one (visualization) where I kind of included pages –layers of pages, with different time trends…

SME1: yes, yes!

Observer: …and each one would kind of show the cost…additional dimensions, the size of the bubble, and the different colors for the different time. How it is changing over time…

SME1: right, right…

Observer: Is it increasing or decreasing over time along the lines

SME1: that's very important the trending. You know, you do the intervention, you want to see what is the impact was, right?

Observer: Exactly. But for this you need different dimensions, like cost of injuries, or…number of cases

SME1: So tell me, you have experienced this, so what are the different representations? Which ones are useful…this is probably the most useful, I guess

Observer: this is useful for this type of information, depending on the data. The other one that I used is the scatterplot as it gives you statistical information

SME1: Uh, huhh. Can you show me an example …the use of a scatterplot in here

VAE: in here, so I'm going to do them for causes, and Uhh…and cases

SME1: Don't you need, sort of a numerical scale

VAE: yes, that's our measure; so the number of cases is our numerical scale for example and then we say divide it by causes. Which will be the most common representation, but you can change the presentation to here…lines for example. Oh well. It's actually to line

Observer: or maybe you can use…

VAE: Ahh, I wonder why it's not taking that one by one

SME1: Because I think there is no relationship

Observer: between this and that

SME1: twice as important as

Observer: What I've done is that I used the cost and the number of cases

SME1: the cost?

Observer: yeah, the cost

SME1: that would be…Can you show me that here again

Observer: Well I have it in one of the files.

SME1: where do you get cost from…cause that's not in CHIRPP data, is it?

Observer: It's calculating the number of days at the hospital and …this is like a previous file that I've worked with…this is a different project.

SME1: right, but it could be done. Do you have to merge the data to create this thing?

Observer: yeah, yeah…

SME1: So if we have a data set with merged data, you can still do this and apply the software to it, right?

VAE: Oh, yeah certainly. Cause every dataset has the dimensions and just bring the dimensions and you can play with them

SME1: very very interesting

Observer: we have done this last year. This is the trend over time

SME1: the number of cases…fair enough

Observer: so as you can see, this is how I meant by animation (showed the SME1 sample of the animation from a previous project). You can see how, it's trending compared to others

SME1: yeah, yeah.

Observer: and you have layers of pages, each page represent a month

SME1: Can you annotate the graph? Can you draw an arrow and say..?

VAE: yeah, I can do that. You can go there and click "annotate"

SME1: yeah

Observer: and mark it either with a point or like an area

SME1: or like a comment

Observer: and day like …I just added my comments in here. And then just like add it in here.

SME1: Very good

Observer: or you can annotate it with a different…This is our last year project and we worked a lot with that. We used the map…and the scatterplot is here…But I've also created another one. This is …it needs an Internet connection to work in here

VAE: to load the map…

Observer: this is the scatterplot that I meant; we have the cost and the number of cases.

SME1: Uh, huhh

Observe; and these are the different areas…Interior id the Red

SME1: right..

Observer: Fraser is Blue

SME1: yeah, very good, very good

Observer: and then I added trend lines to see how they trend

SME1: right

Observer: see the p-value

SME1: yeeesss. Very very good

Observer: the description…the t-value and the p-value

SME1: so once you design, you want to look at…that's the

Observer: and if the databases provide that

SME1: they can give it to you

Observer: exactly

SME1: That's really great.

Observer: so…yeah

SME1: potential to the software

VAE: sorry, I was just going through

Observer:

VAE: I wonder why this has changed to lines…

Observer: I last thing I wanted to show you, is that you have that "Show me" button

SME1: Uh, huhh

Observer: So you have all types of visualization that support whatever data you have.

SME1: right…

Observer: so for this one, this is the best representation…so depending on the data

SME1: yeah, yeah

Observer: dimensions and the number of variables that you have

SME1: yeah that's right, make sense

Observer: so that would make more sense

SME1: yeah, show me this one

VAE: this one, the table?

SME1: yeah

VAE: this is like a very standard

SME1: yeah,

VAE: Table, it's highlighting cost

SME1: you can cut and past this somewhere in your power point?

Observer: exactly, put it in a power point or PDF

SME1: yeah, yeah.

Observer: or just attach it, or just simply copy and paste it

SME1: so just curious how that would work.

Observer: OK

SME1: so this table, you just copied it

Observer: you can export that or copy as an image or cross tab

VAE: copy

SME1: OK

Observer: you choose…

SME1: Say which format

VAE: and the legend, because you'll need the legend to be able to read the graph, because the label

SME1: It's awesome, very good

VAE:

SME1: We look at that again, what does it look like, Can you go to your desktop and show me how it actually looks

Observer: What did you call it? Was it automatic name?

VAE: yeah, it was automatic…where is my desktop?

SME1: Does this work only on a Mac? Does it need?

VAE: No actually, it works only on Windows

Observer: I had to install Windows on my Mac to do this.

SME1: yeah

Observer: Is this the one? Well this is the one that I've created yesterday

VAE: I don't remember the name that I put

SME1: It's wonderful…very nice… So you just cut and paste that anywhere?

VAE: and you can create…you can pretty much too

SME1: Oh this is nice too…this is the depth of colors

Observer: oh yeah, the other thing as well. You can add the dimensions and

SME1: colors, very nice

Observer: the gradient colors

VAE: That is important for the readability of the chart

SME1: yeah

VAE: not just the chart, but the legend

SME1: you can read the number and also be drawn by the colors. That's very good. Yeah, very good

SME1: OK, thank you…I'm going to talk to you later

TE, Observer and SME1: (laughs)

SME1: that's very impressive. Thank you

VAE: Thank you

Observer: Thank you very much

Session II

Observer: OK, so what we're trying to do in here is just start with the all dashboard and you can suggest your own scenario – a specific scenario that you need to investigate and we can help you manipulate the data based on your request, depending on your project and what you're interested in.

SME2: OK, Umm, so just hypothetically, something that I want to explore.

Observer: But fist let start with just one question: How do you think, if you need to approach a specific problem, and analytical problem. What would be the problem that you usual are approaching and how would the tool help you in that?

SME2: OK, I guess, I mean I use data the most to create injuries, like specific mechanism of injury data. So I can write a newsletter for a trauma system. So if I'm looking at say blunt chest injuries, so I'll be looking at not a "Stabbing" but a "blunt injury". Then I think OK, what sports could cause that? Or what activity is causing that?

VAE: Uh, huhh

SME2: and I look back and see, maybe that I reach the time of the year, I'm trying to think…We normally take data and look at what is happening in the hospital and then we triangle back to what could be causing it. And then I look into sort of public sector to see, so say we're getting facial injuries that would happen a lot and it's in the winter and it's from snowmobile. Then I'll go into back, and I look at what are the causes of injuries

Observer: causes

VAE: Uhh, huhh

SME2:and then I go back and research Snowmobile injuries in general as a whole so I could present on that topic..

VAE: Uh, huhh

SME2: So, that's my form of it. Then From there, the trauma coordinator will do the rest, but that's how we link it through what we see in the Emergency

VAE: Uh, huhh

Observer: and then…Do you get to share it at some point?

SME2: yea, and we distribute it. Like, we write a big article and then we distribute it to the whole community of trauma at VGH.

Observer: For that article, you just kind of include images, visualizations?

SME2: yeah

Observer: representations?

SME2: We normally have some charts and we talk about maybe some of the publications that came out of the read it all, but we always try and pull some form of a graph to show age categories.

Observer: OK

VAE: Then, if you were dealing with the CHIRPP dataset, What would be interested in, following the same process?

SME2: So, let's say we look at, Umm, Mountain biking injuries

VAE: So, that would be our cause, right?

SME2: yeah

VAE: Then, let's go to this one, and I had some filters here, I'm going to remove them, I'm just going to put the cause in here. And, Mountain biking will fall under…So, OK. I have here the different causes and I guess, Mountain biking will be related to transport? I want to see if any other cause could be relevant for you for your question

SME2: unintentional, but you can't tell from this. So for me as a user, some of these things I don't what could be in it. Like "Overexertion" could be, for example but I won't really know, like if you're overexerting yourself and you get, maybe get…I don't know, some kind of soft tissue injuries

VAE: Uhh, huhh

SME2: I don't know, versus a fall off a Mountain bike

VAE: We have sub-causes, the data have sub-causes. So we can perhaps…Let's filter out from the causes which one will be interesting for

SME2: Fire and Flame, so …Cutting, Drowning

VAE: I can do…oh here, there you go

SME2: OK

VAE: So, Cutting…

SME2: Cutting, Drowning, Fire and Flames, Firearms

VAE: those stay or … Falls

SME2: Stay. So Flame, Firearms, Foreign body… can all go, homicide

VAE: Flame, Firearms, Foreign body

SME2: everything until “Other Intentional”…or “Machine”…yeah, there you go

VAE: Umm

SME2: I think “Other intentional” won’t really help us

VAE: Well, It will or won’t, and I’m just going to do…

SME2: Suffocation can go, Suicide, Undetermined and Poisoning.

VAE: OK, so now we got these causes and now we can dig into the sub-causes, so I’m going to bring it here

SME2: Is there a way to just search, if I say “Bicycling”?

Observer: Ah Ok, so just give it one and then let it...

SME2: yeah, if I want to say, Umm, Snowmobiling and then any category that has that as a component can just be

VAE: That would be possible, depending on your dataset

SME2: OK

VAE: This dataset is actually being pulled from an Excel file format

SME2: right,

Observation: this is not a Search engine, you cannot really type in a specific world

SME2: OK, I wasn’t sure, if there is like a trigger for like if there is a word Bicycle and there is like a sub-causes to any of them like “Pedal cycling” or

VAE: This is updating…there we go.

SME2: OK, but yeah

VAE: So…

SME2: Unintentional poisoning, yeah

VAE: Unintentional poisoning. We're going to exclude that one. Let me go again to this. We're going to the filter list…so it can…sub-causes, beaten or stuck by a dog...

SME2: Umm, wheel devices; probably would be in there?

VAE: Oh, so

SME2: yeah, so

VAE: I want to keep that one, right, let me just filter this out

SME2: Or maybe, so…wheel devices…OK…then go up a little bit, Wheel devices…down a little bit

VAE: ladder, …scaffolding, stairs

SME2: for Mountain Biking, you could leave… well

VAE: Stairs steps, no?

SME2: Well the thing is in the trees they have ladders and scaffolding …they can have all those things, but it's hard to say whether where it comes from.

VAE: We can keep it in and see…

SME2: and then the next one too. Actually leave the next one, it doesn't matter… OK, then go down…

VAE: Motorcycle, Motor Vehicle

SME2: Go down, and then "Pedal cyclist"

VAE: Other transport

SME2: Like this one cyclist though

VAE: Uh, huhh

SME2: Umm

VAE: by Sports equipment

SME2: Struck by/against objects, yeah

VAE: All right. So, let's take a look at those

SME2: Huhh

VAE: Well there are three that are important

SME2: But aren't necessarily all biking, right?

VAE: This one, it is? But

SME2: that one, but then theses ones

VAE: than this one

SME2: Can you break down that one, “Pedal cyclist”?

VAE: there is no…that’s the final

Observer: …the dimensionality of the data, this is the further you can go

SME2: so maybe, you can just isolate “Pedal cyclist” and then type of injuries

VAE: OK, great, Uh, huhh. Let “Keep only” and let’s bring the Type of injuries in here, yeah

Observer: just bring it in here…What is going on?

VAE: Oh, it contains 27 members…just bring it here

SME2: Oh, so it

Observer: It’s a lot

VAE: yeah, if I’ll bring in in here, it will be too many divisions, so it was just a warning. Umm. Instead we can tae a look here… So we’re looking to Pedal cyclist, Transport related, yeah that is “Pedal Cyclist” and then we have the type of injuries

SME2: Fractures

VAE: take out, I’m pretty sure I can do this.

Observer: it should finish.

VAE: yeah, it should finish. I can keep the top 5, or I can filter out also

SME2: Can you keep the top 5?

VAE: yeah

SME2: Oh, interesting, huhh…And then can you do by…age group?

VAE: The tope 5?

SME2: Uh, huhh

VAE: yes. Once I have the top 5. OK, so now we have “Dislocation”, “Fracture” “Superficial injuries”…

SME2: Uhh, huhh

VAE: And each group that would want it

SME2: huhh

VAE: SO, I guess what this is saying is that you filter down your interest to just “Pedal cyclist”. This is the visualization of the top 5 injuries of all types of injuries that they get. Like I guess this makes sense to you

(VAE is trying to assist the SME interpreting the Graph accurately)

SME2: Uhh, huhh

Observer: Like teenage (laugh)

SME2: yeah (laugh)

VAE: There is biking (laugh). Umm… and this is the type of injuries that they get the most "Fractures".

SME2: So I guess the other way that I would for this, I mean that's great

VAE: Uh, huhh.

SME2: probably that's three and then probably the other that would do it search by injuries. So if we see for adults, I guess, let's say, you see we've have a lot of influx of stabbing – this won't apply to this – but yeah, we have a lot of concussions.

VAE: We can take a look, uh huhh

SME2: So only, but not looking at bicycling. So starting over and say, OK, Concussions and then breaking it down that way.

Observer: different path

SME2: Yeah

VAE: So we can, yeah, we can certainly do that…Let's break it down the type of injuries, if you just want to take a look at the distribution of the type of injuries. Let's start all over and I just want to drag injuries in here.

SME2: yeah

VAE: So I'm just taking out all the filters that we had. So this would be the original distribution

SME2: So maybe look at… I don't know

VAE: so from your perspective, you'll take a look at…

SME2: yeah, let's look at Concussions

VAE: Just concussion

SME2: yep.

VAE: "Keep only" and you want to explore this one by?

SME2: by their cause

VAE: OK

SME2: and sub-cause

VAE: this is the … and then sub-cause…Maybe I didn't do it right…I think… let me do it the other way around...just type of injuries that cause here, and the sub-causes… I'll put it here there you go

Observer: yeah, that right

VAE: So now we have Concussions, the causes are here and for each of this, these are the sub-causes. I can also…

SME2: So if you isolate “Falls”

VAE: Falls and then I can put the sub-causes in here. So that’s just for “Falls”

SME2: yeah

VAE: “Falls from high level”, “Out of building Structure”

SME2: what’s that

VAE: “Involving Skates”

SME2: OK, then do maybe, Sex or Age

VAE: Uh, huhh

SME2: yeah, it’s a nice break down to do, and is there…Oh yeah, there is no mapping function yet, cause that would be interesting for postal codes to like have a map and say most things are happening here.

Observer: yeah, but the other issue with displaying the postal codes, when we spread the data over different areas, we had small number of injuries. Then the issue of confidentiality gets in that. So we’re going to have to aggregate at some points…

SME2: I would be nice eventually to have, though

Observer: yeah

SME2: yeah, that would be a really useful function to

VAE: It is possible… it’s just that

SME2: yeah…really small, or if there are teen cases …huhh

VAE: yeah

SME2: OK, that’s cool

VAE: Thank you

SME2: Thank you. It’s really interesting.

Observer: Thank you so much.

Session III

VAE: Just resetting to the initial configuration

SME3: yep

VAE: there you go.

Observer: So what we're trying to do here is just start with the Dashboard as the first landing page and based on your request, we can go to any specific visualization and dig deep based on your...

SME3: OK

Observer: But first, I'm just going to ask a general question. How do you usually approach a problem when you need to solve an analytical problem in your field? How do you usually approach that? What would the tool help in that regard?

SME3: Often what I would do is I would try to figure out what was I was trying to accomplish and work backwards.

Observer: Ahh. OK. That's interesting. And then what would be the steps that you'll take to kind of…

SME3: Well so in working backwards, I would figure out what my question was and then I would go and look at what the research and the data said to help me answer what my question was.

Observer: then in the data, you kind of look for something in the data…

SME3: Yes, then I would be looking for things like, uhh, trends, causes, related variables and factors, trying to get as complete a picture as I could, but I also would be trying to figure out what would be...what we have and what we don't have cause often times the information I'm looking for, it may not exist. So what tends to happen is we fall back on what are our data sources and we start looking at the data sources. So What I try to do is "this help to answer this" , really want to answer the question, we also need this and we don't have any data for that.

Observer: Oh, I see. So with whatever data available that you have, you kind of look for how to…Ummm

SME3: I would look at trying to answer as much as I could with available data, but I try not to be limited by the available data. Let's say trying to figure out, is that going to answer my question or if not, what else would I need? So it may be quiet often, maybe I'm not actually able to complete the answer to my question because simply what I need to answer simply doesn't exist.

VAE: Uh, huhh

Observer: I see

SME3: Or it isn't available.

VAE: SO is there a question that you would…Like what would be the question your process

Observer: I'm sorry, just one last question…What about sharing your results, how would you get to do that?

SME3: How would I share my results?

Observer: Yeah, Do you get to…

SME3: So typically, I would share my results through reports.

Observer: I see. So that how you communicate the end results?

SME3: Often. But again it depends…part of or a lot of what is happening is through reports, but trying to identify who the audience is? What the audience needs to know? And What I want the audience to do? And so trying to look at broader mechanism, simply reports to get public information out to public audience

Observer: Oh, I see.

SME3: But, typically to a government audience, it would come through some sort of report. Whether it's a short report or official report or special report, typical..

Observer: uh, huhh… And with this report, does it include different perspective of the same problem or different visualizations, or different charts?

SME3: Oh, yes. It likely would set out different factors and variables related to the problem, building the case about how, why we thought what we were proposing, where our analysis…

Observer: So this is mainly for decision-making or policy-making?

SME3: Umm…yes, I suppose mainly, mainly.

VAE: Then following the same line of thought, you were describing, what would be…is there any particular question that you will be interested in answering using the CHIRPP or within the CHIRPP context?

SME3: Sure. I would be interested in looking at trauma through Motor Vehicle incidence.

VAE: Uhh, huhh

SME3: I would be interested in looking at whatever suicide data

VAE: Uhh, huhh

SME3: Is here.

VAE: Umm. Then I think that is cause, right? So let's take a look and start with this one. Everybody starts with this one (referring to the landing page of the one of the visualization on the Dashboard). You have here, and then you have the types of injury here. I wonder. Oh it's causes, I thought it's just ...Umm, By Motorcycle Vehicle you mentioned? So let's filter out this cause. I'm just going to filter out the causes in here. Oh, I'm sorry

SME3: Actually why don't you go. I've noticed that the front end there was a Suicide category

VAE: From here?

SME3: Right here ... Suicide/attempted Suicide

Observer: It's in all data because it's the top leading causes

SME3: Pardon me.

Observer: It's in all the data, all the visualizations because it's ranked as top leading causes of injuries. So any of the visualizations would kind of show you that type of thing.

VAE: Yeah.

Observer: So you can land on any of the visualization and it will kind for sure include the "Suicide" because it is part ...But now, it depends on the different dimensions that you look for, is it Sex, Age, or is it more Time, or ?

SME3: Ahh, I would looking at Age, Sex, Ethnicity… and Means

VAE: We don't have Ethnicity in this dataset, do we?

Observer: I don't think we have that.

SME3: OK.

VAE: You see, that visualization that you're just describing… Sex, Age Group. I can only keep rates...we don't have rates, we have the number of cases.

SME3: yeap

Observer: So as you can see, Suicide is mainly for the Ages 10-19 not younger ages, yeah

SME3: Uh, huhh.

VAE: Umm, we can…

Observer: You can add...

VAE: Any other dimension

SME3: So, it would be sub-cause or cause?

VAE: yeah, it will be the sub-causes. Let's add the sub-cause into this. So we have...

SME3: OK, So if you got rid of attempted suicide

VAE: All of them

SME3: Oh, these are all attempted or …

VAE: Yeah, all sub-causes

SME3: So these are all attempts compared to complete

Observer: Yeah, some of them might end up...

SME3: OK

VAE: So these are the categories here, right here.

SME3: So, nothing...Is there anything about “Hanging” in here?

Observer: by “Drugs”…

VAE: By “Jumping”...by “Multiple means”... by “Sharp”…No all the other are Unspecified

SME3: Oh, that’s interesting; because that’s probably one of the most common ways that young people actually commit suicide is by hanging themselves. It’s interesting that it’s not in here.

VAE: Yeah...most of this is by “Drugs”.

Observer: so maybe this is because this is Emergency data, the other ones would be kind of Mortality data...

SME3: Uhh, huhh...Possibly

(The observer is knowledgeable about the data, suggest a possible interpretation for the lack of specific type of information due to the nature of the data)

Observer: they’re going to die for sure by hanging themselves...

SME3: Well, they don’t always. But this is probably had a lot to do with attempts than...

VAE: than actual...

SME3: than actual, which would makes sense. Because if you notice Females are higher than Males…

VAE: Oh

SME3: In actual suicide, Males are much higher than Females

Observation: Oh. in the death...mortalities

VAE: Ohh

SME3: Yes, in the death. About 4 to 6 times. Yeah, so Females more attempts, Males far more completion.

Observer: Ohh, waw...

VAE: Uhh, huhh

SME3: so I guess this data, this would look the other way of you’re actually looking at completion…

Observer: Oh, waw, that’s interesting

VAE: Yeah.

Observer: So this is a good hypothesis to kind of…

VAE: Is just data, we’re running through the problem you had before. Again the data here doesn’t support the exploration, because we don’t have…

Observer: Yeah, just up to this further level of details…yeah

SME3: So, what else could you overlay on top of this?

VAE: Umm. So we have cause and sub-causes. We have the type of injuries, but I guess

SME3: type of injuries?

VAE: Yes

SME3: Yep, I would be interested to seeing what…

VAE: So let me out it here…and now we have the same but…I can actually filter that for you. So these are all the possible types of injuries

SME3: Yeah, OK.

VAE: Oh, maybe this is related to the “Hanging”, “Strangulation”

SME3: Oh

VAE: “Injury to blood vessel”…Umm “Open Wound”…”Other unspecified head injuries” … “Poisoning” and “Superficial Injuries”… So you wanted to see “Affixes and “Strangulation”

SME3: Affixes …are generally 2 very different things

VAE: Oh..

SME3: cause “Affixes…” maybe putting a bag over their head as supposed to “Hanging”…the other thing I would be interested in, if you were to go back, so we can see a sense what these are..Umm. Would they be any grouping by postal code? I would like to see by postal code

VAE: Oh, the postal code, but then the map is not working

SME3: Oh...OK

VAE: The map needs Internet connection

SME3: Oh, OK

VAE: and right now, we cannot sub-divide by postal code

SME3: OK, What is “Intent”?

VAE: whether or not the injury is reported as “Intentional” or not… but I guess, it will be surprising if all of this is unintentional, cause these are attempts to suicide….Oh, they are!

Observer: Waw!

VAE: Oh, no..all of them are “Intentional”, no report of “Unintentional suicide”

SME3: Well yeah, that's a triangulation on your data then, cause it supposed... it shouldn't be any…

VAE: That's right, yeah, so it's just a confirmation

SME3: Yeah, so you've got 40 causes, Group Cause I, Group Cause II, …What does that mean?

Observer: We created

VAE: just as groups of interest for the exploration here

SME3: Ah, OK.

Observer: Different visualization ranking…

VAE: Since we are not interested in all the causes all the time, but in certain sub-groups of causes, so those were created to explore them differently

SME3: Uh, huhh. Yeah…

VAE: So, we were here…let's go in here…Any other?

SME3: So this is by…this type of injury...Are we're already in that, or are we?

VAE: No, we took it out. So I can bring it back…type of injuries

SME3: All right.

VAE: and we have 2 groups… Are you still interested in the Age group…the division between 10-19 or can I merge those?

SME3: Yeah, you can merge them.

VAE: So I'm going to merge those. OK, now we have again, Female Male and by types of injuries…"Poisoning", "Toxic effects".

SME3: yeah.

VAE: "Sharp objects" and then the types of injuries, what injury was caused?

SME3: Right…Sorry that's

VAE: What do we have? We have "Other" "Unspecified", "By sharp objects", "Poisoning and Toxic effects"...Oh…this is interesting …"By multiple means" and "By Alcohol"

SME3: yeah…

VAE: So these two make sense

SME3: yeah

VAE: this one "By multiple means"…perhaps this one… this one "By Sharp Objects"… but we are in the injury that is "Poisoning…"

SME3: "Poisoning and Toxic Effects", yeah

VAE: “Poisoning and Toxic Effects”.

SME3: And what’s the brown?

VAE: “Unspecified”… So I guess it would be interesting to understand who reported ”By Sharp Objects” as supposed to type of injuries “Poisoning by Toxic Effect”

SME3: yeah, right Ok.

VAE: But that comes from the reports right?

SME3: Right, the cases

VAE: We don’t have that case in here, yeah…any other?

SME3: yeah, what is Body 1?

Observer: they have Body 1, 2 and 3 but the is the major one. The Body part that is most affected by t the injury

VAE: For any specific of this, Can we filter out some or do you want to take a look along all of them?

SME3: Uhh.

VAE: Let’s first bring the general division

SME3: Sure

VAE: It will divide…So what do we have here now? “Elbows”, “Wrists” and “Hands”

SME3: What is the Orange?

Observer: It’s the type of injury

VAE: Yeah, but why for the Body part…says “Poisoning and Toxic Effect” again

Observer: Same as this one

VAE: Exactly, this is the same as this one…cause we have “Head” in here

Observer: Cause we have the types of injuries.

VAE: It’s the Body

Observer: If you click on it…Hover the mouse over …on top of it… what does it say?

VAE: The Body is “Poisoning”, “Toxic Effect”

Observer: Oh, the Body is the same as type of injuries.

VAE: Let me get the sub-causes out and then …because we’re already interested in “Suicide”… So are we still looking into “Suicide”? It’s just that the Body part that was affected, one of the categories is also...

Observer: May be for that type of Suicide, the body part is…

VAE: One of the sub-division, one of the possibilities is that the body is “Poisoning” that’s why it appears in there, it’s the same as type of injuries, I suppose. So what do we see here is, “the type of injuries”…Umm … filtered to “Affixes”, “Open Wound”, “Poisoning Effects”, “Superficial Injuries”…and then it’s divided by “which specific part of the body”.

SME3: Right.

VAE: Umm. For example “Open Wound”: “Elbows and Forearm”, “Waist and Hands”. For “Poisoning and Toxic Effect”, the body part is “Poisoning and Toxic Effect”

SME3: OK

VAE: It’s just the way they does it, I don’t know.

SME3: OK

VAE: What is the meaning of that.

SME3: OK. I think that is going through what is up there.

VAE: No, that’s pretty much what the dataset allows, those are the dimensions, the Age group, the Body, the Cause, we’re digging into sub-causes…

SME3: Yeah

VAE: Sex, Age groups…we took the Age group out… just to see the compiled version. Right now what we have up here is for “suicide”, “Unattempt Suicide”, the “Body parts” that were injured for each specific injury

SME3: Yeah

VAE: that’s what we have

SME3: I think we’re gone through all of those, pretty much

VAE: Yep…We can add the time by year. We have this information for three years.

Observer: We have here fiscal year and not calendar year

VAE: Put it here, there we go. We have for the 2008; there were more reports for this year. For 2010 it’s decreasing

SME3: So these are cases that are showing up in Emergency, is that?

Observer: Yeah…All right

SME3: OK

VAE: Thank you

Observer: So do you have any comments or something you would like to say?

SME3: Uh, no. It’s been year and year that I’m familiar with. But this reminds me of 15 years ago with a program called Cognoz which is a cross tab program in which you load in your variables and …

Observer: I have no idea (laugh)… that's is interesting

SME3: I was using it…it's still available, it's not like…

Observer: Oh, I see

SME3: I've used it a lot, it's still out there and people still use it.

Observer: Thank you

VAE: Thank you so much

SME3: Yeah, thank you

Session IV

Observer: First let's start with an overview idea. Whenever you need to conduct any specific analytical work, what it the process that you use to kind of approach this work? The visualization supports your work?

SME4: You're asking me in general or you?

Observer: Yeah, in general but you can go to your specific work.

SME4: So, maybe if I can think of an example...Umm...OK. So like the last time, I used the injury iData tool…you want me to talk about that. So I was interested to find out one the colleague who told me that they've seen more and more older man in the trauma services for Motorcycle Motor related injuries.

Observer: OK

SME4: So older man basically are increasingly buying Motorbikes and the problem is that older when something happens it's harder for them to recuperate, so what I'm interested in, but it is not related to the CHIRPP data.

Observer: Well this one would visualize whatever data we have.

SME4: Yeah, right because these are kids…but that's the last time…so for kids like the Falls Trees which is again an issue for these data. Umm, because we would have to look for the narrative fields to get…so let's see, something that CHIRPP, so Window Falls, we're doing a project now for CHIRPP with Window Falls across Canada.

Observer: OK, and then usually how do you approach such a problem, would you look for specific information, do you kind of , share?

SME4: SO the first we did is we got the data from all across Canada. All CHIRPP data. Umm, OK, We were interested...So what we did first, we wanted to look at trend data, for example.

Observer: Ok, so mainly trending

SME4: we had few interest, first we… let's look for trends over time. Our "Window Falls" are going up or down?

Observer: OK

SME4: We also wanted regional, because different provinces have different building codes and requirements and so you might expect that there will be different…See the problem here is we want rates of course…and say different numbers in different regions depending on their building codes and so on…

VAE: Uh, huhh…

SME4: So then the other thing we're interested in is the age groups that are most affected because we're expecting, really expecting that the under 3s

VAE: Uh, huhh

SME4: …And, we also had to look for sort of mechanism, so for example…Are they climbing on furniture and falling off the windows? Are they on a balcony and they're just kind of falling over the edge? Or you know…what are some of those things that could happen?

VAE: yeah.

Observer: Interesting

SME4: So, yeah

VAE: So, I supposed you already did that…

SME4: Yeah, we did that, but we could do it for this.

VAE: Yeah, sure. So, we'll do the first one, "Falling from Windows"…

SME4: Let's do Falls from Windows? Well you'll probably have the same issue...Oh, well let's try the "Falls from Windows".

VAE: Are you interested in ...you said Age groups, right?

SME4: Yes

VAE: So, let's start with this one, I suppose.

SME4: Uh, huhh. So these are the Age group….No, just the Sex

VAE: those are Sex by Age group

SME4: Oh, by Age group, I see, right

VAE: So, I'm just going to Age group division and throw it there, are you interested in Sex division?

SME4: Yep.

Observer: Are you interested in a specific Age group?

SME4: Well as I said, I think the “Falls from Windows” is going to be Age 4 and under. SO let’s get rid of the others.

VAE: But that’s right, because...So that would be a cause the “Falls from the Windows”. Is that cause, right?

SME4: Yeah, right. I think it’s the “Fall from height” is the code

VAE: Uhh, huhh, we want to bring it here, we can filter out all that are not “Falls”. So I’m just going to filter out this. Everything that is not “Falls”. So, Cutting, Drowning, Fires?

SME4: No…no, don’t want those

VAE: Fire arms…Unintentional, perhaps… Like for the rest of the

SME4: Get rid of everything but Falls

VAE: OK

SME4: Yeah… Oh Waw

VAE: Umm, and now we can the sub-causes of Falls

SME4: Oh…

VAE: Waw

SME4: So Falls from high level

VAE: I can keep the tope 5 and see if any of those

SME4: Think of what we do, is not to put the top 5, but what..

Observer: you want to see..

SME4: Like Falls from ice… we would exclude those

VAE: Oh, OK.

Observer: Falls involving play equipment

SME4: So keep those…yeah, keep those…No…We wouldn’t keep any

VAE: Play equipment?

SME4: No

VAE: Skates, Skis?

SME4: No

VAE: Wheel devices…?

SME4: No

VAE: Ladders?

SME4: No

VAE: Stairs?

SME4: No…Not the... I mean no

VAE: There you go… that's it.

SME4: So, then…what would I want to know? I want to know what kinds of injuries they resulted from the…

VAE: What is interesting in here is that what we're talking about…

SME4: little kids,

VAE: Yeah, most cases are falling here but there are a lot of cases between 2 and 14

SME4: Well, yeah and that's where you need to go to the narrative field (in the surveillance and data collection sheet) to be able to tease out the data, like Falls from height, cause Falls from high levels for these other kids could be, they were climbing on a wall and they would fell off. So, you know that's the limitation of the CHIRPP data.

VAE:

SME4: yeah, but let's say for the sake of our data...these are other Unspecified Falls, the Falls from a high level are …the blue ones, and Falls from windows are … So it's really these two that we're sure, kind of

VAE: That we really want to dig in details.

SME4: And then, let's see…so, I can't remember actually if there are Falls from Windows, this category, but let's assume they are, let keep them both…Umm… So, in terms of … so then, in this cases we have the 5s, 9s, 0s

VAE: Uh, huhh

SME4: So, if we don't have access to the narrative field, we might be led to believe that we've got the big issue of the older kids just throwing themselves out of the Windows, or something

TE, Observer and SME: laughs

SME4: Umm, that's the limitations of the data…Umm, let's say we pre-decided that we are really concerned about the younger age groups…so you want to get rid the 5 and up.

VAE: Uhh, huhh. Right, so let me just…where is my Age group?

SME4: OK

VAE: So, just little kids, till 5?

SME4: Yeah…no 5s?

VAE: Yeah

SME4: So then what I want to say, what kinds of injuries they're experience. I mean that field we talked about earlier, which is that visit disposition, you know would be another thing in terms of proxy for severity… So yeah, let's have a look at the injuries they were experiencing?

VAE: Well, Fractures…

SME4: Yeah, Lot of Fractures…

VAE: Other specified

SME4: Is it possible to stack the ages?

VAE: Yes, the Age group. So let me ask you something, before bringing the types of injuries. We've already seen the Ages, do you still want the division of 1, less than 1, 2 to 4 or can I group them?

SME4: Keep the division for now, but stack the… so that we can see like how many Concussions, but then the Age groups sacked on top, if you know what I mean?

VAE: Oh, I see. Now you want to have the categories of injuries here and the stack.. use the ages as stack

Observer: Kind of flip

VAE: Yeah… So, I'm going to bring the type of injury here and I'm going to bring the Age group ...here

SME4: Right

VAE: There you go

SME4: Yeah, that's exactly … So, there is Head injuries for both ages or for both Sex. So Head injuries and Fractures is really what you're seeing…Big issues here.

VAE: Yes, there is the superficial injury here too…there are two

SME4: Yeah, but from…Yeah.

VAE: I'm sorry. Are you still interested in the division Female/Male?

SME4: Umm, well it's less interesting…but

VAE: Do you want to keep it?

SME4: Yeah, let's keep it for now. Yeah

VAE: Uhh, huhh

SME4: So, were we want to go form here…

VAE: Uh, huhh.

SME4: So, I want to figure out how…see…this is where I'd be going to the narrative field actually to get more sense of what is going in each of these prevention… Umm. Well I guess, I guess the other, which I wouldn't necessarily use with this, as we saw it earlier is that the time trend. So, if we'd want to know if there is any change over time in the year

VAE: Uhh, let me go to the trend line and …

SME4: Yeah, that, yeah.

VAE: and filter…

SME4: So we want those 2 Falls, the falls from…

VAE: Yes, exactly

SME4: heights… and out of …just

VAE: So, we just want the Falls…and then we want the sub-cause, let me just…one second. And we want to filter out just these 2 right?

SME4: Yeah..

VAE: Umm...From high level and the other one…

Observer: Oh…waw

SME4: Interesting! Waw that's like a 60 case increase

VAE: Yes

SME4: Yes, interesting…this is one is kind of trending downwards

Observer: yeah

VAE: It's somehow regular for Man and …

SME4: Yeah, it's pretty...I don't know if that's significant

VAE: yeah, somehow…

SME4: But…

VAE: we can see the significance

SME4: Oh, you can ask for significance, oh, really!! That's fantastic

Observer: the significance and tend line work with the scatterplot

VAE: Oh, yeah…I cannot ask just for the significance of the variance…no

Observer: just one... than you just need to have two variance for that…

VAE: Yeah, I cannot ask just the significance of the trends and the variance.

Observer: just two, you kind have to have…

VAE: We have time and we have the number of Falls.

Observer: But I mean time is not… the last time we used it, we had cost and the number of cases and we had the scatterplot and then the trend line for each of the variables

SME4: Yeah, that's not a time trend line?

VAE: No, it's not a time trend line

SME4: So, you can...Is it possible to calculate the significance of this trend.

VAE: Not in here…

SME4: Not in this...Ok…But nice to know that it can do it with some of the other trend categorization.

VAE: Yes

SME4: Yeah, so it would be interesting to see whether this… If I have more years included.

Observer: Yeah, that would be

SME4: It definitely needs more years and it just to see what trend you see…whether that is significant or not

Observer: Yeah

(SME observing the visualization and reflecting on the finding)

SME4: Yeah, but this is really interesting. I mean, that's a big jump over time…yeah, so I would want to figure out what is going on? Why the big jump there? And whether maybe across time, whether we're seeing different …say…types of injuries and..

VAE: the causes?

SME4: causes

VAE: We already know that there are Falls from the ... the types of injuries… yes maybe from the types of injuries

SME4: By time.. you know…Like, what is going on in here?

VAE: So Can I filter out this year? So, we want to know

SME4: No…Because I think, what we want to know…see…are there more…

VAE: The difference…

SME4: Yeah…more of... say concussion here, and again…the narrative field would be the most important variable here. It just kind of go in…

VAE: Let's bring it here.

SME4: Codes, kind of main themes that are coming out.

VAE: So, I'm just going to switch to bar in here and…

Observer: uh, huhh…more meaningful

VAE: yeah, exactly…So now we have…

SME4: So the Fracture…See the Fractures stay the same in the twin…and there is Head injuries, Other …this goes up…Superficial injuries…are actually going down or about the same. So it looks like the Fractures and the Head injuries…Huhh

VAE: Fractures and Head injuries…Fall from...Let me just clear this one…So this is "From the Window".

SME4: OK, So Fractures

VAE: Fractures

SME4: Fractures are going down in the window, It's interesting, isn't it?

VAE: Huhh

Observer: But other things

SME4: Superficial Injuries are going down as well…

VAE: Yeah

SME4: So what is going up?

VAE: All of them are going down. So, maybe this one is from high level?

SME4: So we want to figure out what goes in to Falls from high level?

Observer: Yeah, like is it building more high-rises?

VAE: Yeah, but it's Falling from building structures

SME4: Yeah, What is that? So is it Falling out of trees…May be they're Falling more of Trees?

VAE: Yeah (laugh)

SME4: Maybe, there Falling from…

Observer: going back to your…(laugh)

SME4: original query…(laugh) Yeah…We would have to go to the narrative field to figure out what is getting lumped in here? and why that is going up?

VAE: high level… the Playgrounds is yes.

SME4: Well Playgrounds are separate Ummm

VAE: Were they…Let me check again the causes.

SME4: Falling from Playground equipment were the highest causes. yeah

VAE: Yeah…May be we can… I want to see

SME4: Falls Involving play equipment…yeah

VAE: Ahh, so this is just high level…through building structure…I know… So.

SME4: So it's not ladders

VAE: It's not ladder; it's not stairs… what is Falling form high level?

SME4: from Trees??

TE, Observer and SME: Laughs

SME4: I don't know, (one of the participant who is working with the data) would be the best person to know…she deals with these data all the time

VAE: OK

SME4: This is quiet striking

VAE: Yeah, so this is where we go again, where we have to go to the narrative.

SME4: I have to go to the narrative field, yeah, interesting, yeah.

VAE: Ok, thank you so much for your time.

SME4: Thank you

Observer: Have a good day.

Session V

SME5: One of the things that I really want to know… I want to know something about Concussions or Head injuries.

VAE: Uh, huhh

SME5: So what I'd like to know is, I'd like to know what the rates are?

VAE: Uhh, huhh

SME5: So, what kind of, what the rates are for Concussions and head injuries. So for the hospitalization or whatever CHIRPP has in it…

VAE: Uhh, huhh.

SME5: And then the other thing I would like to know is… is causes of that.

VAE: OK, Umm

SME5: So...

VAE: So…we have a bunch of filters in here, I'm just going to take them out.

SME5: OK.

Observer: First let just ask a general question about…

SME5: Huhh, huhh

Observer: So usually when you approach a problem solving if you want to do a specific cognitive task, what do you do? What is the process that you follow to get to that point? And what is the information needed to complete the task?

SME5: Well, I'm asking the question because I have a project right now that is looking at Concussions. And so to me, that is something that I want right after that, cause that is the project, that's more driving it.

Observer: OK

SME5: But I think if you go back to the discussion we had this morning…You know, for me … I would like to, at the beginning, to actually even determine how serious thi issue is.

VAE: Uhh, huhh

Observer: an Overview?

SME5: Overview of all injuries, but then also and I know that we couldn't do that, is the whole admission data, to see, OK, of all these injuries what is…you know…What does it look like? What ones are the tops ones?

Observer: OK

SME5: But the thing with Concussions, I don't think that this is the right…. Like the CHIRPP data would be limited, right?

Observer: That's right. So everything is visualized based on the available data.

SME5: Right, because when you're talking about Concussions. Yeah, a lot of these kids would be seen at the Children's Hospital, but probably more kids would be seen at family physicians' offices, So anyway, that's fine, right?

VAE: Oh, huhh

SME5: So, anyway that's fine. But for right now, if this is what we have as a CHIRPP data, then my question would be, that we've already gone through know that I want to talk about Concussions, or I know there is Concussions and also Head injuries in here, right?

VAE: Uhh, huhh

SME5: So, like. Let's put them both together…If I can

VAE: Yes. I'm just going to filter that out right now…. Concussions and Head injuries…Concussions, not Fractures, not Dislocations

SME5: Is there intracranial injuries?

VAE: Yeah, Uhh, huhh… and none of anything else

SME5: No, just really specific

VAE: OK

SME5: So I want to go into really specific, let's see what can happen?

VAE: Uhh

SME5: OK, so here. What do we have injury to?

VAE: Ok

SME5: Cause what I would like to see, if we could use this tool to actually articulate how serious this is for Children's Hospital

VAE: Because of the analysis that we were doing before, Umm, we have types of injuries in here and then the Age group stacked, but I guess for your analysis it would be the opposite, would be more informative.

SME5: OK, let's see. So here we have Concussions

VAE: Let me just try...The 2 types of injuries..

SME5: Yep

VAE: Gender/Sex

SME5: Yep

VAE: And then the Age groups…. Are you interested in the Age groups?

SME5: Yeah, Can you spread them out, so you can actually see?

VAE: Exactly

SME5: So what you can actually do is…Oh, OK, there

VAE: There you go

SME5: So this is?

VAE: the Concussions are the Orange

SME5: Uh, huhh

VAE: These are the age groups… and the Intracranial injuries are the grey ones…

SME5: OK, so then what I see from here… well first of all, you probably have to see how this compares to all of the injuries within...

VAE: Oh, OK. So what is the rate of this compare to?

Observer: You mean across provinces?

SME5: No, in a datasets. So, how does this compare? Is it significant enough to actually say: "We need to do something about it"?

VAE: I see, so we need to do a ratio. Do you have ratios here (in the database)…No?

SME5: No

VAE: We can do that the system can do it.

Observer: We have the number of cases and this is the issue that we raised this morning. We need to look…not for the number of cases, but more like rates and we need a denominator for that.

VAE: Yeah, but this is the number of cases for these two types specific compared to the total number of cases.

Observer: Oh, I see

VAE: Is that it, what you're asking for?

SME5: Umm. Compared to the total number of injuries that is represented?

Observer: Or compared to the population?

SME5: Well, the challenge though is...Uhh, is some of the total population would come to the Children's' Hospital but not all.

VAE: Uhh

SME5: So I think I couldn't really ask that question, cause it wouldn't give me anything meaningful. So, maybe the question would be… Compared to all of the other injuries, where does Concussion fall? Or where this fall compared to other injuries…Can I ask that?

VAE: Yes.

SME5: OK

VAE: So, I'm going to take back all the other injuries. Umm, and then I'm going to group all of them into one category and leave the two others. So we can see all of the others as one category

SME5: and then this compared…OK, I get what you mean.

VAE: OK. And then I'm going to select all of this and then just take out Concussion and where is the other one…Intracranial...

SME5: What that…Yeah...

VAE: There you go… and then I'm going to say…Group. There you go.

SME5: It's OK, let's see what is going to happen here.

VAE: Numbers are huge for that one, because it's adding up all the others, right. Umm

SME5: Oh, hang on. It's fixed here, why is there strangulation in here?

VAE: No, these are all the other cases.

Observer: You can just name it Other

SME5: So then this little one here is Concussions and Intracranial

Observer: Compared to the overall

VAE: Uhh, huhh

Observer: Aggregated together.

VAE: But I know you want to see the ratio, right? Because right now this is the number of cases, and of course this is...

SME5: Doesn't look like it's a big deal…

VAE: In terms of the number of cases

SME5: You know what I mean.

Observer: I See.

SME5: You look at it and you say: OK, why would you focus on Concussion when …

Observer: But the other ones are combined

VAE: Yeah, But the other ones are combined, exactly

SME5: Yeah, I know

VAE: This is not very meaningful too…because how many categories are in here

SME5: You need a ratio to …

VAE: yeah, the ratio

SME5: Yeah, that's good learning… I guess, right?

VAE: We can do it actually, but we have to calculate another measure in here

Observer: add another… We need data for that.

VAE: So right now I cannot do it (due to the lack of information in the database) but the tool would allow us to do that.

SME5: OK, so that's fine. So let's just go back to just looking at Concussions and Intracranial injuries

VAE: Uh, huhh. There we go.

SME5: OK, so then this tells me…OK let's say that we determined that this is a significant issue at the BC Children's' Hospital…Something needs to be done. You can see the age…

VAE: yeah, 10 to 14

Observer: Yeah, the Age group is really…

VAE: Umm

SME5: Now, what else would I want to know?

VAE: You can know the causes, right? You asked about the causes, so let's add…I'm going to combine these two. We know Concussions; can I combine these two-Concussions and Intracranial injuries? I'm just going to show the causes.

SME5: OK, so when I go over them

VAE: Uh, huhh

SME5: So, that would be Struck by/against… Falls

VAE: Falls, and then this is one is

SME5: Falls, Transports and MV cars …oh no, that could be pedestrians or could even bicycle, right?

VAE: We can filter out… we can even add the sub-causes

SME5: Oh, OK, let's see

VAE: I'm just going to get the top 4 causes

SME5: Yeah

VAE: And, let's add the sub-causes…OK, so those are only the top 4…These Falls, Other unintentional

SME5: Cause one of the issues though is that the categorization, though is interesting, Other undefined right, cause Falls could be anything, right?

Observer: Yeah.

VAE: Yeah, so, I'm just going to –the sub-causes to see what else. Uhh, I'm just going to spread it out…

SME5: That's OK..

VAE: Let's see.

SME5: Oh, holly waw!

Observer: Waw

VAE: because there are all the Falls

SME5: Look you could see…OK

VAE: All green, maybe this here is…I can' tread the sub-causes

SME5: Here, Struck against or Bump into/by another person

VAE: Both cases

SME5: That could be Sports

Observer: Yeah.

VAE: by other objects, yeah

SME5: Involving Skis…that things, it's hard

Observer: Yeah, let's check the older age

VAE: Yeah, this is older age, right

SME5: So that…the thing in this is that it's limited that you're making an assumptions that this is Sports related, right?

Observer: that's right

VAE: Uh, huhh. We're running through the same (issue) as before. Like Falls from high…

Observer: From high level…what does that mean? Is it a tree or a high rise?

SME5: Oh yeah, exactly. So you're limited in the definition

Observer: Yeah, the definitions, the data collection...

SME5: Yeah, who actually puts the data in too, right?

VAE: Exactly, there is a person making a judgment…this is falling from a high level...

SME5: Uh, huhh

VAE: this is …

SME5: So you're also making a judgment from how they judge put it in

VAE: exactly (laugh). Then you judge on top of that one. Do reasoning on top of their reasoning.

SME5: So, I think the important thing with this is to just recognize like for my purposes is that you can't…Like this is interesting information to have, to look at, but you have to be cautious about the assumptions that you're making.

VAE: Uh, huhh.

Observer: That's right. That's why we talked about the role of the analyst. If I know about the data, I know that like this must be questionable, like this is not, you can't say that for sure…

SME5: Here is what you can say from it…

VAE: Uhh, huhh

Observer: You can generate hypothesis, but you can't …

SME5: You can't have conclusions, right.

Observer: Unless the data is confirmed that this is kind of… Fall out of whatever…

SME5: Yeah, but this is that just so dependent upon so many factors…

Observer: Yeah

SME5: that’s a challenge

VAE: But, you’ll have to go back to the origin...to the field

Observer: Yeah, to the field that is essential…and knowledge of…

SME5: So, what is this?

VAE: I just put the Age groups in the colors...So now we have all the Falls and all the possible…

Observer: And the Age groups

VAE: And then the Age groups stacked…This is representative for sure…from 10 to 14…Now I just changed the layout to see if I can…because before…I want to show you something here…Why it’s not green…show me the colors…There you go. So these are the Age groups and on their 10 it’s mostly green, which are Falls

SME5: yep

VAE: And above are mostly pink, which are the Concussions, Struck by/against

Observer: That could not give an idea, this?

SME5: Well for one Age group, you’re looking at Falls. For the other group, you’re looking at Struck by

VAE: Yeah

SME5: What that means?

Observer: You’re the Expert, we don’t know…you’re the Subject Matter Expert (laugh), we’re just the Tool Expert.

VAE: (laugh)

SME5: No, but then What you’re saying though is that, I said, came up with…Well this means this…I can then talk to you about it or talk to the analyst and say: Would they …Well you can’t say that definitely but you can this instead

Observer: OK, I guess this is ..

SME5: Back and forth thing

Observer: yeah, back and forth and collaboration.

VAE: I think it’s also about you understanding exactly how the data is collected…Yeah

SME5: Yeah, and it’s collected in a variety of ways and with a variety of people, and how they interpret those categories depend upon them.

Observer: I guess the process (of collecting data) should be more structured in a way that …the categorization

VAE: Or more informative, when actually somebody is doing a report

SME5: Like how are they're making the decision to actually put this or that... and

Observer: This is also helpful in terms of the surveillance database

SME5: Yeah

Observer: The collection of data to be more accurate

SME5: Yeah…OK

Observer: Thank you so much

SME5: Good. Thank you

VAE: Thank you

Session VI

Observer: So, let me start with a general question. Usually when you approach the problem solving or if you have to some task to report on, what would be the best approach for you? What are the steps that you follow? And how would the tool support in that regard?

SME6: So, normally when I have question, I always look at the bigger picture first.

Observer: OK

SME6: So, overall, depending on the region first in Canada. What is it?

Observer: OK

SME6: And then I zone down to BC, What is my question? So, let's say I'm looking at all injuries. So, in Canada, what are the most common injuries? Then I zone in out to BC and then, looking at the overall picture in terms of, OK these are all the injuries and then zone it down to which are the most leading... Ok, within the leading ones, which are the most common types, regarding the leading causes in Falls for example comes out to be the most common. For example what types of Falls? Out of those, what are the most common, was it "playgrounds" for example, comes out to be big

Observer: OK, so you're going from the general to …

SME6: From the general to the more specific, and then zone it down by Age group, by Sex, by Type of injury, by Severity, by Location

Observer: OK, so…

SME6: …By activity, so from the big picture to the smaller picture.

Observer: OK, excellent. So this is a good staring point. OK, and do you think, the group collaboration would help in that regard…Like collaborating with others?

SME6: Yeah, because it might be other questions that I may not have thought of, which might come up with a group collaboration. They might have other ideas, that may add on to whatever I think of…

Observer: Other perspectives…

SME6: Yeah, a different perspective, yeah.

Observer: Oh, I see, I see. So what would you be interested in, as a scenario to working on?

SME6: Umm. For the emergency department, which are the most common causes of injuries that are coming to the Emergency Department?

Observer: You mean in general.

SME6: In general, like start from there, like the big picture and then the smaller ones.

VAE: OK…the most common causes?

Observer: The general would be the different causes and the different number of cases.

SME6: Yeah, for me, type of injuries is not…

VAE: Not important

SME6: Yeah, so mostly causes of injuries

VAE: OK, then let's bring causes.

Observer: What about the year?

SME6: Year…Uhh, not so much, unless I want to see of there is a trend… If it's an increase or decrease…but for a starting point, I would just look for the general, whatever data I have.

VAE: Uh, huhh

Observer: What about…So… just all aggregated or all separate years.

VAE: So, I just ask for the top 5 causes?

SME6: Yeah

VAE: You're not interested in the year?

SME6: No at the moment breaking down by year…maybe after, when I identify the leading ones, I might see what is happening by year.

VAE: Uh, huhh

Observer: so first is a general idea about…So do you need the Sex in here as a different dimension

SME6: no, just overall picture, just identify...and then go into more specific.

VAE: So, we have the top 5 are: Falls, Struck

SME6: Yeah, that's good…and Struck

VAE: Uh, huhh

SME6: So, and now I know that Falls and Struck by are the big ones

VAE: Uh, huhh

SME6: Then I want to know Umm, OK… for the Falls and the Struck, what is the trend by year? What is the Age group?

Observer: Oh, just for these 2

SME6: Yeah, identified. These are all small (the rest of the injury causes)..I won't worry about those for the moment. I want to just do the 2…and then

Observer: Interesting

VAE: By year?

SME6: Yeah, let's see what is happening by year. Is it increasing or decreasing in numbers?

SME6: Yeah, so see Falls is

VAE: Uh, huhh

SME6: is going up…Struck is slightly going down, but Falls is going up

VAE: Uh, huhh

SME6: Then I want to see, OK…Um, then for the two of them (Falls and Struck by) what is the break down by Age group? What is the break down by Sex?

VAE: Uh, huhh. Umm. Can I take out the …

SME6: You can take out the year, yeah

VAE: Umm, the break down by?

SME6: Age group and Sex.

VAE: Uh, huhh

SME6: So, can you put both of them together?

VAE: Yes, I'm just thinking, where would be the most informative distribution…So, I'm going to put Age group in here…Uh, and then by Sex, I'm just going to color it. So that's it…Male, Female and then the Age groups

SME6: Yeah

VAE: This is for Falls, this is for Struck by

SME6: Yeah, so I see here, from 2-4, from 5-9 and 10-14 those are the Falls and then the Struck are most in the 10-14, some are from 5-9, then you know, it would be interesting to see what type of Fall this is. Like what are they falling from? What are they struck by?

VAE: Uh, huhh

SME6: So, then you'll need sub-cause, right?

VAE: Yes

SME6: Within each group… So, if you could bring another layer, that would color it up.

Observer (talking to the TE): then you would have to take the Sex out of that and then...

VAE: yeah, then filter it out

SME6: I don't want Sex, because I know that Males are more for everything.

Observer: Or you can add it somewhere else…

VAE: Yeah, I'm thinking if I add another division here, it will just divide…

Observer: Oh, I see

VAE: Let's bring the sub-causes in here.

SME6: right.

VAE: And then I can just filter out like…the top 5

SME6: Oh, you can filter that…nice

Observer: just to rank the top 5

SME6: Yeah, that would be…yeah. But for each bar? Oh

VAE: Yes, so there you go.

SME6: Nice

VAE: We have Falls

SME6: Yeah, this is a good picture because you can see for each of those ages, which is the leading. So these ones are "bed and chairs". And then when you get into 2-4 that is slip-trip-trip and then there is this bar?

VAE: Unspecified

SME6: Umm, and what about the other one?

VAE: And this is the Struck by/against

SME6: Oh, OK

VAE: into another person…and then the grey one is by other objects

SME6: yeah, yeah

Observer: So mainly the 10-14 are hitting into other people

SME6: And then once you've done that, you want to know, what types of injuries

VAE: injuries

SME6: injuries are occurring for each of these causes?

VAE: So, I'm going to. I would like to first save these. Let me just copy and leave that image there…there we go. I want to go back to that one. I want to duplicate this… there you go. I want to have a copy do you can explore different… Duplicate sheet...that's what I want…perfect. So the first one that you want to explore is the injuries over years, right?

SME6: Yep

VAE: Umm, so I'm going to take this Struck by/against out. We can explore that one later. And then, I want to bring the injury types.

VAE: I'm wondering if this is the best division I can do…I can do type of injury here…better

Observer: then you won't have the sub-causes as…

VAE: And then I'll add the sub-causes better in here. There are just too many types of injuries. Umm, well…

SME6: It's just showing that this is really high. So maybe, just keep to this one "beds and chairs".

Observer: So, maybe this is high for youger age

SME6: Let's go down…then it goes…So, can you do herethe leading? Can you show the top sub-causes?

VAE: Yes, types of injuries or sub-causes?

SME6: Uh, huhh

VAE: OK…This is just for Falling and the types of injuries are: …

Observer: Exclude some and keep some.

VAE: Yeah, we can also filter the top 5

Observer: Yeah, so filter both to keep whatever is…

VAE: Yeah…

VAE: OK, there you go. We have Dislocations, Fractures, Open Wounds, Other Unspecified and Superficial injuries. Those are dangerous, they occur most frequently under these causes and they are distributed by Age groups. Would you be interested in any in particular?

SME6: (thinking for few minutes)

VAE: so, we have the Age group in here…

VAE: So we have the sub-causes here, the most common ones. Umm, we can say the "bed and chair"

SME6: Uh, huhh, yeah.

VAE: But for the younger ages

SME6: Yeah, then the older ages, it would be something…

VAE: these other...Falling from the same level, Sleeping...

Observer: You can kind of picking any of them and kind of drill

VAE: And this one is…I can't see the name, Uh...Inter… and this one is Ski, skateboard..

SME6: Yeah

VAE: Yeah, in-line Skates, Play equipment...So

SME6: Yeah, so this is a good picture, a good starting point, right?

VAE:

SME6: You can identify what you need to focus on, which cause…

VAE: Yeah

SME6: For me, it sounds like in the younger ages, lots of Falls are coming into the Emergency, from "bed", "chair" then you know, OK, what you need to focus on. What you need to…yeah

VAE: Uh, huhh

SME6: So, it gives a good starting point to see where you can gear your…

VAE: OK

SME6: The thing that would be nice to add on, which I think we can…

VAE: Uh, huhh

SME6: …Are, as one of the participant was asking, Admissions, Sports activities. We can add more information, just so for some of the Falls or the Struck by…

VAE: Uh, huhh

SME6: You can get more information on what is Struck by…playing Soccer or Floor Hockey

VAE: Uh, huhh

SME6: We can add, it would nice to have all of these.

Observer: More layers of details, yeah…. perfect

VAE: OK

SME6: OK

Observer: Thank you so much for your time.

SME6: Good, good.

Session VII

Observer: Let me just start with a general question. Whenever you have a specific analytical problem that you want to approach, what are the steps that you use to approach to solving such a problem and using the tool?

SME7: Using a tool like this? Umm

Observer: Yeah. Or usually how do you integrate the tool in the problem solving?

SME7: So usually, it kind of depends. Fortunately I have access to quiet a lot of data, so sometimes I can use the CHIRPP data that I have for example and I answer questions that I have myself.

Observer: OK

SME7: Umm. But I don't see the CHIRPP data, so. Umm. So usually, I would look…firstly, I would probably look at tables, look at data and trying to figure out what data were available to answer the questions that I have. Umm. Because I'm a researcher, I think my questions tend to be more specific and looking for a lot of information, but maybe different from people who are approaching this with a more general view.

Observer: That's right

SME7: So in terms of this, I probably wouldn't for example use the front page (of the tool) very much because that's all information that I know.

VAE: Uh, huhh

Observer: Oh, I see

SME7: But, what I would do is what I think is fascinating is some of the real drill down options.

VAE: Uh, huhh

SME7: You know, by type, by cause, by sub-cause, by age…

VAE: So is there any particular exploration that you would like to do?

Observer: Just one last question before getting into that. What do you think collaboration would kind of be helpful in that regard…to kind of converge towards a problem solving…collaborating with others?

SME7: Sorry, in regards to the Dashboard specifically.

Observer: Yeah

SME7: Yes, I think that would be helpful to collaborate with others. Because I think it's such a fantastic tool and it's such a wealth of information. It would be important to collaborate. Because as an academic, I have one perspective. I'm very used to looking at data, I'm very confortable looking at data, I'm very confortable trying new things and seeing what happens but not everybody is.

Observer: OK.

SME7: So, I think the collaboration is important to build it and to have ongoing collaboration with people who would use it to say, this is what we find helpful, this is what we didn't find helpful. If you could do this, it would be so much better…

Observer: OK, OK

SME7: So I think that feedback is important to maintain throughout and I think it has to be collaboration as of today beyond every search team, or beyond BCIRPU…

Observer: Ok

SME7: You know, to public health nurses, to ministry officials…to anybody who might really like to use the data.

Observer: OK…Do you have any specific scenario that you would like to try it using the tool?

SME7: Oh, sure, I could think of about a million (laugh)

TE and Observer: (laugh)

SME7: So one of the things what I've said earlier today that interests me is the whole Bicycle related injuries, right. So I would like to look at Bicycle related injuries…

VAE: Uh, huhh

SME7: Divided into "Head injuries" and other injuries

VAE: So the bottom. So…I'm just going to filter all the Bicycles. I know those are Transport related

SME7: Uh, huhh

VAE: But then, let me...Is there any other Transport related?…Oh, I need to add the sub-causes…just a second…before I need the Body parts. You said Bicycles, right?

SME7: Uh, huhh

VAE: Umm, Transport related and then the sub-causes, and we would investigate those that are just...

Observer: So, would you be interested in the Age group as well?

SME7: Uh, huhh

VAE: Just a second. So, just Bicycles you said?

SME7: Pedal…

Observer: the green one, the biggest one (referring to the graph)

VAE: And then, the Body parts that get affected

SME7: Right, and then what I would love to see is “Head injury” versus other Body parts, like 2 categories

VAE: Perfect, we can filter out the other ones. So Body…And you said…

Observer: and then you can select…

SME7: Yep

VAE: Head versus…

SME7: All the rest…yeah

VAE: All the rest…Yeah, let me do it. So, now I know.

Observer: So, We’re trying to aggregate the whole thing into one group and then have “Head” on the other group

SME7: That’s fantastic…That’s amazing

VAE: We had…Oh actually Head is quiet representative.

Observer: Waw!

TE, Observer and SME: laugh

Observer: We’re impressed

SME7: So that’s fascinating. That shows you know that…

Observer: Relative to…

VAE: So to me that shows that really the 5-9 years olds, we need to a real emphasis on how they use stairs..

Observer: and the Male…

SME7: And the Male for sure, but they also have…when they are 10-14, the Head injuries…the proportion of Head injuries goes down, I find that fascinating.

Observer: Oh, I see. Compared to the 5s and 10s

SME7: Yeah.

VAE: What is really fascinating is the proportion here. This is over 50 injuries out of 200 (cases)

SME7: Yep,

VAE: that is like 25% of the injuries

SME7: Yeah. So to me, that would really help with the Prevention planning and the…

VAE: Umm, we can see the injury types…

SME7: Sure. Let's look at that (laugh)

VAE: Now, I'm interested (laugh)

SME7: Laugh

VAE: Injury types…Let me combine the Male and Female now that have explored that one already.

SME7: Uh, huhh

VAE: So now we have those…So let me have those two categories: "Body" versus the rest

SME7: Uh, huhh

VAE: Horizontal categories… and then the types of injuries. That sounds better.

SME7: Yeah

VAE: So, we have...for each of this we have the rest…all of the others versus the "Head", right

SME7: Uh, huhh

VAE: For each Age group. Umm, these are the type of injuries. I'm going to filter the top 5 because there are a lot of types of injuries. Umm. And what we're seeing here is…So we drill down to Bicycles…

SME7: Uh, huhh

VAE: Just on the "Head", compared to …

SME7: Uh, huhh

VAE: "Body parts" and…

SME7: Yep

VAE: and now that we have the top 5 injury types

SME7: OK, Dislocation, Fracture, Open Wounds, Head injuries and Superficial injuries…Fascinating

VAE: And those are more representative above the age of 2...

SME7: Yeah, and which make sense because these little ones would be on their parents' bikes probably…

VAE: Yeah

SME7: While the older ones

VAE: yeah…exactly. So we have Fractures…Umm, "Open wounds", this is the distribution… "Superficial injuries" and "Fractures".

SME7: Oh yeah, so that's fantastic. I mean that has so much potential as far as I'm concerned in terms of the types of questions. And again, I said I'm a researcher and that's the very type of specific question that I would like to see…So that's very exciting

Observer: OK, Perfect.

SME7: And I love the top 5 you know that you can..

Observer: Oh, yeah

SME7: You can filter some other stuff that is not as relevant.

Observer: exactly, that would be a very helpful feature.

SME7: Yeah.

Observer: All right, thank you so much.

SME7: That's it.

VAE: (laugh)

SME7: That was easy

TE, Observer, and SME: (laugh)

Observer: Thank you so much for your time.

Appendix J:
Group Analytics Transcripts

Group Analytics Session I

Facilitator: So if you're ready, we'll take on our first take for the day, and my role as the facilitator is to provide with the problem that you're to solve as a group and to keep you on time. So you have about 25 minutes to solve the problem as well as to keep you on task. So if we find that we're starting to go off into side conversations, I'll ask that you come back, so that Samar can get good data.

So, we'll start with a scenario.

SCENARIO: Imagine that you've been asked to come together as injury prevention experts for the province. Your task is to inform the development of the targeted intervention that will reduce Child and Youth injuries that present at BC Children's hospital.

Facilitator: and if you flip over your agenda, there the problem is there so you can refer to it.

SME2: Extra points

SMEs: (laughs)

Facilitator: So, as a group, we're hoping that you will all participate and again the task is to inform the development of a targeted intervention to reduce Child and Youth injuries presented at the BC Children's hospital. Likely to get started. there is going to be some information you need to know and that's where the Tool and Tool expert will help you. So, when you feel ready, after you discussed it together, you can ask Nadya (the Tool Expert) to use the tool to find out the information that you need. Any questions about the process? Feel free...

(the first Group session, was more of a general problem solving and investigation and therefore manipulation of the tool based on stakeholders' suggestions and requests, compared to the other scenario for GA II where we specified the analytical task)

SME 8: Sounds easy.

SME: I'm quiet keen about some injuries that we may have guessed, and can we develop a targeted intervention that would make… like cycling in BC safer for kids? So I would say bicycling infrastructures, no biking on the roads, things like… as well as helmet promotions. Is that what we're supposed to do?

Facilitator: Absolutely, it's very open ending.

SME 8: I'll be looking at it a little bit differently though.

SME7: I was thinking of…

SME8: In a sense, may be we don't have to lead to that conclusion but may be the process would be: what falls from the data… what is the burden…

SME4: yeah, where is the biggest burden.

SME3: yeah, and how long is our intervention targeted for?

SME8: yeah also, of that burden, what socially resonates? What is actually actionable? So, I think you have to plot it there. What the big things are? And which of them are meaningful to actually do anything about it. Might be very well that it ends up something like Bicycle helmet that is actually very meaningful to doing something. but you want to know where it ranks?

SME3: yeah, unless something in that trends, already something that is heading down already. May be that sounds the right place to start an intervention if you look at increasing trends over the last few years.

SME 6: So, I think what you have up there right now actually supports the beginning of this discussion. So you can actually start seeing, you know, what is the burden right now? And what are some of the trends? Where the trends are going? And, you know, Male/Female and Age groups even.

SME 7: So I guess something that I kind of build on what you're saying that something that I'll be more interested in is "the broad numbers", what are they? But not just the numbers, what are the most serious consequences and what are the actual causes? , because may be that what is really driving the biggest number is sprains or something...You say: Ok, so. Is that something that is going to have serious consequences over long time, versus traumatic head injuries?

SME1: Uh, huhh

SME7: Those are the types of things I'd start to want to do to narrow down before you might want to start doing…

SME 8: So, do we use this to generate a list of burdens in terms of any other… I guess, we need more data to know how many were discharged or how many stayed in the hospital, or how many have died? Or, that kind of stuff, or how much their care cost?

SME 4: We know, if we have these data on, we do know that visit disposition. So whether they end up admitted to a hospital, whether they died, whether they were just treated and released. So, Those are, I mean, they're proxies for scenarios.

SME 8: Right sure. So is that in here. Can we our mortality rate was….

Facilitator: Yes.

SME6: Let's ask our analytical person. (Laughs)

SME 4: You also have the nature of injuries loaded up as well, right. So for example, there is like head injuries.

SME8: right.

SME4: We could look at those kinds of things.

SME5: and whether the amount that they cost… cause that would be good too, that would speak to burden.

SME: What you wouldn't get is how long they were in the hospital for, for example.

Tool Expert (me): It's mainly based on the dimensions that we have in here (the database). This is what we have in the database.

Facilitator: you do have Admissions though, I've saw it last week. Somewhere in there, there is Admissions.

SME 8: So, what we're looking at. Is this incidence or …?

Tool Expert (Nadya): this is the type of injuries…Umm, per year.

SME 4: The Falls were over and above. Like they were way higher than others.

VAE: Those are the causes. Yeah. Then, let me go to the dashboard, then, you want to explore further the causes of…Uhh, so, let's take a look at this…this one (See the Falls).

SME 4: and then the subtypes of the "Falls".

VAE: Uh, huhh.

SME4: That's Chairs, etc.…Furniture, "Falls from Furniture" looks like it's big. I want to see the Age Groups. Is that Ages?

VAE: Yeah, since I have so many categories, I have the Age Group up there. Is there any particular sub-cause that you're interested in?

SME 5: can you get it to show the way it's stacked...Uh, so within each of that, so the "Falls from bed, chairs and furniture", within it to show the Age Group? Can you get to be that way?

SME 4: Oh, like the stacked.

SME 5: yeah, like the stacked, so when you're looking at that bar, you could see which the Age Group that has the most.

VAE: Umm, yes.

SME3: Let me just call sub-category with the ages stacked.

SME5: Yeah.

SME 4: Yeah, what I want to see is like the top "Fall" causes for different Age Groups. So if you have the different Age Groups, what are the 5 year olds Falls?…

SME 6: So, my question is what are we even focusing on "Fall". We haven't even actually determined that that is the highest burden in the system yet.

SME 4: Oh it was, on the first …

SME 7: It was the highest number

SME 6: Well yeah, it was the highest number. But we haven't narrow it down to burden yet, because the question I would have, would be the seriousness of it and the burden to the health care system. So it's like, if you can overlay the Admissions piece on there, then you can start seeing “Ok, which one of those causes were admitted to the hospital.?”

SME 8: Or even, how many died, you know.

SME 6: yeah, yeah, like a little bit more detail.

SME7: What happens as a result of “Falls”

SME 8: Can we know like the top mortality causes?

SME 4: It will be 1 or 2, like really small numbers.

SME 8: the car accident for example, there are a lot of children adjusted in car accident. Can we know how does that compares to “Falls”, versus Suicide, versus…

SME 4: The challenge here is that 3 years of CHIRPP data only for Children’s hospital. So the number of deaths, like serious, there are going to be tiny.

SME8: oh I see.

SME6: yeah, but the Admissions, you have.

SME 5: Admissions would be higher, yeah

SME 7: So, is in here. For one of a better outcome. What happens as a result of the “Fall”? or what happens as a result of the “Motor Vehicle incident? Did we know if this is resulted in a surgery or in a head injury or a Band-Aid?

SME 1: It can tell you the type of injury associated with the “Fall”. So you can drill within Fall to sort of say: “What was the circumstances?” “Was it a Fall from furniture or a Fall form playground”, you can drill. And then you could let’s say: “Ok, if we’ve decided for example that this playground is an issue for us, we can say: “Well, what are the types of injuries?”. But Jennifer’s logic is as I hear it is: “Let’s find out the type of injuries first associated with any of these leading causes, cause that’s would be the burden, right

SME (all): yep, right

SME 1: rights, cause that’s would be the seriousness. So we can back up to the causes of injury and we could sort of say: “Which cause do we want to hone in on to look for the types of injuries associated with or the type of injuries that come out of that cause as a way of getting to burden?” Is that what you’re looking at

SME 6: I just…My question would be: “How do you rationalize why you chose Fall?”. And so that if you’re able to demonstrate that with the tool, so as here is what is seen in CHIRPP. Which ones are the ones that are admitted or mortality? So then that would be to me how you kind of rationalize to… We’re talking about specific decision makers here, right?

SME1: right.

SME6: We’re not talking about…like, that also speaks again, who’s using this tool and to what decisions.

SME 1: Uh, huh. Yeap.

SME 6: because community based organizations, they would be: “Oh my Goodness, look at all these “Falls”. Let’s just deal with those things because they are preventable…

SME 1: Uh huhh…

SME 6: So called ‘preventable’, but they don’t really concern so much with the burden on to the health care system…

SME 1: right…

SME 6: I don’t know. Does that make sense?

SME 8: It does, yeah.

SME 6: So I don’t know if you can do that. Can you do where you sub-categorize…?

VAE (me): well in this visualization, you can see all the different causes injuries and in each of the causes you can see the different types of injuries

SME 4: but you have the Admissions and the visit dispositions? You don’t have it on there…?

Facilitator: we don’t have it on that database

SME 4: or maybe it would be a matter of using another proxy...the types of injuries, new medical types, choosing which of those injuries

SME 8: Can I ask you head injuries obviously or neurologic injuries, do you have even severity, may be you classify the variables thing.

VAE: Maybe sub-causes of that…

SME1: No

SME 5: not in here.

SME 4: so head injuries could include is like minor stuff as well.

SME8: yeah.

SME 3: If you put that in general, like at least have…

SME 7: But if we’re looking what we’ve got now, if you hover on one of these boxes, one showed “Concussion”, one showed “Fractures”. On the last screen that you had (ask the VAE to go back to the last screen)

SME2: yeah, I think what we want is the type of injury alone at the bottom. And then the causes stacked in there.

SME3: yeah.

SME4: Uh, huhh.

SME7: yeah.

SME2: that's what we would like to see.

VAE (me): if I'm going to, let's say.

SME 7: Can you have a sense of…that showed like head injuries…"Head injuries", "Fractures"…and stuff.. Could you actually look, how many "Fractures" you have, how many head injuries you have, how many those kinds of things…

SME 6: Superficial there.

SME7: Superficial

SME1: yeah…

VAE: yeah.

SME 1: 297 cases there over the 3 years

SME 7: right, but that's per "Falls". Can you get: "How many superficial injuries..

SME1: In total?

SME7: In total

SME1: yeap.

SME7: How many "Fractures" in total?

SME 4: you want the superficial, like the type of injuries on the x-axis and the…yeah, yeah

VAE: And this is the total…per year, or no?

SME4: No

VAE: Not even per year, just the total?

SME 3: yeah, total by cost.

SME4: … "Concussion" is there!

SME 7: I mean that would give us some sense of where the burden is.

SME 1: that's the total there.

SME 7: that's the superficial injuries… (direct the conversation to the VAE), so if you go up to biggest chunk of the bar.

SME (all cooperating together, looking at the chart and interacting with the changing display): Fractures!

SME 2: what is that yellow (pointing at the graph)

VAE: This one? (Hovering the mouse)

SME (all together): "Open wound"

SME 6: and then the blue?

SME (all together): “Head injuries”

SME 7: the green?

SME (all together): “Dislocations”…

SME 4: So “Fractures” the problem here too is…like, there is severe “Fractures” that end up in Admissions and Surgeries and so on. And there are those that are treated and released and…

SME3: Yeap.

SME7: Uh, huhh.

SME4: these data aren’t going to … at least without the Admissions details…

SME 8: Nicely those traces me how trapped in the parameters of our dataset. This is opposite experience of what we have in the Trauma Registry, We have a lot of information about dead patients and hospital stays, but we have no information about what they represent, the end point of, whether they are “Driving injuries” or “Falls” or “Suicides”. So, we don’t have the incidence data that goes with it and you don’t have the burden data that goes with this and somehow we’re going to find to how all this fits together. I think this tool is amazing, yeah . It shows you, but it’s only as good as what’s in there obviously.

SME4: yeah.

Facilitator: Yeah, Admissions is available as SME4 was saying and it’s just not displaying on this particular tool, but we do have it and that’s a good feedback for us to make note about it. It needs to be available.

SME 1: Because the way to do would be to highlight for example, if you wanted to ask that question about “Fractures”.

VAE: Uh, huhh.

SME1: If you can hover over that and *keep that one only* (addressing the conversation to the VAE)

VAE: Uh, huhh. Let me do it from here (side menu) so I can keep all Male or Female…”Fractures”...”Keep only”…there you go.

SME 1: Ok. And then what we could then is drag in dispositions and then it would divide up those bars into stacks that said: This many were admitted, this many were treated and released and this many …

SME7: that’s good.

SME1: It’s not in this dataset, but this is calling on.

VAE (me): No, this is more…

SME1: It was in the Transport dataset, right!

VAE: …in the main file, right?

Facilitator: It's in the iDOT for sure.

SME 1: So we, It's just not looking at that column (the Admissions) and including in the dimensions. So, my apologies., but that's captured on video and audio, so we'll put in into that. So that's a good recognition.

SME 6: do you have to go though to the causes first before you put to Admissions on top or do you have to do it right from the beginning?

SME 1: you can do it in any order you wish!

SME 6: OK…

SME 1: that's the beauty of this; you can drag up any factor and cross tab it with any other factor.

SME6: Ok.

SME1: So you could start. And it's really how you does your mind work things, right?

SME8: Right.

SME 6: Right. What are you using this tool for?

SME 1: that's right

Facilitator: So We've got about 4-6 minutes to wrap up; though you don't have to come up to a final conclusion especially if the dataset doesn't offer you what you need.

SME 2: But can we say that pretend that all of these fractures are severely high, that we think that they should be prevent

SME1: Uh, huhh

SME 2: … where do we go next? I would say we would look at the causes of "Fractures" next, right?

SME 8: yeah.

SME4: yeap.

SME3: yeah.

SME 7: yeap, yeap.

SME5: Uh, huhh.

SME 3: Let's look at the "Fractures"…

VAE: Uh, huhh

SME 8: Sorry, is that all the causes of "Fractures", was that correct?

SME1: no, she's (VAE) just generating them.

VAE: So, I'm just going to keep the "Fractures"

SME1: Keep the Fractures,

VAE: "Fractures"…and then I'm going to add the causes.

SME1: and the causes go up there and that should stack it up

SME 2: Oh Look, it's Fall!

SME (all): laughs

SME 7: Struck by what?

SME 4: Struck by/or against (one of the dataset dimensions), yeah. It's rather useless until you go to the narrative descriptions.

SME5: these specifically are "Sports related".

SME4: yeah.

SME 8: where is this categorization coming from?

SME 4: you mean "struck by/or against?

SME 8: Well I guess these are causes of injures, right

SME4: It's a CHIRPP, yeah.

SME1: those are the CHIRPP check boxes.

SME8: is it the same as in BC or Trauma Registry? Is it that same…

SME 2: I think it's based mostly on the barometrics from the national collaborative efforts and so they started grouping them like that largely follow that, based on the ICD-949 originally.

SME1: but, it's not ICD.

SME2: no, but it's the same kind of thing.

SME 8: Well it's interesting because…I know we're going out of topic…(looking at the facilitator), I know, I know (laugh)

Facilitator: yeah, yeah (laugh)…we'll have time at lunch,

SMEs: (laugh)

Facilitator: (laugh). You can go off topic then. (laugh)

Pause

SME8: Ok, so we see that we have a lot of 2000 "Falls" in three years causing "Fractures" in the Boys, is that right?

SME 4: so what then, I want to see myself, is the sub causes for the “Fractures” of the “Falls”.

VAE: Uh huhh

SME 4: So the Falls, sub-types. Which I suspect would be “Furniture” for a younger age group and…(laugh)

SME4: and cars for the older ages (laugh)

VAE: ok…the causes…

SME 3: There is bicycle and “Transport” stuff in there too.

SME4: yeap.

SME3: Oh, no no that wouldn’t, cause the “Transport” is in a different category.

VAE: …And then the sub-causes

SME 7: but what if they were falling off a bike?

SME 1: OK, so this is the sub-causes for…oh the Males got lost in there…no, no, different colors…

SME 4: (observing the visualization) So play equipment for the …

SME8: yeap..

SME4: ... So these are all ages, all Females …

SME1: yeap...

VAE (me): that’s right, yeah.

SME: So it would be nice to the age group

VAE: group? uh…huhh

SME 1: So let’s drag the age groups in

VAE: where are my age groups? Up here, there you go!

SME 1: On the top.

VAE: Here.

SME8: now we’re going to see the bars.

SME1: yeah. It’ll go spread that way, right (anticipating how the visualization would look like)

VAE: but I don’t want to divide them, I want to stack them.

SME4: All those “Monkey bars”.

VAE: yeah.

VAE (me): These are the ages down there, down there.

SME8: so basically all 5-9 year old playing outside should basically all wear Hockey equipment (laugh).

SMEs: (laugh)

SME3: injury paradox, right (laugh)

VAE: Let me I want to stack them.

SME4: …the type of fracture.

SME 8: It's pretty impressive how the system laid this out. I mean you can see a lot.

SME: Can you alter that to make those a stacked bars rather than

VAE: yes, Umm. I want to do that…

SME1: Yes…

VAE: Let me take this back.

SME 8: what software makes this?

SME 1: It's called "Tableau".

SME8: Tableau!

SME1: It's U.S. software. According to Brian at SFU, he's all over this stuff. The leading Software…The shortcoming for us., which was noted at the beginning is… They have a really cool mapping function, but they've got no maps of Canada,

SMEs: Uh, huhh.

SME1: … in terms of the polygons that you can then call... you know, the fact that you want to attach data to it.

SME8: right.

SME1: So, we've said: "Look this is a national system that we're building here, you've already got a client to CIHI, make Canadian map polygons, so we could start using this"

Facilitator: So, I think that the Tool Expert has it up ready for you now. (Bringing stakeholders back to the main conversation topic)

SME8: Oh, that's nice.

VAE: So, we have the filter for the type of injury "Fracture" and then it's stacked, we have the age groups…

SME 1: So now you can pick up which of the age group…

SME4: So, what is the purple?

VAE: I guess the purple one? (Hovering the mouse over the visualization to display details on demand information), the purple one are…

SME 1: 10-14 and the reds one are 5-9s.

SME 7: This seems to be the big category, doesn't it? (observing the visualization)

SME 8: mostly the purple one, yeah?

SME 7: purple and red

SME 3: Skis and skateboards and stuff… yeah

SME 8: Skis, yeah, that's it.

VAE: Do you want to take a deeper look at the purple one?

SME 4: It's ok, I mean what it's telling us is that for younger kids it's playground equipment and for older kids, skis, skateboards, ect…

SME 8: right, right

SME1: Uh, huhh.

SME 5: So when you'll have the dashboard on, like when it goes live or whatever, will it allow the user to do what you've just did in terms of the changing it to stacked and that can…ok…

SME 1: that interactivity is there, and that's the beauty of it. So, it doesn't require somebody to do it, once we've giving you the orientation as on how this works, you can sit at your own PC, work on it in the cloud

SME8: Uh, huhh

SME1:…and produce whatever it is according to the questions you have, 'SME8: Uh, huhh…

SME1: …and you can take it away and away you go.

SME 8: How long does it take for someone to go fast aisle with this?

SME 1: with this?

SME 8: yeah.

SME1: It depends how much sort of other software, similar software orientation you have. But we're not thinking that it would take too long.

SME3: PhD! (laugh)

SMEs: (laugh)

SME1: I mean it's a drag and drop, right! So if you have understanding about cross-tabbing data then this should be like, like, where do I drag it from.

SME8: Uh, huhh.

SME 7: so, is there any ability with this, cause there is obvious, there is a lot of data and there is a lot of cross-tabs and you could get hugely wide little tiny bars. Is there any for one or better word a way to describe, say: "look, what I wanted is the top 5 or the top 10 or the top3. I want to sort of get a quick look at where the major things that I then may want to go in. I know that sometimes, if you want to say, I want to look at the top 3 what are the top 4? It's just a tiny bit below…I mean you could deal with that. But is there a way that you could sort of collapsing all out to sort of give you sort of just…

SME 8: It's like a selection…?

SME 7: yeah, but…

SME 1: It's a really good question and we go right back to the opening Dashboard, it's limited to the top 5.

SME 7: OK

SME 1: and that is something that is been asked. So the yearly trends and the causes, that it's only the top leading 5 causes that are represented there…

SME3: 6

SME1: …6…because there is in 'Others". So we kept the "Other". But if you say: "Well I'm interested in "Poisoning and it didn't make a cut, you can go in there and you can then drill down on the "Poisoning".

SME 8: correct

SME 1: you can still pull out all the rest. But for the purposes of that big picture, we hope that this is it. And that top left corner will be a map.

SME 8: that still on the basis of incident released as entry to the system. It's not necessarily the major 5 causes of "Fractures" or anything else, right. You can set it up that way. I mean could you … like this is assuming that this is an incidence is what do you mean by top 5? Yeah.

SME 1: That's… it's incident in those columns that we're using, right?

SME 8: …Top 5 causes of head injuries or top 5 causes of …you know whatever might be also you'd like to follow…

SME 3: this could be the actual injury itself

SME 1: what's that?

SME 3: the actual injury itself

SME 2: they're pretty consistence, I mean across country, they're pretty consistent across countries, like "Falls" is always been the number one injury.

SME 8: I mean what I'm saying is in terms of what the result from "Falls" is. If you're a health administrator and you want to know where the dollars are going in, you want to know how many patients get admitted to ICU with head injuries, that would be what I want to follow as a data…

SME 1: yeah

SME 4: Could you use like the key function, but like choosing 3 or top 5 or whatever

SME 1: yes

SME 8: I guess the question is, can you set up your own open sheets, your own opening page where you have selected your own top 5? You know what I mean…

SME 1: Would it remain that the next time you come back, that's a really good question? I don't know.

VAE (me): yes, it does

SME 1: yes, it does. OK, so we've already asked an answer from Tableau. So yes you can set up your own display according to your own questions and you could track that over times.

Facilitator: so I'm just going to jump in here just for the interest of time. We're going to move on to the next activity.

Group Analytics Session II

Facilitator: For the second group activity, I am going to ask you to be a little more concrete in getting to an answer. So task 2 written also on your sheet, is to work with a company named "*Nutcase*". *Nutcase* produces helmets, quiet cool-looking ones, have you seen them?

Nutcase wants to promote their brand by giving 1000 bicycle helmets. Use the Dashboard to develop a distribution strategy. Explore both concussion and head injuries.

SME 4: (talking to the VAE) OK, so. Give us concussion and head injuries. (Laugh)

SMEs: laugh

SME 4: by age and sex

SME 3: cause

VAE: I'm sorry, How is that again, by cause?

SME 4: I guess, we want transport related injuries because it's bicycle helmets, right?

SME 3: ski and skateboard…

SME 4: helmet, right, good point!

SME 3: sports related, Ski board, skateboard and land skating

SME 4: yeah

SME 8: we’re going to solve it in five minutes here. Laugh

SME 7: so we want to get rid of the cutting, Can we get rid of them?

VAE: yep

SME 3:Can we set by injury causes instead?

VAE: I’m sorry what?

SME 3:Can we set by…

SME 1: Types of injuries?

SME 3: yeah, types of injuries instead of causes.

SME 1: Ok

SME 3: OK

VAE: OK, injury type.

SME 4: concussion

VAE: I’m just going to remove the causes here

SME 7: So do concussions not show up as head injuries?

SME 4: they have separate categories.

SME 5: yeah.

SME 8: Severe injuries, right. So maybe, yeah… So can we get both?

VAE: let me go back to the types of injuries here.

SME 5: yeah, they’re intracranial

SME 4: Intracranial.

SME 5: yeah, so normally concussions are counted with cranial when we do the coding. But what we’ve done is because of the focus on concussion right now, we tried to pull out concussion out and put as intracranial. Put it as a separate category and leave the rest as cranial?

SMEs 8: What are the 3 categories?

SME 5: there is normal head injuries, there is the severe ones and the “ cranial’ and concussion is grouped as part of the “cranial”, but we tried to exclude so it’s on its own. Not as part of the cranial, just so that you can capture the number of concussions.

SME 8: Can we see those three?

SME 1: What are the types of injuries, now?

VAE: types of injuries are in colors here.

SME 5: yeah, “Fractures”, all of those will be in head injuries

SME 1:We want the type of injuries at the bottom. By…

VAE: By?

SME 1: Sex.

VAE: All right

SME 5: Umm..

SME 8: If you exclude everything, it’s not head injury related?

SME 5: yeah, because they have it

VAE: we can, but you have to go one by one.

SME 4: the body part yeah,

SME 5: the body part might give you the head injuries

VAE: Uh , huhh… body parts, then let’s get the body part instead of the causes

SME 4: and then just keep “Head”, exclude all others.

SME 1: (smile)

VAE: (short laugh), all right

SME 1: there you go!

{

VAE: So I have…this one, just want to keep the head

SME 4: that’s right, yeah

SME 4: yeah

SME 8: very good! So you can see concussions, others…that others is concerning

SMEs: laugh

SME 4: so “Open Wound”, we can get rid off…because helmets aren’t really…

SME 3: they might.

SME 2: yes, they do!

SME 7: yeah

SME 5: sometimes

SME 3: something comes of it too

SME 4: Well yeah… But helmets kind of don’t prevent cuts

SME 3: well in skiing

SME 2: skiing!

SME 8: We're really interested in head/brain injuries, right. I assume that "Open wound" being excluded, not just because of Open Wound as a possible brain injury. That wouldn't be in that category.

SME 1: it's hard to know how it is coded.

SME 8: yeah, but it is interesting.

SME 1: You know, you'd take the sheet that ER had filled down and that's what we're working with, right!

SME 8: that's right.

SME 4: but they have these several causes.

SME: yeah

Facilitator: Yeah, this is the top one of three potential causes that could have been listed data, it's the…

SME 3: the main ones

SME 4: yeah

SME 5: yeah the main ones

Facilitator: yeah

SME 1: the most serious types of injuries

SME: yeah

SME 8: sure, just so that I know the methodology for filling out that format (ER). Is it generally, they were supposed to put the most serious one first?

SME 3: well yeah, typically that's what they expect

SME 1: supposedly, that's right

SME 3: yeah

SME 4: you can get rid of "Eye Injuries". (Addressing the comments to the TE)

SME 1: get rid of "Eye Injuries"

SME 2: Really?

SMEs: laugh

(Many SMEs interacting to the comment presented by SME 3)

SME 7: Hockey helmets counts for the big part of Eye injuries?

SME 1: yeah, Hockey helmets

SME 8: We can see what we're going here

VAE: is there any subdivision that you would like to?

SME 4: Then, would you like activities, when injured, then? To see…

SME 8: yes

SME 5: mortality?

SME 4: yeah

SME 8: Can you do that in a bar form, or is it (addressing the comment to the VAE)

VAE: that's the

SME 8: Can you do that? That would be nice

VAE: A stacked bar? Yes.

SME 1: yeah.., we wanted stacked, yeah

SME 4: Hummm….yeah…useful

SME 8: Here you go!

SME 1: OK!

VAE: and the green color "Fall"! (laugh)

SME 2: yeah (laugh)

SME 3: but what is the legal intervention

SME 8: that's "Open wound". What do you think is there in the "Other" category?

SME: really?

SME 7: It's a big category

SME 3: oh yeah

SME 7: so if you work with intracranial injuries, if it wasn't a "Concussion", and it wasn't an "Open wound", what would that leave? What is it? A superficial injury?

SME 3: but it's the ones that are unlisted, isn't it, unspecified?

SME 5: yeah, others

SME : yeah other categories

SME 7: Ah…Oh, OK!

SME4: It's unspecified

SME 3: yeah, unspecified

SME 4: yeah, if they leave that category blank, then it will go into that, the “unspecified category”.

SME 8: I’m not sure…

SME 3: if you don’t record everything, they go into that category (addressing SME 8)

SME 4: (big laugh) a little lesson

SME 8: yeah, but what deal with is head injury, but what type head injury.

SME 1: yeah, all they would list is head injury… with no further details, so we all know that..

SME 8: I see, so no brain injuries

SME 1: yeap

SME 8: I see

SME 4: And they can’t read your writing on the chart, all goes into that category.

SME 8: They’ll make sure that nothing is nothing is traceable.

SMEs: laugh

SME 7: so in other words, it doesn’t sound like we can do a whole lot with that column

SME 4: what, the unspecified?

SME 7: yeah

SME 1: yeah

SME 2: Well, I think we could

SME 5: we know it’s a head injury

SME 2: we know it’s a head injury, right.

SME: It’s affecting

SME 4: and they’re mostly caused by falls

SME2: not necessarily

SME 2: it’s not a superficial injury

SME 8: I think probably, we know it’s not all these other things. Right? We know it’s not scalp laceration or fracture. What else is there? It’s a brain…, right?

SME 1: right

SME 3: should we go to…

SME 8: What “Unspecified” injuries could that possibly be? I’d be thinking that a lot of that is actually really severe head injuries. Most people mistake brain injury for head injury, right!

SME 7: Oh Do they?

SME 8: yeah, they do.

SME 1: So what I would want to do, though is to go down the causes and exclude the ones

VAE: Uhh, huhhh

SME 1: the ones that are unrelated to the protection of helmet can get, right

SME 4: uh, huhh

SME 1: So, let “Cutting”… is that?

SME 4: Well, no. I fear if you want open wounds, I think that

VAE: OK

SME 3: “Fire Flame”

SME 4: yeah, get rid of “Fire and Flame”

SME 1: yeah, get rid of “Fire and Flame”.

SME 4: Firearms are going to…

SME 1: I’m sorry, helmets will not going to serve you, I don’t think so

SMEs: laughs

SME 8: so it’s not changing anything, look at the bar, the purple one.

SME 1: well

SME 8: That concerns me. I don’t understand what category that is.

SME 5: Fall? No

SME 1: Foreign body

SME 7: really yeah.

SME 1: What’s “foreign body”?

SME 4: “Foreign body” is like when something in …

SME 1: most of it, you got something in your eye, right?

SME 4: yeah. So we can get rid of those.

SME 8: that’s a “Struck by/against”. Looks like “Legal intervention”

SME 1: I don’t think Homicide or assault, you know.

SME 3: head helmets

SME 4: If you’re planning on getting arrested, we’ll give you a helmet

SMEs: laughs

SME 3: yeah, totally

SME 1: so you’ll get rid of those.

SME 8: “Struck by/against”, OK

VAE: OK

SME 1: exclude the..

SME 8: so “Falling”

VAE: “Legal interventions”?

SME 1: yeah

VAE: “unintentional”?

SME 4: Keep that one for now

SME 3: Keep that one

SME 1: yep, keep that one

SME 1: “Overexertion”?

SME 4: You can get rid of that one, I think

SME 1: yeah

SME 4: Keep that one.

VAE: Yeah

SME 1: “Suffocation” and “Chocking”? There shouldn’t be any of those here.

VAE: Should I exclude this one?

SME 1: yeah

SME 4: yeah

SME 3: Suicide

SME 4: Exclude that…Keep that (choosing from ta list of injury causes on the Tableau Screen)

SME 1:Keep that

SME 3: It's interesting…that categories too.

SME 4: well yeah,

SME 1: The "Poisonous" can go

SME 7: you're probably talking about very small… to begin with

SME 5: yeah

SME 4: yeah

SME 2: yeah.

SME 4: yeah, it will be very small number

SME 3: the teens are generally very

SME 5: it has

SME 4: the 17 years and above go to VGH, so it's only 16 and under that come here, yeah.

SME 1: so there is the sort of…

SME 8: Can we see what "Struck by/against"? Whether it is bicycle or what? Can you tell us more about that?

SME: well, the transport related would include the bicycles.

SME 3: yeah

SME 2: yeah

VAE: the sub-cause?

SME 1: "Struck by/against" is typically sports and Rec related stuff…the ball hit me, the bat hit me, … the hockey…

SME 5: sub-cause?

VAE: specifically for the "Struck by/against"?

SME 8: and the "Falls"

SME 5: …and the "Falls"

VAE: and the "Falls"?

SME 5: Can you keep both?

VAE: yes, I can…there we go, and then I'm going to use the sub-causes

SME 1: So, it is nice if you can keep more than one, right?

SME 3: Is there a limit to how many you can have?

SME 1: No, any of the numbers, you can keep

VAE: now I want to use the sub-causes. Let me pull…So we want to explore “Falls” and “Struck by/against”, they’re going to be shown in here. And then, I’m going to stack the sub-causes here

SME 1: yep

SME 8: yep, that’s good

VAE: so let me open this, now we have…

SME 3: It would be nice if you could select the top 5 of these for each category, something like that?

SME7: Uh, huhh

VAE: you can do that

SME 7: Uh, huhhh

TE (me): than you have to kind pick that

SME 1: yeah, now you sort of... because the top 5 varies across these, you have to manipulate this a little by hand, just to say : “I want to keep, that, that and that” and the rest can go”.

SME 3: Oh, OK.

VAE (me): Group the rest

VAE: but there is …I’m sorry

SME 3: But there is no way to say, concussion top 5…for the screen just to do it. Top 5 injuries, top 5 ...

SME 1: you could do it, I mean

SME 3: without doing it by hand..

SME 1: yeah, you can focus on the concussion column by itself… then you can do it.

SME: Ah, OK

SME 1: because as soon as you say top 5, if you select 5 in any of these columns, it is going to get the plate whole, because that’s the nature of the data that we’re looking at.

SME 3: OK

SME 2: I think that makes sense because that’s a comparison

SME 1: yep

SME 7: so what in that if you go to “Open wound” and to “Unspecified”, the big bars? What is in those?

(pause, as the VAE hover the mouse over the bar on the screen to get Details on the Demand)

SME 7: “Falls from Beds”, OK

VAE: “Falls”

SME 4: what’s the grey one?

VAE: Other

SME4: “Unspecified”

SMEs: laughs

SME 1: isn’t it true data. The biggest category is “ Other”?

VAE: and then for the “Struck by/against”

SME 3: Give helmets for kids in Bed

SME 4: that is indeed a new marketing strategies

SME 3: I see a little ones

SME 4: the follow me ones…

SME 1: Crib crash helmets

SME 8: yeah, I mean it’s a lot of creation, it’s hard to, the problem is that... the same struggle as we have. We’re looking for actions to come out of our data, but our data doesn’t go in with that intent. It goes in as a descriptive function. But really, there are certain actionable things that you could really do, you almost got to put that in the beginning, to get that by the end

SME 3: We want helmets; can we look at what uses helmets what for? What if we isolate sports, bicycle?

SME 8: we’re trying to, but we don’t know what “Struck by/against” means and we don’t know what …

SME 3: No, but what if we search by that instead of by the causes? Can we take that out and …

SME 4: like falling from skateboards, something like that

SME 3: yeah, switch it, like. So we’re actually looking by the things that we know there is helmets for.

SME 7: Oh, and that stuff is in there, isn’t it?

SME 3: I don’t know

SME 1: Well, you can go down then and remove the sub-causes, so you can sort of do the same exercise we just did, but with say, is it reasonable with the sub-causes

SME 8: yeah

SME 1: would be prevented by helmet?

SME 3: yeah.

SME 1: if not, let's get rid of that

SME 3: yeah.

VAE: Then, I'm going to go back

SME 8: if you can see that the ones that are involving skates, what are the numbers in there? Can we see those 3 red bars?

VAE: yes

SME 8: just got to hover over the three red bars

VAE: the red ones

SME 8: in the graph, and what numbers are in here? How many?

VAE: yeah

SME 8: 75…so that's a 125. And the other one is probably 60 or something

VAE: Do you want me to quickly to keep only that one

SMEs: laughs

SME 8: why don't give helmets to those people!

SME 3: Why don't you go through them and pick the ones that are not applicable.

SME 1: So that's all the red bars that you've asked for, you know

SME 8: so any one who gets a skates, gets a helmet, how is that?

SME 3: that's tedious too! but we don't have bikes, we don't have..

SME 4: bikes with transports

SME 3: Oh, right.

SME 8: We only have how many helmets? A 1000, yeah

SMEs: laughs

SME 8: give them 2

SME: that would cover all

SME 4: If you come in with a head injury, you get a helmet.

SMEs: laughs

SME 7: that's pretty self-inflicted

SME 1: that's right.

SME 8: I think the process is right, you take out the causes that you couldn't do that, so what is left and you just pick

VAE: I'm just going to go back to the big picture

SME 8: Try to do that? Does it take a minute or 2?

SME: Uh, huhhh.

SME 8: let's take all the sub-causes lest there

SME 1: so if we can go through the sub-causes

VAE: Uh, huhh

SME 3: there

SME 1: "Call a crash".. no

SME 8: take that out

SME 1: (looking at the screen and identifying what to keep and what to exclude) No…Exclude… "Fall from high level"

SME 8: I think leave that

SME 1: Leave that

VAE: just to . I'm sorry before doing that. As I highlight them you can think at…just want to reduce the size of this window, I'm just going to

SME 8: "Fall from high level" that might be "Suicide", I don't know

SME 4: skateboarding in terms of you know when they skateboard in front of the building and stuff

SME 3: or biking?

SME 2: yeah

SME 1: I don't think you'll find that

SME 4: they won't be there (in the database)

SME 1: no, I think those are the balcony falls and things like that

SME 8: I think with the time being, we can leave that and we can edit this after

VAE: OK

SME 1: OK

SME 8: Can we take this…

SME 1: This one, those Crip crap helmets are important

SMEs: jokes and laughs

SME 8: “Ice and snow” does that mean skiing?

SME 4: No

SME 8: or climbing

SME 7: what “Ice and Snow”?

SME 8: you don’t mean probably slipping

SME 2: skiing and skateboard?

SME 3: that could be tobogganing?

SME 1: would be the same case

VAE: yeah

SME 1: remember that they fill in every piece of information on every case, right. So “Ice and Snow” is a sub-cause

SME: yeah

SME 3: What about tobogganing?

SME 1: Could relate to a (pause)

SME 4: ski

SME 1: a skiing incidence

VAE: next one

SME 4: I think we excluded this one, you don’t want them to wear helmet. We’ve told them not to wear helmet on playground equipment, if they don’t want to strangle themselves.

SME 1: exclude that

SME 2: that we want

SME 8: yeah, that one

SME 4: yeah

SME 1: yeah

SME 4: ladders, uhhh!

SME 2: really?

SME 8: yeah, up there

SME 7: yeah,

(All together triggered conversations)

SME 4: exclude

SME 8: yep, a helmet is not going to help

VAE: Ummm

SME 4: Although, could that be skateboard as well…Uhh…For the sake of this exercise let's just move on, that's fine

SME 8: Ok

SME 4: we can exclude those

VAE: Ummm, oops. "Falls"

SME 3: Or is that sports related?

SME 4: that could be… could be a lot of

SME 1: OK

VAE: next one

SME 2: get rid of that one

SMEs: laughs

SME 4: "Hit by another person" could be sports as well.

SME 3: scratching, hitting and biting…

SMEs: laughs.

SME 3: in Rugby

SME 4: very interesting

SME 2: How specific the real world is?

SME 4: yeah

SME 8: you know what it is, you just … "Stuck by" that's a sports, contact sports, intentional. You can figure out what the intent was in that or not?

SME 4: yep

SME 1: yes, you can

SME 3: let's just leave that one, that could be

SME 8: yeah, that's could be a big category…just leave it there

SME 1: yeah, cause that's all sport related…"struck by a thrown" object

SME 4: I don’t think so, if a ball hits you, would that be “a falling object”?

SME 5: It’s “struck by/against” by sports equipment.

SME 4: Ah. Oh, OK. So that’s a separate category.

SME 1: you can exclude that last one I think.

SME 5: “Falling objects” would be like a rock, only..

SME 3: right

SME 8: sounds good, it’s a better picture

SME 1: only a small numbers of child…

SME 4: struck by another person.

VAE: so we’re looking for just “Falls” and “Struck by/against” and then the sub-cause are the colors here that we have just filtered

SME 3: can we take out the “Unspecified”? cause

SME 2: I guess it just won’t make our decision change

SME 8: yeah, that’s true.

VAE: so, I’m just going to take this out by excluding it

SME 8: what is the light blue (addressing the question to the VAE)

VAE: this light blue…or this light blue? Which one? (Pointing at the screen)

SME 8: that one (pointing at the screen)

SME 1: “Fall from a high level”

SME 4: or from a tree

SME 8: uhh, huhh. We’re looking at sort of the intracranial injury ones, they are not many of them

SME 3: Can you call your own list? So that you could say, Ok Let’s say let me make my own filter and it’s going to be “Sports”

SME 1: Uhh, huhh

SME 3: like I can make this and it stays in my own. When I log in, I have my own creation.

SME 1: yep, yeah.

SME 3: OK

VAE: those are usually these filters that you build over here…and they stay

SME 3: OK

VAE (me): and also if you want to share your own creation, you can…

SME 1: As we said, if you have a group at VGH and you decide these are the indicators that you want to follow, then you can set it up.

SME 3: Ok

VAE: I'm just going to go back to the previous

SME: Is it worth just keeping the intracranial injuries for a second, you know just to see

SME 8: yeah, I think so

VAE: Uh, huhh.

SME 4: just have it stand out, to see what is going on here.

SME 8: you know that's the tip of an iceberg, right. So, it's "Falls". Again, there are three things that lead to serious injuries

SME 4: "Sports", "Out through building and structure" and "High level"

SME 1: Uh, huhh

SME 7: So is that the balcony step you think? (Addressing the question to SME 1)

SME 1: I think that "Out through structures" are windows and balconies, yeah. And of course we see a spike in that during the springtime.

SME 4: The "Falls from windows" is a separate categories?

SME 3: but we don't have bikes in here

SME 5: yeah, but it is separate. It's taking care of, it's in transport related.

SME 1: no, it's not in here.

SME 3: yeah, it isn't in here, cause we're missing a lot for this one.

SME 8: I think my conclusion is, I would go to a skateboard store and offer a helmet with each skateboard and that would probably get the red group, right! Is that how it would work?

SME 1: Uh, huhh. Ski, skates, and…yeah

SME 8: I'm not sure what the high level means and how you would actually target these to get these helmets to as a result.

SME 3: Can you sub-categorize that into…

SME 4: the red ones?

SME 3:… ski, skate, skateboarding?

SME 5: the "Falls from a high level", those would be Falls from a cliff or falls from a balcony, or falls from a windows

SME 8: I assume some of them are mountain-climbers or rock-climbing or something like this sports related

SME 1: kids out of trees, are high level, yeah, those are high level, yeap

SME 8: yeah, that's a high level. Yep, fair enough, yeah. From a procedural point of view, possibly, I wouldn't know how to target that group.

SME 2: not with a helmet

SME 4: no, you would want them to wear helmets

SME 8: I could definitely target the group that are skateboarding down town

SME 1: What did you want to know?

SME 3: Can you actually sub-categorize the "Falls" and then show us skates, skis, skateboarding? Like can you sub-categorize that category, so we could see, is that a sports or summer sports, skateboards or ice skates?

VAE: I think the last division is sub-causes. Is there any further division?

SME 5: It can be done, It can be done ,it's just not showing up here.

SME 1: so how can we do it? We just keep the "Falls" section of that

SME 5: and then you would need, Umm. It's not showing up as a dimension. But there is a sport related ones.

SME 3: I see

SME 5: There is a sport activity that you could bring in, that will break it down by Hockey, by soccer, by…

TE (me): OK

SME 1: I see

SME 5: all the different types of sports

SME 3: cause there is for the sake of this, I would also want bicycles to go in here.

SME 5: yep

SME 3: but we've excluded it, but I don't know if there is a way to break that down.

SME 4: in a vehicle

SME 5: no. It can be done. yeah.

SME 1: So what we need to built that..

SME 2: I think it would be under the transport sub-cause, I would surprise if it wouldn't.

SME 4: add transport related

SME 5: So like if you go back to the causes, the Transport and if you go to bring in sub-causes that will bring in all the bicycles.

VAE: uhh, OK. Let me take the cause. We had a filter called, it was just “Falls”. I’m just going to bring in “Transport”

SME 1: Uh, huhh

SME 4: yeap.

SMEs: Uh, huhh.

SME 5: I don’t know if you want to show the intracranial, if you bring in all the heads

VAE: “Transport”

SME 1: yeah

SME 3: yep

VAE: just those too, right?

SME 2: yeah. So, you did have, yeah.

SME 3: yeah.

SME 4: so you get rid of Motor Vehicle Occupants, like all of those, except there is a bike category.

SME 5: yep.

VAE: “Motor Vehicle”

SME 4: Or do you want off road vehicle. Will those people would be offered ATV helmets

SME 3: laugh. It depends on what…

SME 5: so these will be the..

SME 1: Pedal cycle, that where they belong

SME 7: right

SME 3: What is the light blue?

SME 1: The light blue, is at the bottom?

SME 2: Pedestrians

SME 3: OK. So

SME 1: So I don’t think we want to put helmet on the pedestrians

SME 4: but we want it for off road and the bicycles, right?

SME 1: right

VAE: Uhh, so, I'm going to filter out this one.

SME 1: Uh, huhh.

VAE: the Pedestrians, you said.

SME 1: Uh, huhh

SME 3: yeah

SME 4: yeah, exclude

VAE: exclude…and

SME 4:Oh, we want… what is that one

SME 5: what about the motorcycles?

SME 1:well, they're required to

SME 7: yeah

SME 3: yeah, and that's enforced

SME 2: and the top one, yeah, the occupants.

SME 1: yeah, we don't want

SME 3: Off road, they are not required to wear helmets, or not enforced?

SME 1:it's hard to enforce, right? They're supposed to wear a helmet on quad machine

SME 3: but not

SME 1: right

SME 3: cause you don't have to on a snowmobile?

SME 1: right

SME 7: but see then, I mean, out stuff down to your question. So you're looking at concussions and head injuries and so, if you see there is a lot of skateboards, I mean one of the palsy question you need to ask so: "So, are you more likely to get an uptake on a helmets with bicycles or skateboard? Because if you have a culture that says, we don't wear helmets. you're going to have a program that give away a thousand helmets that don't get used

SME 1: right

SME 7: versus looking at, is it going to be more of an uptake people are actually using those things?

SME 1: yeah, yeah. And that's when you sort of enter that realm of what johna phelona called the "sausage making"- which the policymaking, right! It's messy and dependent on a whole bunch of different sort of…

SME 3:I think if there is more data, I would be nice too, to sub-categorize into postal codes.

SME 1: yeah

SME 3: you know, we could say: “we’re going to target Prince George with a 1000 helmets” and then run a campaign, and the money that you’re getting the most of…

SME 1: and we can do that, there is postal codes there, so you could ..

SME 3: Oh yeah,

SME 1: you can do that, cross with postal codes, you could do that.

SME 3: Oh, OK, yes!

SME 7: So you could actually see that in cross Greater Vancouver?

SME 1: yeah, yeah, which community should we target?

SME 7: Uhh, huhh

SME 1: yeah.

Facilitator: So for the sake of time, are you able to come to a … least tentative conclusion?

SME 8: I think so

Facilitator: Uhh, huhh

SME 8: what that green category “Struck by/against” again, next to intracranial?

SME 2: and this is only intracranial injuries, right!

SME 3: Pedal Cycling.

SME 4: Pedal cycling

VAE: yeah, that’s right

SME 8: yeah, So we decided that you know, to prevent the worst, what we think that other injuries we would target different kinds of skates and the group that are cycling, is that correct?

SME 3: yep, If you want wheel

SME 8: yeah, we would have to think about what you said, what’s socially going to work? What with the policy and what the cultural around? That is going to be the story and an issue. But that’s would be likely to target, I think.

SME 1: I think that’s right. The protective nature of the helmet, where advocating for kids on small vehicles and cycles, right. So, Now, all right having identified the target - where are they? and how do you market it and the policy and get it all in place?

SME 3: and if you give them like to a bike shop in that postal code you can find the people that are selling those things

SME 1: Uh, huhh.

SME 3: the people that are selling them.. like all over the place, community center

SME 1: Uh, huhh.

SME 2: get the BC ambulance information…

VAE: concussion

SME 1: so there are the concussion ones as well,

VAE: As you mentioned before…

SME 8: So I mean this is interesting, in terms of the value of the CHIRPP data. And to me, it's parallel is direct with our trauma registry data, yeah. It's a misery database that we tried to do a lot of research with and very little policymaking based on, unfortunately. And part of that is that we don't have a culture of using that, it's not data type going in with that purpose, right

SME 1: Uhh, huhh.

SME 8: So this kind of exercise would be interesting to go back to the CHIRPP data and say maybe there are other data fields that would make this more meaningful

SME: Uhh, huhh

SME 8: just the whole reason of getting the database registry

SME 3: or even getting burden of injury data putting into this

SME 7: Uhh, huhh…that would be really useful too

SME 8: really exactly. Really I just got through an exercise for my busy grant to look at the data registry report. I've tried to analyze…sorry 2 seconds, if it's OK (addressing the talk to the facilitator to allow extra minutes for an off topic conversation)

Facilitator: Oh, no no. We're good now, I'm confortable

SME 8: If I wanted to analyze, I've asked around the provinces, what are the trauma system reports that come out? And you know, most of our online in a way or another, and I found pretty comprehensive regional trauma system reports for BC, Alberta, Ontario, Quebec doesn't roll and they're not available, the rest, all of them are registry reports. It really link back to the major lead centers.

SME 1: Uhh, huhh

SME 8: really that's the surrogate for the trauma system report for Ontario is really the "x?" hospital and associated registry data that gets spread out. And if you look at the data elements across the different reports, they're all the same…pretty much. And none of them serve any purpose other than describe or experience how many patients you get and how many…None these were actually reused to drive such a change. They are simply descriptive statistics. What goes on for Alberta and they're all the same. None of serve any purpose to drive. I don't believe.

SME 4: because of what they are reporting or because of what?

SME 8: number one, is because they become from a different place, it's all data. Clean data. Lots of clean data. Not very useful clean data though, right in terms of…If you look at a system report, this is the report that comes of the system at the end of all of it., it's not

SME: interesting

SME 8: We haven't made that conceptual link that would do any more with this and describe our experience with patients

SME 2: CIHI does it sometimes. Like they did the Sports and Recreation reports, which I think had the potential to go somewhere, but didn't.

SME 1: Uhh, huhh

SME 8: sure, I don't know if one of the registries or not. But we

SME 2: minimal data sets, not comprehensive data.

SME 8: That's right. And interestingly CIHI has decided to actually what they're going to do and they actually. CIHI, they decided what they're going to do. I'm not sure if you know that, but we have the national trauma registry is basically a feed from all regional trauma data or provincial databases. They would collate at national datasets that will link it back to us, so our data is registries in their original database. By a week ago, they told us they're not going to fund that anymore.

SME 2: Oh, no

SME 1: CIHI, says no

SME 4: that's terrible

SME 8: the national trauma is now no longer.

SME 4: Ahh

SME 1: no one is going to support it.

SME 8: and I think for this reason, well CIHI. I think it's interesting that what we're going to do is we're going to have our own plan B, which is to have our own dataset. You know, they didn't see a value in it.

SME 4: Jee!

SME 8: So, I think that that's interesting.

SME 3: yeah

SME 2: Oh God. interesting, just getting decimated at the policy levels all the time.

SME 8: yeah, that's the problem. We've spent 15 years trying to create it and now it's been unfunded, so.

SME 4: As of when?

SME 8: A week ago.

SME 4: But is it tiny affecting you?

SME 8: I don't know, I just heard this from our data people.

SME: Waw!

SME 8: it goes to the relevance of the data, it really does. it's hard to find huge data repository that people do research out of, even they're not very good researchers a lot the time, Umm

SME 1: And I've always wanted to ask, your point of we're using administrative datasets as we're trying to solve some problems, and then my immediately go. "But, OK, what was the point of the administrators of the system setting up their administrative dataset?

SME 8: excellent question

SME 1: if it was not to improve health or prevent injuries or like…the system exists to do that.

SME 7: but lots of time with administrative datasets, it's a matter of actually tracking, all of this is expenditure tracking

SME 1: yeah.

SME 7: where does the stuff go?

SME 1: yeah.

SME 7: yeah, I think, yeah. The other problem we're getting into is that is there is lots of problem about administrative data. But, from a policy standpoint, we say go grab the administrative data and it's going to tell us what we need to do. And the reality is that it's not going to tell you, it's going to highlights the things that you want to look at

SME 1: yeah

SME 7: which a completely different issue. So, we see that the major thing here is head injuries and 8 and 4 years old and it's about "Falls". So that at least really does start narrowing it down but it still say: "So, what are you going to do about that?" I mean that's another question that you then need to qualitatively look at. So "what is it about these "Falls"? "Where do they happen?" "Why are they happening", "what are the circumstances?", and "what are the proving interventions?". But we expect that because there is data there that the data is going to tell us the answer.

SME 1: and I think you're right on. Because, I mean the point of this tool is to get some refinement and understanding about where to target the resources.

SME 7: But what are they?

SME 1: The next piece is well, is then well, if that's the target, you've dealt with this issue, and that's playing the evidence, right. From else where

SME 2: Or developing your own interventions

SME 1: Or developing your own, but firstly looking and say: "Who's dealt with this group before at some success, how can we apply it here. Yeah.

SME 7: cause I know the child health mobility that was always my push back. People get really excited once we've got this, we're going to know what to do. And I would say, not at all. It's going to tell you what the issues are, if they're tracking it down, but you're going to have to solve it. You're going to decide, is that a good thing? Is that a bad thing? What do we want to do about it?

SME 1: exactly, yeah, yeah.

SME 2: and I think you sort of, add to SME 4 point, maybe we want all this types of injuries, we don't want playground head injuries. But maybe we're ok with a couple of kids breaking their arms trying to climb on playgrounds.

SME 1: yep.

SME 4: uh, huhh

SME 2: that's what we say I think, so we kind of …

SME 7: right, so if what the data says is: "We've got this huge number of playground injuries". That's all it's telling you. It's not telling you if that's a good thing or that's a bad thing.

SME 3: exactly

SME 7: That's the policy piece

SME 3: where dollar spent… means compared to mountain bike injuries.

SME 7: yeah, so sometimes we have unrealistic expectations about what we want out of the data

SME 1: Yeah, oh, absolutely. Interestingly enough yesterday on the playground data, when we were downloading the iDOT for the CHIRPP data to the PHAC people. Well they said: "What about Falls from monkey bars?", let's look at that. We looked at, we looked at… You know who's Falling off the monkey bars?

SME 8: parents??

SME 1: girls

SME 8: Oh, really!

SME 5: Girls!

SME 1: everybody went like watch those boys.

SME 2: It's always girls

SME 1: It’s always girls…across all ages

SME 3: The girls hang up…We used to sit on top of the monkey bars the entire lunch…

SMEs: laughs

SME 2: I mean, but to think again about the opportunity caused by the girls not developing upper body strength, they do more stuff that develop their upper body strength

SME 1: Uh, huhh.

SME 3: yeah, we can’t get rid of the monkey bars.

SME 2: so we need the monkey bars for

SME 1: Anyway

Facilitator: So the next part of the day lunch combined with the paired sessions. So, we hope each and every one of you engages in a paired session with Samar and complete the questionnaire and get the chance to eat. So before you leave today, please do these three things. For the paired sessions, we do want to do them one at a time, so those of you who are already working on site, maybe don’t mind waiting until later today, cause you can go to work and come back. So, maybe we’ll start with SMEs who work offsite. So let’s start the paired sessions.

Appendix K:
Injury Indicators Meeting

This meeting took place in Toronto, October 2010 present the mock-up of the dashboard and present vision, purpose, and role of the dashboard.

October 6	**The Old Mill Inn, Garden Room**	**21 Old Mill Road, Toronto**
Time	**Activity**	**Speakers**
1:30 – 2:00	Introductions and Overview of "Travelling Road Show"	Ian & Alison
2:00 – 2:30	History of the Team and Injury Indicators	Alison
2:30 – 3:00	Presentation of Measuring Injury Matters – Volumes 1 and 2 - Discussion of how indicators drive decision making and action	Ian
3:00 – 3:15	Break	
3:15 – 3:45	Dashboard presentation with mock-up	Ian
3:45 – 4:30	Vision for the Dashboard – Discussion Purpose and Role of the Dashboard Utility of the indicator information Users and Accessibility	All
4:30 – 5:00	Data for illuminating the Dashboard: the plan going forward How CIHI data could be included How Statistics Canada data could be included Others	Ian
October 7	**The Old Mill Inn, Garden Room**	**21 Old Mill Road, Toronto**
Time	*Activity*	*Speakers*
9:00 – 10:00	Design of the Dashboard – Discussion Visual appeal Placement of 'more important' information Grouping of indicators 'Best way' to present data Colour schemes	All
10:00 – 12:00	Designing our own Dashboard Ideas flipchart paper markers and sticky notes	Small Groups
12:00 – 1:15	Lunch	
1:15 – 2:15	Report Back	All
2:15 – 3:30	Building the Plan to Move Forward What next? Input and Feedback from who else? Accessing the Data	All

3:30 – 4:00	Summary and Close	Ian and Alison

Appendix L:
Dashboard: Research Results Summary

This report presents summary of the research results pertaining to the development and promotion of online Child and Youth Injury Dashboard.

SUMMARY OF RESEARCH RESULTS

Background: Each year in Canada, 25,500 children are hospitalized—and nearly 400 die—because of unintentional injury [1]. Unintentional injury is the leading cause of hospitalization among those aged 10-14 years; the 2nd leading cause for ages 5-9 and 15-19 years; and the 4th leading cause for 1-4 year olds [2]. It accounts for more deaths to Canadian children and youth than does any other cause [3]. The economic cost of these injuries is estimated to be $5.1B per year [4]. Canada still has a significant burden of injury among children and youth, despite initiatives such as bike helmet and booster seat legislation that have been successful in addressing injury among these age groups [1, 5].

Directly addressing a recommendation that Canada should choose a set of indicators comparable across institutions and organizations to monitor injury [6], the *Child and Youth Injury Indicators Team* was established in 2006. The Team has defined and specified a set of 34 indicators specific to Canadian children and youth with regard to injury outcomes, risk factors and policies [7, 8, 9], under CIHR funding reference numbers INJ-79996 and PCY – 86890. This work has been lead by:

Drs. Pike, Macpherson, and Brussoni with Drs. Babul, Barr, Desapriya, Hameed, Howard, Macarthur, Raina, Schuurman, Swaine, Warda, and Yanchar

Decision Makers/End-user stakeholders: Ms. Fuselli (Safe Kids Canada), Dr. Groff (SMARTRISK), Mr. Herman (Min of Healthy Living and Sport), Dr. Simons (Vancouver Coastal Health), and Mr. Young (Nova Scotia Dept of Health Promotion and Protection)

Partners and Collaborators: Public Health Agency of Canada, Child Health BC, BC Child and Youth Health Research Network, Trauma Association of Canada, European Child Safety Alliance, and Health Canada - First Nations and Inuit Health Branch

Research Results: A peer-reviewed publication (in press) and a lay-language summary *Measuring Injury Matters: Injury Indicators for Children and Youth in Canada – Vols. 1& 2* form the core knowledge and information to be disseminated at the first of the two meetings as well as at selected conferences [8, 9]. These products describe the creation of the 34 indicators and make the Indicator Specification Tables available to the injury prevention community.

The **significant contribution** of these indicators is to make the measurement of child and youth injury comparable across Canada by defining and specifying indicators for consistent measurement and standardized use. Prior to this work there has been no common set of validated injury indicators across Canada. Indicator development was informed by work from Australia, New Zealand, the US and Europe, and they are aligned with the Australian National Health Priority Area Technical Review.

In the absence of a Gold Standard for injury indicators, determining the **validity** of these indicators becomes a challenge. The development has been an iterative process informed by other jurisdictions and national injury prevention experts. A modified Delphi process was used to create the 34 indicators, ranked by experts as likely to be *useful in child and youth injury prevention* and also *likely to prompt action to reduce injuries*. Future monitoring of injury trends and patterns will ultimately be evaluated in terms of the resulting decisions and actions, and their contribution towards reducing child and youth injury. **Reliability** will be demonstrated by using the same indicators across all phases of this process, using currently accepted sources of data and data coding systems (e.g. ICD codes).

The Canadian Child and Youth Injury Indicators are relevant and **generalizable** to Canadian child and youth injury prevention researchers, practitioners and end-users/stakeholders. The next step in the knowledge translation plan is to make the information related to the development and utilization of the indicators accessible to the injury prevention community via an online dashboard.

Potential Impact on Health:

Greater awareness and understanding of trends and patterns of child and youth injury in Canada

Improved child and youth injury prevention activity in Canada – improved decision making, timely and targeted – leading to reduced child and youth injury burden

Capacity building among researchers and stakeholders in terms of new resources and tools

PROPOSED KT ACTIVITIES

Funds are requested to undertake an integrated, comprehensive knowledge translation strategy for the dissemination of two products and the design and development of a dissemination tool – The Canadian Child and Youth Injury Dashboard (**Table 1**). Two dissemination and planning meetings of the *Canadian Injury Indicators Team* are to be held in Ottawa to allow for direct participation of an Ottawa-based dashboard software company – Klipfolio – in its role of dashboard development, as well as representatives from the Canadian Association of Paediatric Health Centres (CAPHC) and the Child Welfare League of Canada.

Conference workshops are anticipated to be held at: BC Injury Prevention Conference (November, 2010, Vancouver); 2010 Ontario Injury Prevention Conference (TBA); 2010 Alberta Injury Prevention Conference (TBA); and Atlantic Collaborative on Injury Prevention Conference (June 2010, St. John's).

Description of Meetings & Workshops: The goal of this strategy is to continue CIHR and BC Child and Youth Health Research Network (CYHRNet) funded injury indicators projects through the dissemination of completed products and the development and design of a dissemination tool – a web-based, interactive graphical injury indicators dashboard. The aims are to:

Distribute dissemination products presenting the final 34 child and youth injury indicators and their role in injury prevention decisions and activities

Solicit input on what is meaningful to injury prevention practitioners and stakeholders with regards to the design and functionality – Look and Feel – of the Dashboard.

The **specific objectives** of these meetings and workshops are:

To promote further understanding and use of the child and youth injury indicators through the dissemination of the CIHR *Canadian Injury Indicators Team* results.

To inform the development and design of the *Canadian Child and Youth Injury Dashboard* in terms of visual appeal, specific features, utility of the information, and the perceived functionality with a prototype as final product.

To continue to build and strengthen relationships within the *Canadian Injury Indicators Team* through collaborative work among researchers, partners and other stakeholders in child and youth injury in Canada.

The first Ottawa meeting will entail a presentation of the Indicators project as a whole; specifications of each of the 34 indicators; and a discussion of the role of these indicators to drive decision making and action. The meeting will then focus on the development of a knowledge translation tool – the Dashboard. End-user/stakeholder input on the development of the Dashboard will be supported by a mock-up presentation, simulated working demonstrations, and small group work. Visual appeal and specific features of the Dashboard will be explored, along with the utility of the indicator information, and the perceived functionality as a tool, balancing utility, ease of use and visual interest. The placement of 'more important' information, grouping of indicators (e.g. easy comparison of Mortality Rate, Potential Years Life Lost and Cost), the 'best way' to present certain types of data (e.g. charts, scorecards, gauges, maps) and colour schemes will be addressed. Next steps in the production of the Dashboard will be discussed.

The second Ottawa meeting will allow further opportunity for end-user/stakeholder feedback as Klipfolio will have taken the input from the first meeting to begin developing the Dashboard. This prototype will be presented and refined.

Conference workshops will be in a similar format to that of the Team meetings – presenting the completed indicator products and proposed dashboard design – to ensure widespread dissemination among the **appropriate target group** of Canadian partners, stakeholders, practitioners and researchers in injury prevention. The Dashboard presentation will reflect the stage of development achieved, and will focus on soliciting important end-user/stakeholder feedback to further direct the dashboard design and functionality.

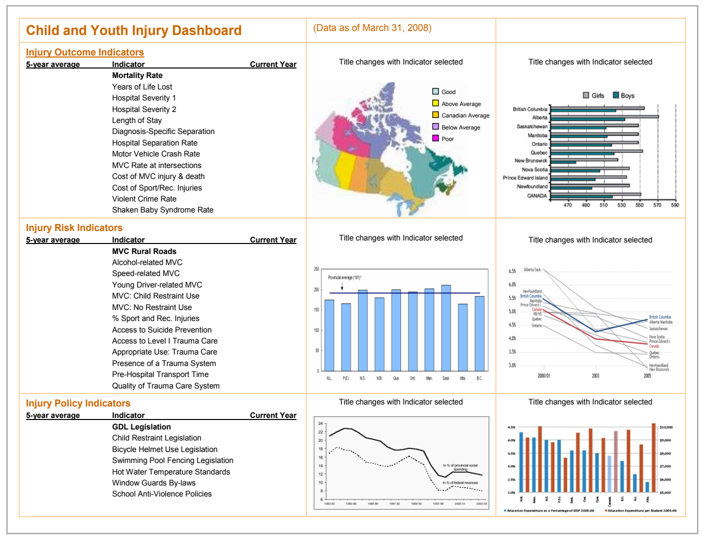
Rationale for Supplemental KT Activities: Bringing this Team together supports the parallel development of the mainstream Canadian dashboard with the First Nations and Inuit dashboards. The general operational requirements and means of connecting the data will be similar for the dashboards therefore production can be co-ordinated to ensure an efficient use of resources. However, it is recognized that the design 'look and feel' of the mainstream Canadian dashboard must be specifically informed by the relevant user groups, as has been successfully accomplished with the First Nations and Inuit partners and stakeholders in injury prevention, including the Assembly of First

Nations, Inuit Tapirit Kanatami, and the First Nations and Inuit Health Branch at a CIHR-funded September 2009 meeting (Funding Reference Number KWS-99426).

This *Canadian Child and Youth Injury Indicators Dashboard* will incorporate available data (i.e. Statistics Canada, Canadian Institute for Health Information [CIHI] and others) and integrate and display these indicators as temporal and spatial trends in data. This will allow for identifying important issues not apparent with more traditional, paper-based approaches. This user-friendly web-based application will provide current measures of the standardized Canadian child and youth injury indicators, with the capacity to inform and monitor the development of injury prevention research and activities, such as policy and legislation, prevention programs, and the evaluation of new strategies.

In general terms, a "dashboard" is a graphical user interface that organizes and presents information in a format that is easy to read and interpret [10]. Dashboards allow users to quickly see the state of complex systems and are designed to assist in making informed and timely decisions for improvement [11]. In the public health arena, dashboards have been used for drug development [12], disaster preparedness [13], and employee health promotion and productivity [14].

Example of a Canadian Child & Youth Injury



Development will entail operational requirements, connecting the data, dashboard design, and user experience and feedback. Evidence will be used to develop questions to elicit input from partners and stakeholders in the development and design of this dashboard [15-19].

Barriers and Facilitators: A barrier to the uptake of the child and youth injury indicators is the comprehensive understanding of what they are and how they can be used. This anticipated barrier has been addressed by bringing this concept to the injury prevention community over the past few years, thus raising the interest among practitioners and stakeholders in the anticipated results of this initiative. A second potential barrier is to have the child and youth injury indicators and dashboard design accepted as workshop presentations at the targeted provincial conferences. It is anticipated that the Team's previous foundational work of bringing the concept of these indicators to the injury prevention community, as well as the stakeholder involvement in the development of these indicators, will lead to the acceptance of these workshops.

Feasibility: This team is committed to moving forward with the development of the Canadian Child and Youth Injury Indicators Dashboard. The peer-reviewed paper and lay document describing the indicators are ready for dissemination. Questions to elicit input from partners in the design and function of this dashboard have been developed based on current evidence. Development of the front-end of the dashboard is a key activity in the knowledge translation of the work completed by the Canadian Injury Indicators Team.

POTENTIAL IMPACT OF THE PROPOSED KT ACTIVITIES

Anticipated Outcomes:

Improved understanding and enthusiasm to use the 34 Canadian child and youth injury indicators.

A consensus of the vision of the *Canadian Child and Youth Injury Dashboard* from the perspective of the injury prevention partners and other stakeholders based on:

Focused discussion directed by specific questions relating to the placement of 'more important' information, grouping of indicators, the 'best way' to present certain types of data, and colour schemes.

A detailed list of examples and/or resources in line with the vision of the *Canadian Child and Youth Injury Dashboard* for the designers to consult.

A detailed plan to move forward with the development of the *Canadian Child and Youth Injury Dashboard* including opportunity for further input and feedback from partners and other stakeholders in child and youth injury in Canada.

Participation of the Canadian injury prevention partners and other stakeholders is a key element in the collaborative development of the *Canadian Child and Youth Injury Dashboard*. These meetings will continue the work of the Team and inform future grant-funded work. Continued relationship building among researchers and stakeholder groups will ensure that the dashboard, as well as child and youth injury prevention activity as a whole, will continue to move forward.

Knowledge Exchange: These meetings and workshops are knowledge exchange events for an established Team consisting of injury prevention researchers and the relevant primary national stakeholders. This integrated knowledge translation initiative has produced 34 injury indicators to be disseminated in the form of a peer reviewed publication and a plain language report. The dashboard as an up and coming tool in injury prevention will be promoted, and Team members will engage their own networks in information sharing and feedback solicitation. The partners will provide relevant information required for the development and design of the *Canadian Child and Youth Injury Dashboard*, which itself is a knowledge dissemination tool.

Meeting Reports will be produced within three months of each meeting date and made available to all participants. Ultimately, the *Canadian Child and Youth Injury Dashboard* will address data, monitoring and surveillance, and capacity building among researchers and stakeholders.

Significance and Future Plans: The *Canadian Child and Youth Injury Dashboard* will provide readily accessible information to injury prevention stakeholders, practitioners, policy makers and researchers. Expanding public access to health services and health information through web-based applications is one of the Service Plan priorities of the BC Ministry of Health Services.

This tool will be unique and a first of its kind, serving as a model for other jurisdictions. More importantly, the dashboard will provide a basis for injury prevention decision-making and action, and will improve child and youth injury prevention systems in Canada. Ultimately this will have an impact on child and youth health in Canada.