Master Thesis

Assessing the Role and Value of Interactivity in Visual Business Intelligence

A User's Perspective

submitted by

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Abstract

The development and success of many organizations to a large extent depend on how well and how timely they manage to gain insight into collected data. Business Intelligence (BI) provides methods for analyzing business-critical information and supports decision-making processes. But the ever growing amounts of data and information clearly overwhelm traditional manual methods of data analysis such as spreadsheets, standard reporting or simple diagrams.

One possibility to face this problem is Information Visualization (InfoVis). By utilizing the powerful human perceptual system that is extremely efficient in processing visual input, visualization, for example, can help to make sense of data, explore complex information spaces or spot patterns and relationships within the data. Interactivity or the possibility to engage in an active discourse with the representation lies at the core of Information Visualization. However, empirical evidence and detailed approaches to model the concept of interactivity are largely missing in research today.

This thesis is a first step towards bridging this gap and approaching the concept of interactivity more in depth. In order to do so, a twofold approach was chosen. First, the concept of interactivity was investigated from a theoretical point of view. In particular, cognitive theories and models were analyzed in order to determine their ability to explain and predict the value and role of interactivity in visual methods. Second, a qualitative empirical study was conducted among six IT-managers working in the field of Business Intelligence to assess the current practice at work concerning visual methods and interactivity.

The main results are that cognitive theories and models do not explicitly account for the role of interactivity but rather concentrate on modeling the elements of a cognitive system and explaining how these entities interact with each other to achieve a certain goal. How different types of interactivity influence these processes is usually not part of the theories, and the effect of interactivity on cognitive processes was hardly ever mentioned.

Apart from that, the empirical study showed that interactive visual methods in the area of Business Intelligence aren't used very often. One of the main reasons reported is the fact that visualization is still two steps ahead and at the moment mostly more basic problems concerning data gathering, data modeling and data quality prevail. Moreover, most users are used to work with numbers and tables and are not aware of the possibilities in terms of visualization. However, the interviewed IT-managers acknowledged that using more interactive visual methods in Business Intelligence would be beneficial for users.

Zusammenfassung

Business Intelligence (BI) bietet Methoden zur Analyse unternehmensrelevanter Daten, um Entscheidungsprozesse zu unterstützen. Die immer größeren Mengen an Daten und Informationen überfordern allerdings traditionelle Methoden der manuellen Datenanalyse wie Tabellenkalkulationen, Standard Reporting oder einfache Diagramme. Eine Möglichkeit, dieser Herausforderung entgegenzutreten ist Informationsvisualisierung (InfoVis). Aufgrund der hervorragenden Fähigkeiten des Menschen im Umgang mit visuellen Sinneseindrücken, kann Visualisierung wesentlich dazu beitragen, komplexe Sachverhalte verständlich zu machen, die Gewinnung neuer Erkenntnisse zu erleichtern und die Generierung neuen Wissens zu ermöglichen. Interaktivität, oder die Möglichkeit in einen aktiven Diskurs mit der Repräsentation zu treten, sind Kernelemente der Informationsvisualisierung. Allerdings sind heute kaum empirische Belege oder Ansätze zur Modellierung des Konzepts der Interaktivität vorhanden.

Diese Master Thesis ist ein erster Schritt, um diese Lücke zu schließen und den Wert und die Rolle von Interaktivität zu untersuchen. Kognitionswissenschaftliche Modelle und Theorien wurden dahingehend analysiert, ob sie den Wert und die Rolle von Interaktivität erklären bzw. dazu benutzt werden könnten, Vorhersagen über den Effekt der Interaktivität in visuellen Methoden zu treffen. Anschließend wurde im Bereich Business Intelligence eine qualitative empirische Untersuchung unter sechs IT-Managern durchgeführt, um den aktuellen Stand des Einsatzes der interaktiven visuellen Methoden in der Praxis zu erheben.

Die Hauptergebnisse sind, dass kognitionswissenschaftliche Theorien und Modelle die Rolle von Interaktivität nicht explizit erklären und sich eher auf die Modellierung der Elemente eines kognitiven Systems konzentrieren. Wie verschiedene Formen der Interaktivität diese Prozesse beeinflussen, ist meist nicht Gegenstand der Theorien. Darüberhinaus konnten nur wenige Erklärungen über den Effekt von Interaktivität in kognitiven Prozessen gefunden werden.

Die empirische Untersuchung hat gezeigt, dass der Einsatz von interaktiven visuellen Methoden im Bereich Business Intelligence bei den betrachteten Unternehmen nur sehr gering ist. Eine häufig genannte Ursache dafür ist, dass im Moment viel grundlegendere Probleme – vor allem in den Bereichen Datenerfassung, Datenmodellierung und Datenqualität – noch ungelöst sind. Darüberhinaus sind die meisten Benutzerinnen und Benutzer gewohnt mit Zahlen und Tabellen zu arbeiten und sind mit den Möglichkeiten der visuellen Datenanalyse nicht vertraut. Allerdings standen alle befragten IT-Manager dem verstärkten Einsatz von interaktiven visuellen Methoden sehr positiv gegenüber und halten deren Einsatz für sehr nützlich.

Contents

Chapter 1

Introduction & Motivation

"The best thing about doing business is the wealth of information available.
The worst thing about doing business today is the wealth of information available"
Guy Kawasaki, cited in Devlin (2001, book cover)

The development and the success of many organizations to a large extent depend on how well and how timely they manage to gain insight into collected data. For example, consider the case of a simple shoe store. Gathering valuable information from collecting and to analyzing data regarding customer frequency, seasonal demand variations, price politics of competitors, anticipated hypes, etc., helps the manager in making better informed business decisions. Personnel planning could be improved, warehousing costs lowered and competitors might be outperformed by basing decisions upon collected data and hard facts rather than guessing and gut feeling.

Business Intelligence (BI) provides methods for analyzing business-critical information (e.g., about customers, competitors, economic environment, internal processes) to make high quality decisions and view the business's strengths and weaknesses on a daily basis. During the last decade, the possibilities to both generate and collect data and information have grown tremendously. Advances in business data collection (e.g., from retail or production devices) have generated heaps of data and information. Advances in data storage technologies, such as faster and higher capacity and cheaper storage devices, better database management systems and data warehousing technology, have enabled us to collect mountains of stored data. Traditional manual methods of data analysis such as spreadsheets, ad-hoc queries or simple diagrams cannot cope with this amount of data and information. We need new methods and tools that can intelligently and (semi-)automatically transform data into information and, furthermore, synthesize knowledge. Considering these technological developments, the importance of Business Intelligence is growing (see also Grothe & Gentsch (2000, p.11ff)). As Bowett (2008) states, "The computer does not make decisions; managers do. But it helps managers to have quick and reliable quantitative information about the business as it is and the business as it might be in different sets of circumstances".

Information Visualization (InfoVis) is an important asset in this set of tools. InfoVis methods are intended to present information graphically and allow for utilizing the outstanding capabilities of humans in terms of visual information exploration. *Visual Business Intelligence* is a term coined by Few (2007) and describes the application of *Information Visualization* in the domain of Business Intelligence to represent and analyze business data visually. As D'Aveni (2007, p. 110) reports, visualization can be of crucial importance in business contexts: "A simple chart shows how much a customer will pay for a perceived benefit. This is more than a marketing aid, it's a powerful tool for competitive strategy". Card, Mackinlay & Shneiderman (1999, p. 16) list the following benefits of visualization:

1. Increasing the memory and processing resources available to the user
2. Reducing the search for information
3. Using visual representations to enhance the detection of patterns
4. Enabling perceptual inference operations
5. Using perceptual attention mechanisms for monitoring
6. Encoding information in a manipulable medium

The last item in particular, refers to the characteristics of interactivity. It describes the human user's ability to directly interact with the visual representation in order to change its appearance in a repetitive process of active discourse. User interactions are one of the most important elements in visualization or even the core as Spence (2007, p. 136ff) stated. As Saraiya, North, Lam & Duca (2006, p. 453f) found out in a study, users prefer inferior visualizations with interaction over superior static visualizations. Furthermore, they mention that visual representations provide only an initial direction to the data and their meaning, while through the combination of visual representations and appropriate interaction mechanisms, the users achieve insights into the data.

Despite being recognized as an important asset in the field of Information Visualization, Business Intelligence has not taken advantage of these features in full depth yet as stated in a recent white paper of a visual information analysis software vendor:

> "Traditional business intelligence tools are not able to satisfy the analysts need to interactively explore the data. As a result, these tools and current data visualization products are too hard to use, too static (they lack interactivity), too disconnected from the immediate needs of business users and too isolated. Interactive, visual exploration and collaboration are much easier to adopt and apply to rapidly make substantive business decisions. Visualization must support the ability to pose questions through direct interaction with heterogeneous data sources simultaneously. Users need to be able to "shift the lens" and view the data through different visual representations while also maintaining the threads that link these views together" (Centrifuge Systems 2008).

With regard to interactivity, both the Information Visualization and Business Intelligence communities are consistently stating the value and importance of interactive features for visual data analysis, on the one hand, and the lack thereof in current systems, on the other hand. Despite these views, empirical studies or theoretical models that support these statements are scarce or missing at all. Until now the value of interaction has largely been treated as a minor issue in empirical studies. Nevertheless, it has mainly been promoted by experts on both sides as valuable asset. Moreover, there are almost no systematic accounts for investigating the users' perspective on the value and role of interactivity in visualization and data analysis.

The aim of this thesis is to bridge this gap between interactive Information Visualization and Business Intelligence and step onto new ground by systematically assessing the role and value of interaction. The role as well as the benefits and limitations of interactivity in visual methods for business data analysis as perceived by users will be assessed in a qualitative empirical study.

The concept of interactivity will be approached from two points of view. First, cognitive theories and models will be investigated. It will be of particular interest, whether and how these models and theories incorporate interactivity. Second, a qualitative empirical study will be presented to shed some light on the practical use of interactive visual methods in the context of Business Intelligence. In the course of the study, six IT managers of large Austrian corporations participated in semi-structured interviews. A qualitative approach was chosen in order to gain a better initial understanding of this area that was not subject to much research up to now.

1.1 Relevance

In the course of the last two years, many innovative providers of visualization software have been acquired by big players in the BI business. E.g., the visualization company Inxight has been acquired by the BI company Business Objects in May 2007 and Business Objects, in turn, has been acquired by SAP in October 2007 (cmp. Bange 2008). This indicates, how relevant the topic of visualization and business intelligence currently is in the industry.

From a scientific point of view, a call for a "science of interaction" in the field of visual analytics that aims to integrate the outstanding capabilities of humans in terms of visual information exploration and the enormous processing power of computers has been made:

> "Too often in the visual analytic process, researchers tend to focus on visual representations of the data but interaction design is not given equal priority. We need to develop a 'science of interaction' rooted in a deep understanding of the different forms of interaction and their respective benefits." (Thomas & Cook 2005, p. 73)

1.2 Research Question

The main research question to be answered in this thesis is:
What is the perceived value and role of interactivity in visual methods for business data analysis?

Based on that, a set of three hypotheses are derived:

1. Most visual methods currently applied in Business Intelligence are static or employ only very limited forms of interactivity.

2. Increasing the interactivity of visual methods is desired by users.

3. According to users, interactivity helps to gain information and knowledge in business data analysis.

1.3 Beneficiaries

Possible groups of people who benefit of the results of this thesis are:

Developers of Visual Business Intelligence Tools: Empirical guidance on possible future developments for Visual BI Tools that best support business needs.

Executives and Analysts: For demonstrating the applicability and value of interactivity in Visual Business Intelligence.

Researchers in Visual Data Analysis: Enhancing the state-of-the-art in research by providing empirical evidence on the perceived role and value of interactivity.

1.4 Overview

This thesis is structured as follows. In Chapter 2 an introduction will be given to the areas of Business Intelligence, Information Visualization, and Visual Business Intelligence. In Chapter 3 cognitive theories and models will be discussed along with a theoretic view on the concept of interactivity. In Chapter 4 the method of research for the empirical part is presented. The empirical study itself is summarized in Chapter 5 and followed by a discussion in Chapter 6. A conclusion will be given and ideas for future work will be presented in Chapter 7.

Abbreviations that are introduced throughout this work are listed and explained on page 89. Material of the empirical study can be found in the appendix. This includes the used interview guideline in Appendix A.1, the interview transcripts in Appendix A.2, as well as the coding scheme applied for qualitative text analysis in Appendix A.3.

1.5 Acknowledgements

Many people contributed to this thesis directly or indirectly and I would like to thank them very much for their help to make this possible.

Above all, I would like to thank my wife Beatrix and our little sunshine Valentina for their love, support, and understanding when I had to spend weekends and work long hours for carrying out this thesis.

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Chapter 2

Background

2.1 Business Intelligence (BI)

“We are drowning in information but starved for knowledge”
Naisbitt (1982, p. 24), cited in Chamoni & Gluchowski (2006a, p. 74)

In the wake of ever growing amounts of data in business and everyday life, it is increasingly harder to find the important assets in this big mess. Especially in business contexts, the ability to make faster and better decisions is decisive for sustainable success. Therefore, it is important to find relevant relationships and patterns and the knowledge treasures hidden in the data. The goal of Business Intelligence (BI) is to support this process. Grothe & Gentsch (2000) acknowledge that due to the huge amounts of data that need to be processed and the advances made in information technology (IT), the relevance of BI is still growing at a very high rate (cmp. Grothe & Gentsch 2000, p. 11ff).

As described in (Power 2007), Business Intelligence (BI) is a generic term for a set of IT-based concepts and methods to improve business decision making that was introduced by Howard Dresner of the Gartner Group in 1989 (cmp. Power 2007). It marks the current state of a development that started well over 40 years ago. In the 1960s, the need for IT-based decision support mainly arose at top management levels and controlling departments (cmp. Chamoni & Gluchowski 2006a, p. 4). A short summary of the developments that led to the notion of BI will be given in the next section.

A single and undisputed definition of the term *Business Intelligence* cannot be found in the literature. Rather, every author uses his or her own definitions and views. As mentioned earlier, BI is a generic term for a wide variety of processes, techniques and methods. Considering this, it is not surprising that no clear definition exists. However, an attempt towards concretizing the term shall be made here in order to provide a basis for further investigations in the context of this thesis. When exploring the term *Business Intelligence*, we might want to start by dissecting the term into its components “business” and “intelligence”: According to Luhn (1958, p. 314) business is “a collection of activities carried on for whatever purpose, be it in science, technology, commerce, industry, law, government, defense, et cetera”. This definition refers to the perspective of understanding “business” not only as an “enterprise” or “firm” but as a purposeful and multi-faceted process. Following this view, Chamoni & Gluchowski (2006b) describe “enterprise” as a complex socio-economic structure within the contexts of sales and supply markets, money and financial markets, and public authorities (cmp. Chamoni & Gluchowski 2006b, p. 13). When investigating the term “intelligence”, we already get a glimpse of the goals of BI: “Intelligence is [...] the ability to apprehend the interrelationships of presented facts in such a way as to guide towards a desired goal” (Luhn 1958, p. 314). Following the business-oriented path of these explanations, we arrive at the following three concise and potentially useful definitions for BI with an increasing level of detail:

1. “Business Intelligence is a process for increasing the competitive advantage of a business by intelligent use of available data in decision making” (Jarrad 2003).

2. “An interactive process for exploring and analyzing structured and domain-specific information to discern trends or patterns, thereby deriving insights and drawing conclusions. The business intelligence process includes communicating findings and effecting change” (Few 2007).

3. “Business Intelligence encompasses a broad set of applications and technologies for a decision-oriented collection, preparation and presentation of business-relevant information.”[1] (Humm & Wietek 2005, p. 4, transl. by the author).

4. “It denotes the analytical process that transforms business and competition data into action-oriented knowledge about the capabilities, positions, actions, and goals of the observed internal or external action fields (actors and processes)”[2] (Grothe & Gentsch 2000, p. 19, transl. by the author).

An important point when dealing with BI is to acknowledge the fact that we are neither dealing with technology, nor with social or business aspects alone, but with interwoven socio-technical systems that need to be well-balanced. According to Chamoni & Gluchowski (2006b, p. 2), computer-based information and communication systems consist of three aspects:

1. Information & communication technology

2. Application areas

3. Humans

[1]Translated from the German original version by the author: “Business Intelligence umfasst ein breites Spektrum an Anwendungen und Technologien zur entscheidungsorientierten Sammlung, Aufbereitung und Darstellung geschäftsrelevanter Informationen. ” (Humm & Wietek 2005, p. 4)

[2]Translated from the German original version by the author:“Es bezeichnet den analytischen Prozess, der – fragmentierte – Unternehmens- und Wettbewerbsdaten in handlungsgerichtetes Wissen über die Fähigkeiten, Positionen, Handlungen und Ziele der betrachteten internen oder externen Handlungsfelder (Akteure und Prozesse) transformiert.” (Grothe & Gentsch 2000, p. 19)

In the course of this thesis, all three aspects will be addressed accordingly. In the upcoming explanations regarding BI systems the first two aspects will be covered by taking a look at BI from a business as well as technological perspective. The third aspect will mainly be covered in Section 2.2 about Information Visualization (InfoVis) and in Section 3.1 on Cognitive Theories and Models.

2.1.1 Historical Developments

As mentioned in the previous section, BI can be considered as the current state of affairs of a development that began well over 40 years ago. In order to understand the breadth of the field and provide a clear view of different terms and their interrelationships used, it makes sense to provide a short summary of the history of the field.

Management Information Systems (MIS)

The first attempt of IT support for management was made in the 1960s and is known as "Management Information Systems (MIS)". According to Chamoni & Gluchowski (2006b, p. 55f), the term MIS has various interpretations and, thus, no single definition is possible. MIS usually refers to standard reporting functionalities without much data processing or analysis:

> "Management Information Systems (MIS) are IT-supported systems that enable managers on different hierarchy levels to extract detailed and aggregated information from operative data. Information processing is performed without sophisticated methods (logically-algorithmic processing)."[3] (Chamoni & Gluchowski 2006b, p. 56, transl. by the author).

Information technologies were very promising for how computer-based methods could support business processes in MIS but in the 1970s it became clear that most of these promises could not be fulfilled, which was mainly due to the technical constraints of the computer hardware at that time. This disillusion also lead to discrediting the term itself. Chamoni & Gluchowski (2006b, p. 59) report that the major point of criticism was that the lack of information for managers before MIS were in use was replaced by information overload as no filtering, cleansing, or aggregation was applied to the data. However, in the 1990s a revival of MIS took place at the same time as a demand for reporting simplification was voiced.

Decision Support Systems (DSS)

In contrast to MIS, which mainly collect and provide quantitative data, Decision Support Systems (DSS) focus on modeling the problem-solving behavior of experts and managers. Cha-

[3] Translated from the German original version by the author: "Management Information Systeme (MIS) sind EDV-gestützte Systeme, die Managern verschiedener Hierarchieebenen erlauben, detaillierte und verdichtete Informationen aus der operativen Datenbasis zu extrahieren. Die Informationsverarbeitung erfolgt ohne Anwendung von anspruchsvollen Methoden (logisch-algorithmische Bearbeitung)." (Chamoni & Gluchowski 2006b, p. 56)

moni & Gluchowski (2006b, p. 62) identify the main aim of DSS as the support for planning and decision-making processes in a model and method-oriented way. A formal optimization methodology that is closely connected to DSS is the area of Operations Research (OR), where optimization problems can be modeled and solved mathematically. Power (2007) provides the following definition of the term:

> "A DSS is an interactive computer-based system or subsystem intended to help decision makers use communications technologies, data, documents, knowledge and/or models to identify and solve problems, complete decision process tasks, and make decisions. [...] In general, Decision Support Systems are a class of computerized information system that support decision-making activities".

Executive Information Systems (EIS)

In the mid 1980s, following substantial progress of computer technology, there was a new boost for MIS with the introduction of Executive Information Systems (EIS):

> "Executive Information Systems (EIS) are dialogue- and data-oriented information systems for managers with a particular focus on communication features that provide experts and managers with up-to-date, decision-relevant internal and external information via intuitive and customizable user interfaces." [4] (Chamoni & Gluchowski 2006b, p. 75, transl. by the author).

Similarly to MIS, the end-users of EIS are foremost top managers. Apart from technological improvements, also substantial methodological innovations were introduced in form of a new and powerful data model – the *multi-dimensional data cube*. This data model allows for arbitrary navigation and exploration of information structures from different perspectives. This is in contrast to the static information provided by MIS in the early days. Also personal information management (PIM) components like calendars or address books are integrated into EIS. Furthermore, EIS are not generic but always corporation-specific which might also be a reason for their relatively slow spreading (cmp. Chamoni & Gluchowski 2006b, p. 82).

Executive Support Systems (ESS)

Executive Support Systems (ESS) provide both data support and decision support and can be seen as a more holistic approach towards supporting management processes by combining features of EIS and DSS. Moreover, an ESS is typically not a certain product but rather a concept or strategy.

[4]Translated from the German original version by the author: "Executive Information Systeme (EIS) sind dialog- und datenorientierte Informationssysteme für das Management mit ausgeprägten Kommunikationselementen, die Fach- und Führungskräften aktuelle entscheidungsrelevante interne und externe Informationen über intuitiv benutzbare und individuell anpassbare Benutzeroberflächen anbieten." (Chamoni & Gluchowski 2006b, p. 75)

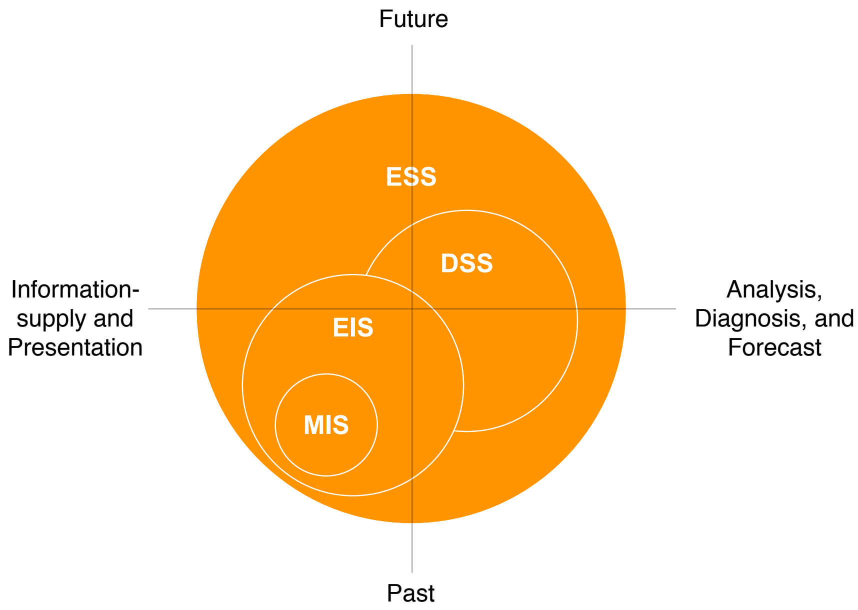


Figure 2.1: Overview and classification of areas within BI.
Source: cmp. Chamoni & Gluchowski (2006b, p. 84)

> "Executive Support Systems (ESS) are workplace-oriented combinations of problem-solving oriented DSS- and presentation and communication oriented EIS features that are geared to user types and problem perspectives. Possibly, apart from conventional DSS, also knowledge-based DSS are included." [5] (Chamoni & Gluchowski 2006b, p. 82, transl. by the author)

Figure 2.1 provides a graphical overview and categorization of the main areas within BI. Chamoni & Gluchowski (2006b, p. 84) characterize the different areas along the two axes as "Past – Future" as well as "Information-supply and Presentation – Analysis, Diagnosis, and Forecast". MIS merely focus on information supply and presentation of data of the past, whereas DSS are more geared towards analysis, diagnosis and forecast, therefore focusing on the future. Albeit EIS main focus is on information supply and presentation of past data, they provide much more functionality than MIS but only little consideration of analysis and future. Finally, ESS encompass the full spectrum provided by the two dimensions in an holistic attempt to support management processes.

Management Support Systems (MSS), which are synonymous to Business Intelligence Systems, go even beyond ESS and include the full spectrum of IT support for managers. Hence, they subsume ESS including EIS and DSS, on the one hand, and basic systems like word pro-

[5] Translated from the German original version by the author: "Executive Support Systeme (ESS) sind arbeitsplatzbezogene Kombinationen aus problemlösungsorientierten DSS- und präsentations- und kommunikationsorientierten EIS-Funktionalitäten, die an Anwendertypen und Problemperspektiven ausgerichtet sind. Unter Umständen werden neben konventionellen DSS auch wissensbasierte DSS einbezogen." (Chamoni & Gluchowski 2006b, p. 82)

cessing, spreadsheet applications, image processing, calendar, and mail system, on the other hand (see Figure 2.2).

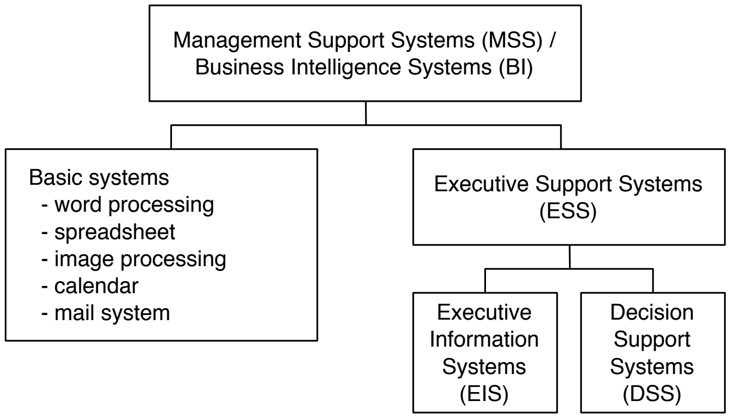


Figure 2.2: Components of Management Support Systems (MSS) = Business Intelligence Systems.
Source: cmp. Chamoni & Gluchowski (2006b, p. 88)

In the following, we will look at BI from a business and a technological perspective.

2.1.2 Business Perspective

> “The computer does not take decisions; managers do. But it helps managers to have quick and reliable quantitative information about the business as it is and the business as it might be in different sets of circumstances.” (Bowett 2008).

In an attempt to systematize different business areas and different sets of circumstances, Chamoni & Gluchowski (2006b, p. 5) provide a conceptualization of the application pyramid for computer support in businesses as represented in Figure 2.3. When talking about BI systems, we mainly deal with the upper half of the pyramid denoted “Planning and Monitoring systems”. As we are moving higher in the pyramid, the provided methods are getting more powerful and sophisticated.

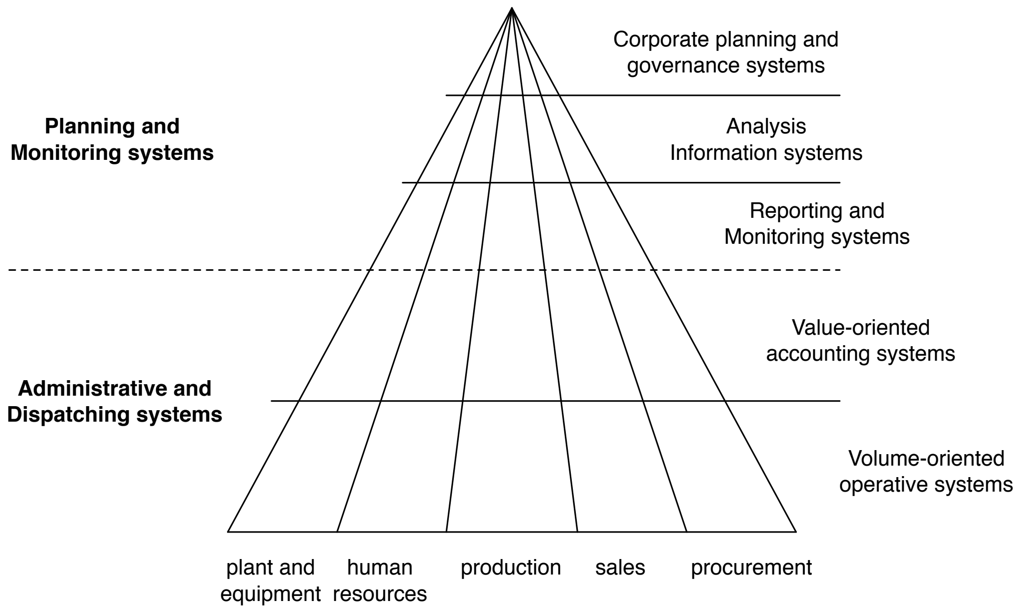


Figure 2.3: Application Pyramid.
Source: cmp. Chamoni & Gluchowski (2006b, p. 5)

Following Chamoni & Gluchowski (2006b, p. 21), many business processes can be broken down into a 4-step cycle of

1. (situation) analysis,
2. planning & decision making,
3. management & control, and
4. monitoring.

To support and have an impact on business processes, BI methods have to support the different stages as well as the cyclic process itself. During the last couple of years, a number of different sub-areas were developed in BI in order to support different business areas (cmp. Hummeltenberg 2008):

> *Process / Operational Intelligence* is concerned with supporting and optimizing business processing, for example demand forecasting or supply-chain management.
>
> *Competitive Intelligence* strives for the analysis and evaluation of business competitors (It is often connected to *market intelligence*).
>
> *Location Intelligence* supports the strategic planning of location politics of a business and it is of particular importance, for example, for retail chains.
>
> *Market Intelligence* is concerned with analyzing the dynamics and movements of whole markets a business is interested in.
>
> *Customer Intelligence* is a vital asset in a BI portfolio and concerned with tasks like customer segmentation, customer acquisition or customer retention.

Apart from the positioning of BI techniques within different business aspects and tasks, it is essential to investigate the *business value* of BI. After all, acquiring business intelligence solutions is a both technically and organizationally complex and financially expensive endeavor. Only if the value gained by applying BI methods outweighs their cost, BI is truly successful. Considering this, it is important to differentiate benefits and value. Benefits, on the one hand, are much easier to express and show. Value, on the other hand, is much more difficult to measure as Williams & Willi (2003, p. 3) state:

> "While there are hundreds of ways to express business benefits, there is no business value associated with an investment unless the benefits achieved result in increased after-tax cash flows."

This implies that no matter how many business benefits a BI solution might carry, it only has value, if it has a positive effect on cash flow. Furthermore, they state that organizational measures need to be taken in order to generate business value out of BI; buying and putting software in place alone is not enough.

After investigating BI from a business point of view, a technical perspective follows in the next section.

2.1.3 Technical Perspective

Bange (2006, p. 91) describes BI technology based on five layers (see Figure 2.4). At the basis of this model are the operational systems that support day to day business processes, for example transaction processing. To link various operational systems and collect data for a unified, corporation-wide view, a data integration layer is necessary, which is often subsumed

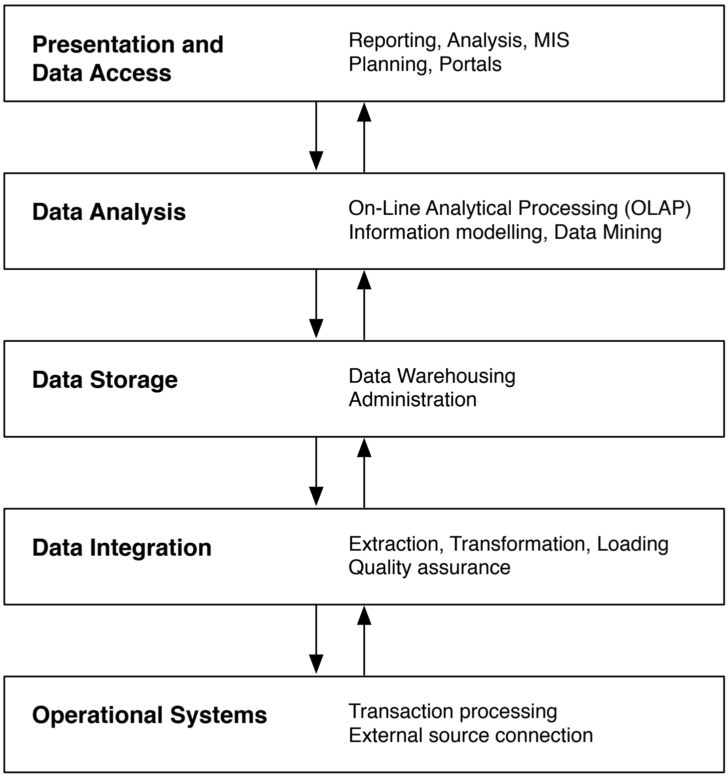


Figure 2.4: Architectural conceptualization of BI in five layers.
Source: cmp. Bange (2006, p. 91) and Gluchowski et al. (2008, p. 109)

under the term *ETL* (extraction, transformation, loading). The core element of a BI system is the central data store, termed *Data Warehouse*, which holds the unified, corporate-wide view of business data. Subsequently, this data is modeled and analyzed automatically in the data processing layer. On the top of the list, we find those elements that are visible to the end-user: Tools for reporting and analyzing, dashboards etc.. This kind of structure is also known as *hub and spoke architecture* (cmp. Gluchowski, Gabriel & Dittmar 2008, p. 129).

As the main focus of this thesis is on user-oriented issues, only the three upper levels will be presented in depth.

Data Storage

As described in the previous section, the data storage layer is based upon the data integration layer, which extracts, transforms, and loads (ETL) data from different internal but also external data sources, for example the world wide web (WWW). The data storage layer provides a unified and global database, which is independent of the different platforms, systems or formats of the various operational systems within a corporation. The commonly used term for this global data store is *Data Warehouse (DW)*. An advantage of this central store is that operational systems are not accessed directly, thus, avoiding performance problems at that level. Chamoni & Gluchowski (2006a) provide a concise definition of the term Data Warehouse:

> “a corporation-wide concept [...] with the goal of providing a logically central, standard and consistent database for the manifold applications to support experts and managers in their analytical tasks, which is decoupled from the operational databases” [6] Chamoni & Gluchowski (2006a, p. 12, transl. by the author).

Data Analysis

Based on the unified view provided by the Data Warehouse, data can be automatically analyzed by using mainly two different approaches: *On-Line Analytical Processing (OLAP)* and *Data Mining (DM)*. Power (2007) defines OLAP as:

> “[...] software for manipulating multidimensional data from a variety of sources that has been stored in a data warehouse. The software can create various views and representations of the data. OLAP software provides fast, consistent, interactive access to shared, multidimensional data. These systems are used to discover trends, analyze critical factors and perform statistical analysis.”

The same author defines DM as

> “A class of analytical applications that help users search for hidden patterns in a data set. Data mining is the process of sifting through large amounts of data to identify data content relationships.” (Power 2007)

According to Chamoni & Gluchowski (2006b, p. 143), the most distinct factor between the two approaches is their different goals: The main goal of OLAP is to *verify* hypotheses that are already known, whereas the main goal of DM is to *generate* potentially new and unknown hypotheses.

Presentation and Data Access

The parts of BI systems in this layer are the ones end-users actually using. Raskin (2000, p. 5) states that “As far as the customer is concerned, the interface is the product”. Following this, it is decisive to provide a usable and intuitive user interface and interaction design for BI systems, which are successful and accepted. The role of interactivity in this context will be the main focus of this thesis.

In the current systems, this layer is mainly represented by standard reporting and so called *Information Dashboards*:

[6] Translated from the German original version by the author: “ein unternehmensweites Konzept [...], dessen Ziel es ist, eine logisch zentrale, einheitliche und konsistente Datenbasis für die vielfältigen Anwendungen zur Unterstützung der analytischen Aufgaben von Fach- und Führungskräften aufzubauen, die losgelöst von den operativen Datenbanken betrieben wird.” (Chamoni & Gluchowski 2006a, p. 12)

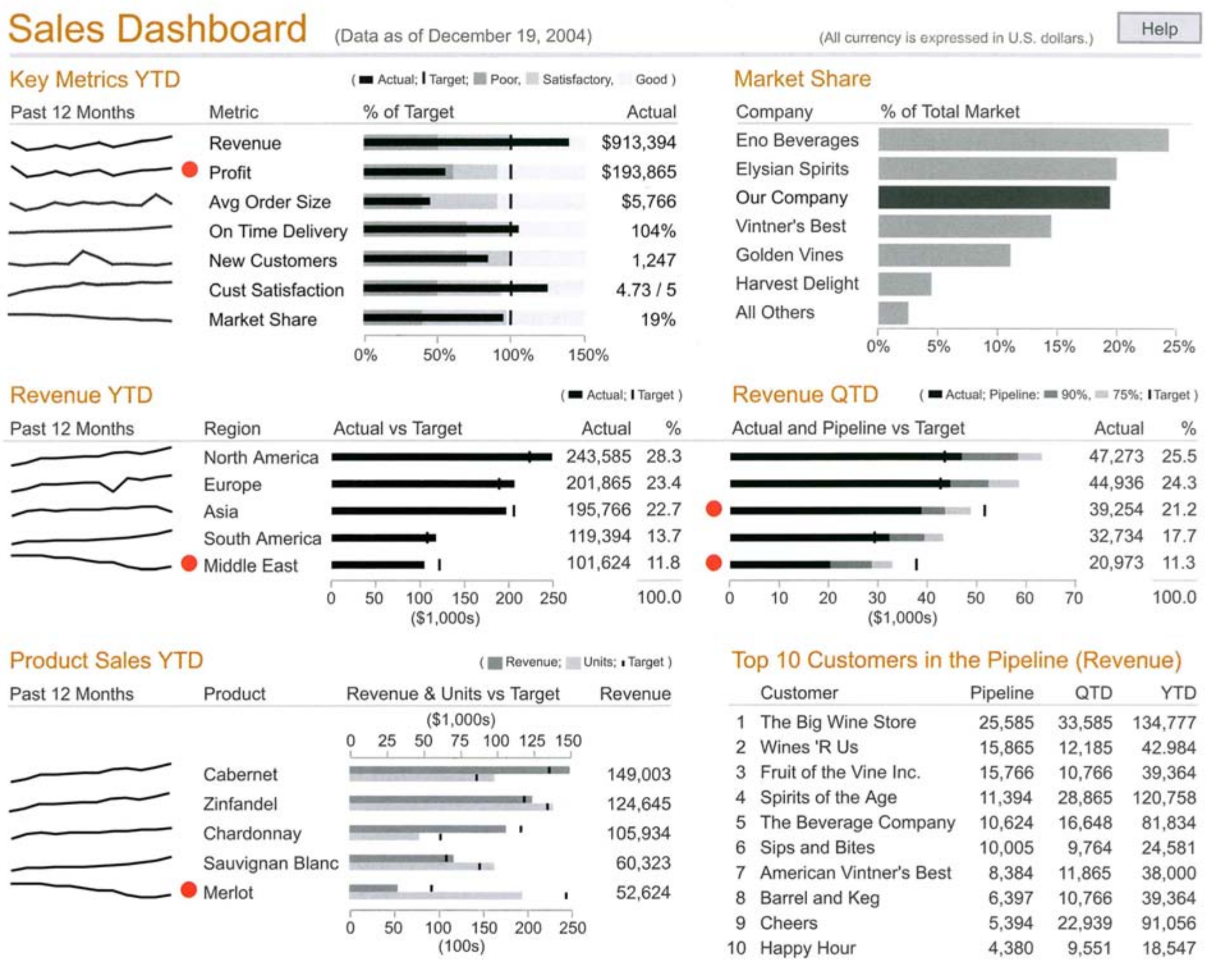


Figure 2.5: Example of an information dashboard that provides a concise graphical overview of business-relevant variables and their development over time.
Source: Few (2006, p. 177)

> “A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance.” (Few 2006, p. 34).

Figure 2.5 presents an example of an information dashboard that provides a concise graphical overview of business-relevant variables and their development over time.

2.1.4 Summary & Discussion

In the previous sections, the term BI was explored along with views from a business as well as a technological point of view. In general, BI is a complex and multifaceted area with a history of more than 40 years. BI methods and techniques are to support managers and experts in business processes from operations to strategic decisions.

Williams & Willi (2003, p. 1) note that a shift from an IT-centered to a business-centered view on BI has taken place. This also leads to the discussion of the business value of BI, which is much harder to quantify and measure than the benefits of BI.

Moreover, a lack of scientific literature on BI as a whole can be observed. Albeit many publications on particular topics, methods, and techniques that are part of BI in business-oriented as well as technology-oriented communities exist, only few scientific accounts on BI as holistic unit can be found.

BI, and more specifically *business analytics*, has recently received growing interest as a vital asset for businesses today. *Analytics* is seen as a new form of competition and the basis upon which companies compete today, which is emphasized by Davenport & Harris (2007, p. 3ff). One of the key relevant factor that impacts business is the ability to gain relevant information from the growing amounts of data in order to make better decisions. To achieve this, several experts in the field call for more interactive navigation and exploration functionalities along with advanced visualization possibilities (e.g., see Howson (2008, p. 208ff) or Bange (2006, p. 103)). Already in 1978, Szyperski (1978) called for more (inter)active support for managers:

> "Szypersky warns from the exclusive use of automatic reporting systems. He emphasizes that it is important for a manager to search for information and relationships rather than 'attentively dozing off as an observer in a control room' and he calls for a combination of active and passive support for decision makers."[7] (Chamoni & Gluchowski 2006b, p. 9, transl. by the author).

As Howson (2008, p. 208ff) states, all leading BI tools offer basic visualization possibilities but more advanced visualization features are needed to better support analysis and exploration tasks.

As Centrifuge Systems (2008) notes, this is a very significant problem and in order to satisfy this need, analysts need tools that support the interactive exploration of the growing amounts of data. They state that currently used tools do not fulfill these demands and emphasize the lack of interactivity as one major limiting factor. Furthermore, they provide their vision of next generation systems that support business decision-making at a higher level:

> "Visualization must support the ability to pose questions through direct interaction with heterogeneous data sources simultaneously. Users need to be able to 'shift the lens' and view the data through different visual representations while also maintaining the threads that link these views together." (Centrifuge Systems 2008)

In the following section, an introduction and overview of the field of Information Visualization (InfoVis) will be given.

[7] Translated from the German original version by the author: "Szypersky warnt vor dem ausschließlichen Gebrauch aktiver Berichtsysteme. Er betont, dass es für einen Manager wichtig ist, ständig nach neuen Informationsverknüpfungen zu suchen anstatt "als Kontrollperson auf einer Schaltbühne aufmerksam zu dösen" und fordert dementsprechend eine Kombination aus aktiver und passiver Unterstützung für den Entscheidungsträger." (in Chamoni & Gluchowski (2006b, p. 9))

2.2 Information Visualization (InfoVis)

"The eye ...
the window of the soul,
is the principal means
by which the central sense
can most completely and
abundantly appreciate
the infinite works of nature."

Leonardo da Vinci (1452–1519),
cited in Fekete, van Wijk, Stasko & North (2008, p. 4)

Not only in business contexts are we confronted with growing amounts of data that are increasingly harder to make sense of. One possibility to face this problem of *information overload* is visualization. By taking advantage of the powerful human perceptual system that is extremely efficient in processing visual input, visualization can help to make sense of data, explore complex information spaces or spot patterns and relationships within the data:

> "Information visualization is a process of constructing a visual presentation of abstract quantitative data. The characteristics of visual perception enable humans to recognize patterns, trends and anomalies inherent in the data with little effort in a visual display. Such properties of the data are likely to be missed in a purely text-based presentation" (Ahokas 2008, abstract).

Figure 2.6(b) provides a simple example of data visualization. Figure 2.6(a) contains the raw data of a small car data set consisting of the variables brand, type, trunk volume, and price in form of a table. Figure 2.6(b) shows a visual representation of the data given in the data table. When confronted with the task of finding good deals for a large trunk volume at a low price, visualization is much better suited than the table. What can be said from the visualization is that there is no apparent relationship between price and trunk volume and this insight is much harder to gain from the tabular view. Moreover, outliers are much easier to spot in the visualization than in the table.

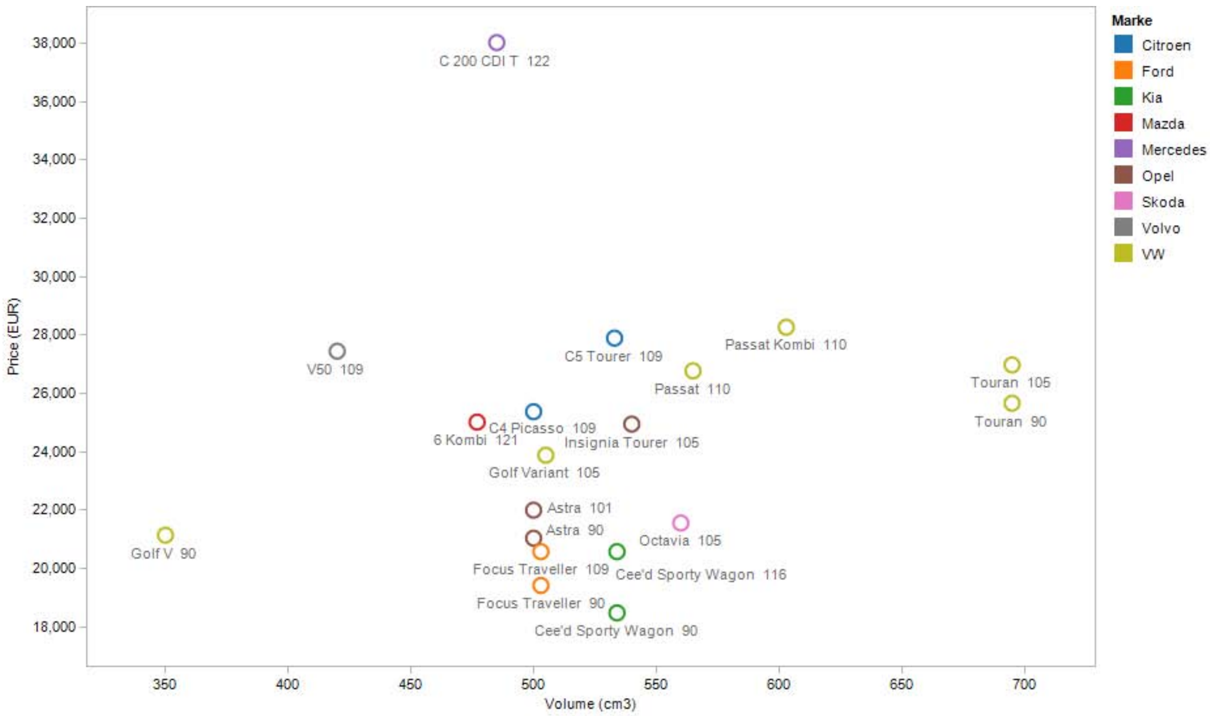
Information Visualization (InfoVis) is an interdisciplinary field of research that is concerned with interactive visualizations of mainly abstract data and has its roots primarily in computer science. The most well-known definition of the field was provided by Card et al. (1999) in their landmark publication *Information Visualization–Using Vision to Think*: "The use of computer-supported, interactive, visual representations of abstract data to amplify cognition." (Card et al. 1999, p. 7). This implies that the ultimate goal of Information Visualization is to amplify cognition. The authors provide some ideas on how this is achieved via InfoVis (cmp. Card et al. 1999, p. 16):

1. Increasing the memory and processing resources available to the user

2. Reducing the search for information
3. Using visual representations to enhance the detection of patterns
4. Enabling perceptual inference operations
5. Using perceptual attention mechanisms for monitoring
6. Encoding information in a manipulable medium

Brand	Type	Volume	Price
Kia	Cee'd Sporty Wagon	534	18490
Ford	Focus Traveller	503	19430
Ford	Focus Traveller	503	20590
Kia	Cee'd Sporty Wagon	534	20590
Opel	Astra	500	21050
VW	Golf V	350	21155
Skoda	Octavia	560	21570
Opel	Astra	500	22010
VW	Golf Variant	505	23894
Opel	Insignia Tourer	540	24960
Mazda	6 Kombi	477	25030
Citroen	C4 Picasso	500	25386
VW	Touran	695	25676
VW	Passat	565	26786
VW	Touran	695	26990
Volvo	V50	420	27460
Citroen	C5 Tourer	533	27907
VW	Passat Kombi	603	28280
Mercedes	C 200 CDI T	485	38038

(a) Data table of numbers and text.



(b) Visualization of data table in form of a scatterplot showing trunk volume on the x-axis, price on the y-axis, brand as color and car type as labels.

Figure 2.6: Example of a small data set represented as (a) table and (b) visualization.
Source: author

The ultimate purpose of InfoVis – to amplify cognition – also leads the way towards *cognitive science* which is discussed in the next chapter.

According to Keim, Mansmann, Schneidewind & Ziegler (2006, p. 10), visual tasks associated with data analysis can be divided into three categories:

- Visual exploration
- Visual analysis
- Visual presentation

With regard to *visual exploration*, the user has no pre-defined hypotheses about the data but the goal is to generate hypotheses via browsing, searching and analyzing the given data set (undirected search). *Visual analysis* supports confirmatory analysis when the user has predetermined hypotheses as a starting point (goal-oriented examination). The main goal in *visual presentation* is to visually communicate findings and analysis results. Following Fekete et al. (2008, p. 2), InfoVis systems are best suited to support visual exploration of large information spaces.

In the following, the basic principles of visual data analysis and their main components will be presented.

2.2.1 Basic Principles

As Chen (2002, p. 1) states

> "[...] information visualization can be broadly defined as a computer-aided process that aims to reveal insights into an abstract phenomenon by transforming abstract data into visual-spatial forms. The intention of information visualization is to optimize the use of our perceptual and visual-thinking ability in dealing with phenomena that might not readily lend themselves to visual-spatial representations."

The basic goal in all data analysis tasks is to gain insight from data (see Figure 2.7). Visualization supports this via visually encoding the data and by harnessing the powerful human perceptual system in order to gain insight from the data via visual information processing (see Figure 2.8).

Human visual perception is the fundamental component on which visualization relies on. The basic functionality of visual perception will be briefly explained in the following.

2.2.2 Perception

The power of visualization lies in the fact that the visual sense is the human sense that has by far the highest bandwidth (amount of data transferred per time unit). Moreover, most visual pattern detection is a hard-wired capability of our perceptual system and, therefore, executed

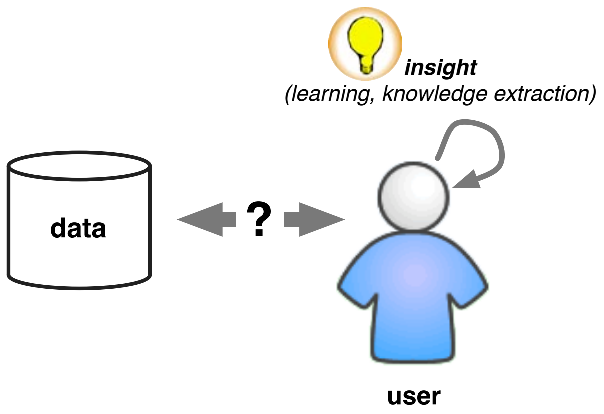


Figure 2.7: The goal of data analysis – to gain insight from data.
Source: author

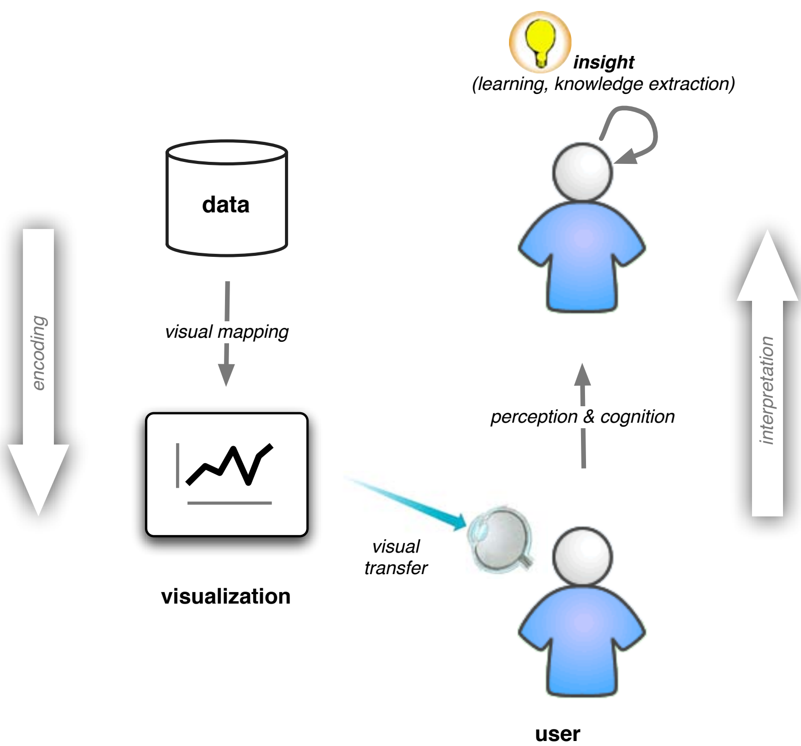


Figure 2.8: Schematic view of how visualization is applied to support data analysis.
Source: author

effortlessly (cmp. Ware 2004, p. 13f). Perception itself consists of both, bottom-up and top-down processes. Two phenomena of perception that are of particular relevance to InfoVis are *preattentive processing* and *Gestalt principles*.

Preattentive Processing

Preattentive processing denotes the phenomenon that certain visual attributes are processed automatically below the level of consciousness as presented in Healey, Booth & Enns (1996, p. 109). This process happens very fast, typically between 200 and 250 milliseconds or less. Attributes at that level, such as color, make elements stand out among a set of other elements. Figure 2.9 shows an example for preattentive processing. Try to solve the task by counting how often the number "5" appears in Figure 2.9(a). Now try to do the same in Figure 2.9(b). It is quite obvious how much easier the task gets in the second case. This is due to the preattentive attribute *color* that is used to make all appearances of the number "5" stand out clearly.

1561321203658413076510374627
4173127527327592732990709742
1703707774179527931749270973
4019743217909370945179279417

(a) No preattentive attributes used.

1**5**613212036**5**8413076**5**10374627
4173127**5**27327**5**92732990709742
1703707774179**5**27931749270973
401974321790937094**5**179279417

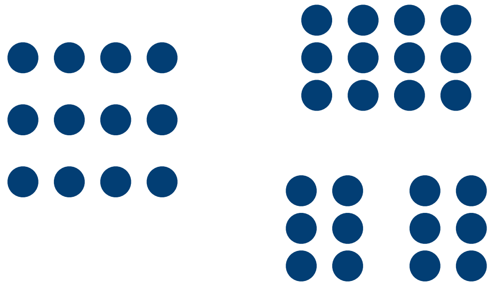
(b) Preattentive attribute *color* is used.

Figure 2.9: Example of a preattentive attribute.
Source: cmp. Ware (2004, p. 163)

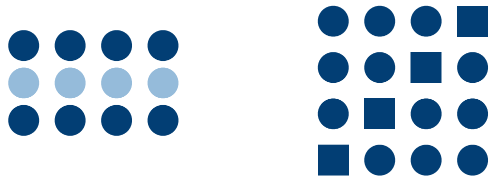
According to Ware (2004, p. 151f) there are four basic categories of preattentive attributes:

1. Color
   (hue, intensity)
2. Form
   (line orientation, line length, line width, size, curvature, added marks, numerosity, spatial grouping, line collinearity)
3. Spatial Localization
   (2D position, stereoscopic depth, concavity / convexity)
4. Movement
   (direction of motion, flicker)

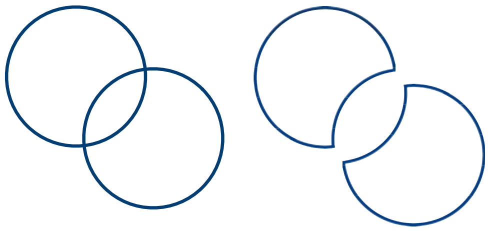
Caution is to be taken when combining multiple preattentive attributes as this can reduce the intended effect and limit preattentive processing.



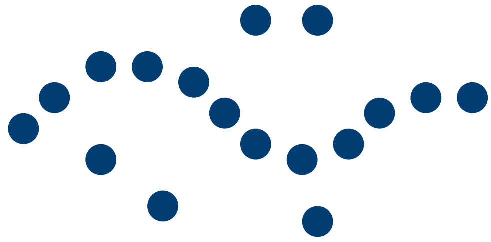
(a) Proximity: Things that are near to each other appear to be grouped together.



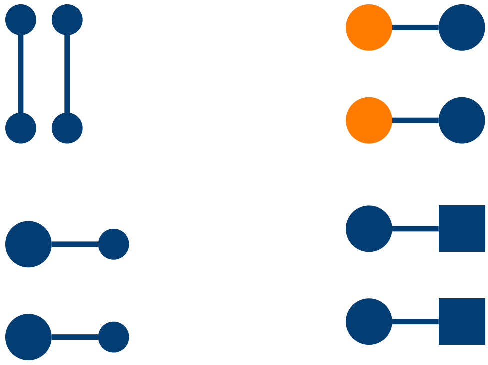
(b) Similarity: Similar things appear to be grouped together.



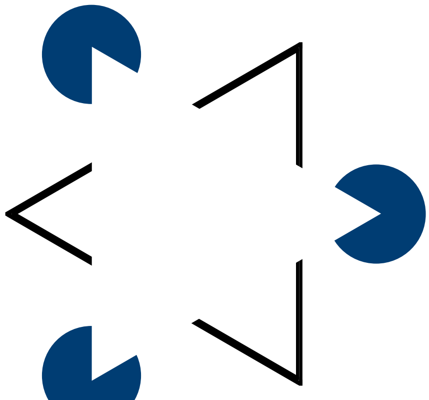
(c) Prägnanz / Simplicity: Every stimulus pattern is seen in such a way that the resulting structure is as simple as possible.



(d) Good Continuation: Points which, when connected, result in straight or smoothly curving lines, are seen as belonging together, and the lines tend to be seen as following the smoothest path.



(e) Connection: Elements that are connected appear to be grouped together.



(f) Closure: The tendency to unite contours that are very close to each other.

Figure 2.10: Gestalt principles.
Source: author

Gestalt Principles

In the case of preattentive processing, certain visual attributes make elements stand out among a set of elements. Gestalt principles present a different set of perceptual phenomena that make multiple elements appear as a group or being related. The experiments that led to the creation of so-called Gestalt principles were conducted by Max Wertheimer, Kurt Koffka, and Wolfgang Köhler within the Gestalt school of psychology in Germany, which started in 1912. The laws of perceptual organization that were discovered by them follow the hypothesis that the mind groups patterns according to rules and they reflect things we know from our experience in our environment and we are using them unconsciously all the time. Gestalt principles are very useful design guidelines. A couple of examples of Gestalt principles are given in Figure 2.10.

2.2.3 Interactivity

As demonstrated before, InfoVis uses visual representations to encode data. But apart from that, interactivity lies at the core of InfoVis as well: “Information Visualization couples interaction and visual representation so its power is better demonstrated interactively.” (Fekete et al. 2008, p. 9). This is in contrast to *static* visual representations, for example printed on paper that can only be viewed passively. According to Yi, Kang, Stasko & Jacko (2007, p. 1224), static visual representations clearly have analytic and expressive value but their usefulness becomes more and more limited the larger the data sets are they represent and the more variables are involved. To provide a more illustrative example, consider a map on paper and Google Maps[8]. Despite the fact that a paper-based map contains huge amounts of information on different layers, a lot more functionality can be provided by *interactive* tools like Google Maps, for example, the representation can be zoomed and panned, locations can be searched for, routes can be calculated, different views can be toggled, and many more.

A useful design guideline for interactive features of InfoVis methods is the *Visual Information Seeking Mantra* by Ben Shneiderman: “Overview first, zoom and filter, then details on demand” (Shneiderman 1996, p. 337). He proposes that a visual overview should be provided as starting point. Moreover, interactive features for zooming and filtering shall be provided to support the visual exploration process. It should also be possible to show additional information on demand for certain data items.

While interactivity has always been considered as a crucial element in InfoVis methods, interaction is treated as side-issue in literature most of the time. Only recently, a small number of publications can be found that focus on interaction itself, as for example the recent paper of Yi et al. (2007, p. 1224ff).

[8]http://maps.google.com, Accessed at: 2009-01-30

2.2.4 Summary & Discussion

The field of InfoVis has generated a considerable amount of methods and techniques for supporting data exploration, analysis, and presentation tasks. However, as it is a relatively young field that started in the first half of the 1990s, it consists of small, quite disconnected pieces. As Liu, Nersessian & Stasko (2008, p. 1077) mention, most importantly: “[T]he field still lacks supporting, encompassing theories”. Therefore, Liu et al. (2008, p. 1077) call for cognitive theories and models as the basis for research. Most empirical studies and evaluations in visualization research have focused on comparing different kinds of visualization based on error rates and task completion times (e.g., comparing pie charts and bar charts or tables and line charts) (cmp. Chen & Yu 2000, Chen & Czerwinski 2000, Plaisant 2004). It has recently been recognized, e.g., in (Saraiya et al. 2006, Smuc, Mayr, Lammarsch, Bertone, Aigner, Risku & Miksch 2008), that the ultimate goal of visualization and data analysis is to gain valuable insights into the data and that *insights* should be the basis of measurement rather than error rates or task completion times. However, following the literature on research conducted, there are no theoretic models that sufficiently describe the role of interactivity, no empirical evaluations of the immediate effects of interactivity and almost no systematic accounts for investigating the user’s perspective on the value and role of interactivity in InfoVis and data analysis. This lack of research has also been accounted for in the new area of Visual Analytics that aims to create a sound scientific basis for interaction called “science of interaction” (Thomas & Cook 2005, p. 73ff).

In the next chapter the two areas of Business Intelligence and Information Visualization will be related in the field of Visual Business Intelligence.

2.3 Visual Business Intelligence

"Solving a problem simply means representing it so that the solution is obvious."
Simon (1996), cited in Thomas & Cook (2005, p. 50)

To put it in a nutshell,

Visual Business Intelligence = Business Intelligence + Information Visualization.

The term itself has been coined by Few (2007) and denotes the use of interactive visual methods in the field of BI. It follows the call for advanced visualization in BI as stated in the chapter on BI.

As Borzo (2004) reports, "[e]xecutives in a broad range of industries around the world are finding that information-visualization software helps them make critical business decisions by cutting through information overload." Interactive visualization can be applied to provide a quick overview of large amounts of data along with the means to interactively drill-down into whatever level of detail needed. It enables managers and experts to see patterns and relationships in the data using visual means that they would probably not have noticed otherwise.

The current popular reports and dashboards represent only a fraction of Visual BI that supports mainly presentation tasks. More sophisticated and, most importantly, interactive techniques need to be utilized to provide support for analysis and exploration. "A review of current BI software products reveals that the visualizations included in them are often quite ineffective in communicating important information" (Ahokas 2008, abstract). Related to that Kohlhammer, Tekusova & Bange (2008, p. 24) report that broadly used BI products did not improve interactivity during the last years, even to the contrary, the moves towards web-based versions even worsened the situation.

Visual BI seeks to change this by introducing advanced visualization possibilities to BI. The first steps in this direction can already be observed in industry. Along with the rise of business analytics, Visual BI has grown very fast lately and can be traced by recent mergers and acquisitions where large BI vendors have acquired companies specialized in InfoVis and visual data analysis as reported in Bange (2008, p. 3f). Swoyer (2007) says, "Data visualization is one of the hottest segments in BI right now, with a host of vendors – both old and new – plying the trade [because] [...] it provides a better way to consume and act upon data – better, that is, than traditional reporting and analysis tools"

One open question in this regard is, whether Visual BI tools are suited to be used by *all* managers and experts in a company. In Swoyer (2007), Wayne Eckerson, director of TDWI Research, expresses the opinion that "[...] advanced data viz is getting more use (sic!) by power users [...] it takes time to understand the new visual paradigms and chart types, and only power users have the patience for that". On the other hand, this might also be a question of user interface and interaction design, which means how usable and easy to learn the new tools are.

2.4 Summary & Discussion

In the previous chapter, the fields of Business Intelligence, Information Visualization and Visual Business Intelligence are described. Huge amounts of data, ever growing in size and complexity, lead the way towards advanced visualization and interaction methods to be applied in the context of BI.

Two clear gaps were identified: First, there is a lack of underlying theories for InfoVis and second, the phenomenon of interactivity has not received enough attention so far. The goal of this thesis is to focus on the second issue of *interactivity*. As a first step, the field of *interactivity* will be approached from different perspectives in order to shed some light on what interactivity actually means and what its value might be. While the first mentioned gap of missing theory affords some larger effort to be solved, we will follow the suggestion by Liu et al. (2008, p. 1077) and investigate cognitive theories and models with a clear focus on interactivity in order to find out whether they can provide a theoretical basis in the following chapter.

Chapter 3

Theory

"Although theory without experiment is empty, experiment without theory is blind."
(Thagard 1996, p. 8)

3.1 Cognitive Theories and Models

3.1.1 Cognitive Science

"Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology." (Thagard 1996, Preface). A central idea of cognitive science that emerged in the mid 1950s is that "[t]hinking can best be understood in terms of representational structures in the mind and computational procedures that operate on these structures." (Thagard 1996, p. 10). Following this, one approach of cognitive science is to compare the mind with computers leading to a Computational-Representational Understanding of Mind (CRUM) (cmp. Thagard 1996, p. 11):

Program	**Mind**
data structures	mental representations
+	+
algorithms	computational procedures
=	=
running programs	thinking

Different approaches towards cognitive science were developed over the years, which are now presented briefly following the work of Thagard (1996, p. 23ff).

1. The first approach is that of *formal logic*, which has its roots in the ancient Greek philosophy of Aristotle. Here, inferences are made based on statements. A famous example is to infer from the two statements "all humans are mortal" and "Aristotle is human" that "Aristotle is mortal".

2. In the second approach, the mind is modeled by using *rules*. Basically, it assumes that IF-THEN statements are the representational structures in the mind that are getting processed. For example "IF it is raining THEN the streets are wet".

3. The third approach of *concepts* was developed by Minsky (1975). It says that thinking is understood as frame application rather than logical deduction. It proposes that we have cognitive scripts or frames that are getting parameterized and instantiated. It assumes that we have representations of typical entities or situations rather than strict definitions as in the rule-based approach.

4. The fourth approach of *analogies* postulates that we are dealing with new situations by adapting similar situations that are already familiar to us. This approach is often also called *case-based reasoning*.

5. In the fifth approach of *images*, mental representations are assumed to be picture-like. This view is also reflected in the theories of many philosophers from Aristotle to Descartes and Locke.

6. The newest and sixth approach is about *connections*, which says that the mind is modeled as a neural network of simple nodes and links that are highly interconnected. It is based on the advances in brain science, which identified the biological entities of neurons. This allows for parallel, distributed processing and parallel constraint satisfaction.

Cognitive Architectures

Computer science and especially Human-Computer Interaction (HCI) draw upon cognitive science approaches to model the interaction between humans and computers in so-called *cognitive architectures*. Byrne (2003, p. 97ff) provides a useful overview of the approaches that have been developed in the past. Examples are *Model Human Processor (MHP)*, *GOMS (Goals, Operators, Methods, and Selection rules)*, *Cognitive Complexity Theory (CCT)*, *Collaborative Activation-based Production System (CAPS)*, *Soar*, *LICAI/CoLiDeS*, *Executive Process Interactive Control (EPIC)*, and *ACT-R 5.0*. The first two attempts to conceptualize HCI are well known in the community. Apart from these, cognitive architectures have been implemented in computer systems. Almost all of the mentioned frameworks are production rule systems that build upon IF-THEN rules.

Model Human Processor (MHP) was proposed by Card, Newell & Moran (1983, p. 23ff) and provides a framework resulting from a synthesis of the literature on cognitive psychology and human performance up to that time. It describes a system that is composed of different types of memories and processors along with performance measures that are grounded on empirical studies (see figure 3.1 for an overview of the framework). In MHP, the human mind is a specific type of an information processing unit, which has three subsystems (cmp. Kaptelinin 1995, p. 103f):

1. sensory input subsystem
2. central information processing subsystem
3. motor output subsystem

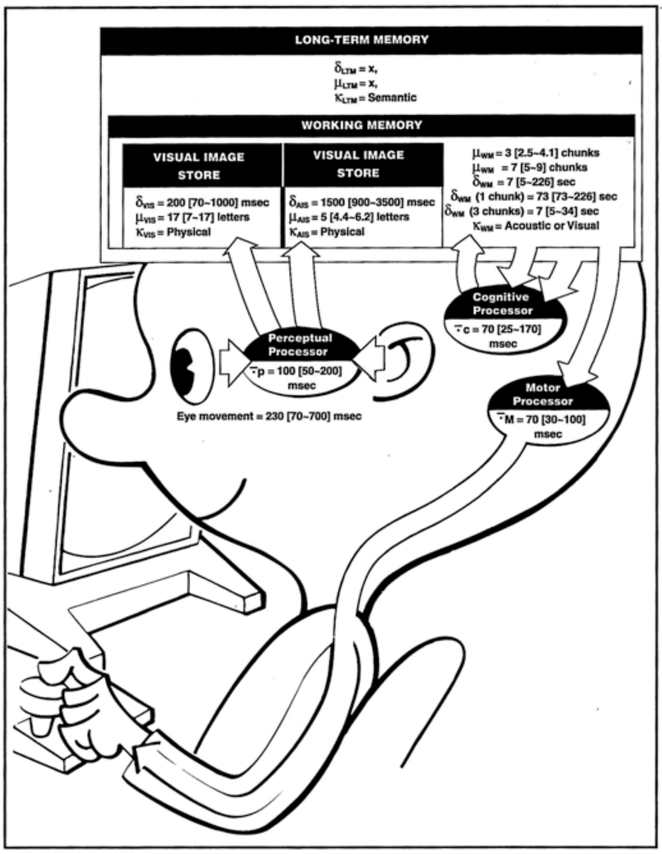


Figure 3.1: Model Human Processor (MHP).
Source: Card et al. (1983, p. 26)

GOMS (Goals, Operations, Methods, and Selection rules) is an attempt to provide a framework for task analysis, which describes routine cognitive skills in terms of the four components – goals, operations, methods and selection rules. It was also developed by Card et al. (1983, p. 139ff) and describes the hierarchical procedural knowledge a person must have to successfully complete a task:

- Goals are users' intentions to perform a task.
- Operations are elementary physical actions (e.g., moving mouse, pressing a key).

- Methods are sequences of operations to accomplish specific goals.
- Selection rules specify conditions under which certain methods are executed in order accomplish a specific goal.

Moreover, quantitative predictions about the execution time for a particular task can be made. A number of different and extended forms of GOMS analyses have been developed, for example NGOMSL (Natural GOMS Language). A problem of this approach is that it is applied at a very atomic level of keystrokes and mouse moves and is therefore cumbersome to apply for more complex systems.

Criticism

The main points of criticism of the mentioned approaches are that neither physical nor social environments are recognized properly as cognitive science focuses on phenomena inside the head of a single human being:

> "The information processing loop is closed, so it is difficult to take into consideration the phenomena that exist outside it. It is obvious, however, that human-computer interaction can be understood only within a wider context" (Kaptelinin 1995, p. 54).

Therefore, so-called "post-cognitivist theories" were developed that take these external factors into account. These approaches will be presented in the following.

3.1.2 Postcognitivist Theories

As mentioned before, traditional cognitive science largely neglects the role of environmental and social factors in cognition:

> "Traditionally cognition has been regarded in terms of internal symbolic representations and computational processes, while the environment largely has been reduced to inputs and outputs [...] we still have only a limited understanding of the ways artifacts are used and adapted to support cognitive capabilities" (Susi 2005, p. 2110).

Artifacts in particular are of special interest to HCI because computer tools can be seen as cognitive artifacts for external cognition that expand human capabilities (cmp. Norman 1993, p. 127ff). Their use not only affects the individual but also social interactions. The role of artifacts and social environments is emphasized in the theories, which will be presented next – *Situated Action*, *Distributed Cognition*, and *Activity Theory*.

Situated Action

According to Kaptelinin & Nardi (2006, p. 16), Suchman (1987) challenged the assumption that human cognition can be modeled in a computer program and introduced a new theory of *Situated Action*. Thagard (1996, p. 157) notes that Situated Action sees human beings as thinking through interaction with the world rather than by means of representing it and processing these representations – the individual's actions are influenced by the context of their specific situation. Or as Nardi (1995, p. 72) puts it

> "[a] central tenet of the situated action approach is that the structuring of activity is not something that precedes it but can only grow directly out of the immediacy of the situation".

It builds upon the concept that the specific situation is the most important factor in determining what people will do. Thus, if every situation is different, people's behavior cannot be generalized from one situation to the next, which rejects generalization and abstraction as noted by Kaptelinin & Nardi (2006, p. 17).

Moreover, Dourish (2001, p. 100) points out that "[...] the ways in which we experience the world are through directly interacting with it, and that we act in the world by exploring the opportunities for action that it provides to us [...]." To put it more simply, Situated Action postulates that we do not primarily form a goal in our mind and generate a detailed plan of action which is then executed as suggested in traditional cognitive science, but we are rather determined by and emerge in the specific situation via the opportunities for action it provides to us. The last definition – "opportunities for action" – in particular, points clearly to the notion of "interactivity".

> "These days, this idea of dialogue is central to our notion of "interaction" with the computer, replacing configuration, programming, or the other ideas that had largely characterized the interplay between users and systems in the past." (Dourish 2001, p. 10).

Distributed Cognition

Distributed Cognition largely originated from the work of Edwin Hutchins and colleagues at the University of California, San Diego in the mid 1980s as reported by Liu et al. (2008, p. 1077). The basis for this approach is the Hutchin's field study (Hutchins 1996) aboard a naval ship, where he observed and analyzed group processes, for example navigating into a harbor. As Thagard (1996, p. 162) puts it, "[c]ognition is said to be "distributed", meaning that it occurs not just in individual minds but through the cooperation of many individuals." People, tools, systems, etc. are all "media" and part of a system of nodes while human and nonhuman nodes are of the same type. Structures inside the human body as well as outside of it are part of the same cognitive system and treated equally. This means that knowledge is not only represented inside the heads of individuals but also in the artifacts we are utilizing. Apart from being concerned with the structure of the cognitive system, Distributed Cognition also deals with the question of what transformations these structures undergo.

In contrast to the Situated Action approach in which a subject is the starting point whose actions are influenced by interacting with the world in a certain situation, Distributed Cognition emphasizes not the individual level but the cognitive system as a whole, which consists of different nodes that interact with each other.

Another central concept of Situated Action as well as Distributed Cognition is *embodiment* and *embodied interaction*. Dourish (2001, p. 100) describes it as “the creation, manipulation, and sharing of meaning through engaged interaction with artifacts” and that it is “[...] the common way in which we encounter physical and social reality in the everyday world.”

Nardi (1995, p. 78) mentions that another major element of Distributed Cognition is to understand the coordination among individuals and artifacts, that is, to understand how individual agents align and share within a distributed process . Thus it is of particular interest when dealing with interactivity. This led to a first attempt to adopt Distributed Cognition as the underlying theory for InfoVis in (Liu et al. 2008).

Activity Theory

Kaptelinin & Nardi (2006, p. 31) provide a concise definition of activity theory:

> “Activity theory is an approach in psychology and other social sciences that aims to understand individual human beings, as well as the social entities they compose, in their natural everyday life circumstances, through an analysis of the genesis, structure, and processes of their activities.”

Activity Theory distinguishes clearly between individual human beings and things. Moreover, a cornerstone of Activity Theory is that people deliberately commit certain acts by using certain technologies. This is at odds with the Distributed Cognition theory where both, people and artifacts are types of “media” in a system of nodes as reported by Kaptelinin & Nardi (2006, p. 203). However, Distributed Cognition takes both points of view throughout the work of Hutchins (1996) – that of tool mediation and human performance which clearly separates humans and tools, as well as that of a cognitive system of like nodes. Activity Theory is an answer to both points of criticism of traditional cognitive science by including a rich social matrix of people and artifacts that grounds analysis: “The focus of activity theory is on *purposeful, mediated, human social activities*” (Kaptelinin & Nardi 2006, p. 27). Moreover, it takes into account cultural factors and developmental aspects of human mental life. The aspect of purposeful activities that are carried out deliberately is in contrast to Situated Action. In the context of Situated Action, cognition and action is subject to influence by the environment and often not based on the deliberate and conscious goals of individuals.

Activity Theory is based on Aleksey Leontiev’s work *Activity, Consciousness, and Personality (1978)* and its roots go back to the work carried out in the former Soviet Union dating back to the 1920s. According to Kaptelinin & Nardi (1995, p. 104ff, 2006, p. 29ff) there are seven basic principles underlying Activity Theory which shall be presented next.

Basic principles

- unity of consciousness and activity
  This implies that activities are carried out deliberately by humans.
- social nature of the human mind
  "[S]ociety and culture are not external factors influencing the human mind but rather generative forces directly involved in the very production of the mind" (Kaptelinin & Nardi 2006, p. 65).
- object-orientedness
  Objects of activities can be thought of as "objectives" that give meaning to what people do. Moreover, Activity Theory differentiates between *objects* and *motives*, while there may be radically different motives for the same object, for example, the object of "finishing a master's thesis". The motives for this object might be "breaking new scientific ground" or also "earning an academic degree".
- hierarchical structure of activity
  Activities consist of *actions* which may include *operations*. Activities are oriented towards motives we might not be aware of immediately. Actions are directed towards goals we are aware of. And operations are routine processes we are typically not aware of. A person might want to go from Vienna to Krems. In order to do so, she has to conduct actions like getting the car out of the garage and driving it to Krems. The action of "car-driving" can further be decomposed into operations like shifting gears or hitting the breaks, which we are usually not aware of consciously.
- internalization–externalization
  This describes mechanisms on how mental processes are derived from external actions (internalization), (for example, using your fingers when learning to count) and how mental processes are externalized (for example, using pen and paper for performing a multiplication).
- mediation
  "Human activity is mediated by a number of tools, both external (like a hammer or scissors) and internal (like concepts or heuristics)" (Kaptelinin 1995, p. 55).
- development
  Human development is considered an important factor.

> "In activity theory, **people** act **with technology**; technologies are both designed and used in the context of people with intentions and desires. People act as **subjects** in the world, constructing and instantiating their intentions and desires as **objects**. Activity theory casts the relationship between people and tools as one of **mediation**; tools mediate between people and the world." (Kaptelinin & Nardi 2006, p. 10).

The unit of analysis in Activity Theory is an *activity* which is composed of *subject*, *object*, *actions*, and *operations*. The subject is a person or a group that is engaged in an activity. The object is the objective held by the subject. Actions are goal-oriented processes that must be carried out in order to fulfill the objective and actions might have operational aspects, which are low-level processes we are not aware of most of the time.

3.1.3 Summary & Discussion

A number of traditional cognitive science approaches as well as post-cognitivist theories and models were presented in the last section. In general, Activity Theory appears to be the most encompassing theory but also the most complex one. To compare these approaches, it is helpful to take a look at the unit of analysis of the individual approaches:

Model / Theory	**Unit of analysis**
Traditional Cognitivism	individual mind
Situated Action	people acting in a situation
Distributed Cognition	cognitive system composed of individuals and artifacts
Activity Theory	(purposeful, mediated, human social) activity

In a report at Indiana University School of Informatics (2007), postcognitivist theories of Situated Action, Distributed Cognition, and Activity Theory are represented in a coordinate system along the axes of Classic Systems Theory – Cognizant Human Actors and Subjective Pragmatist – Objective-Rationalist as depicted in Figure 3.2.

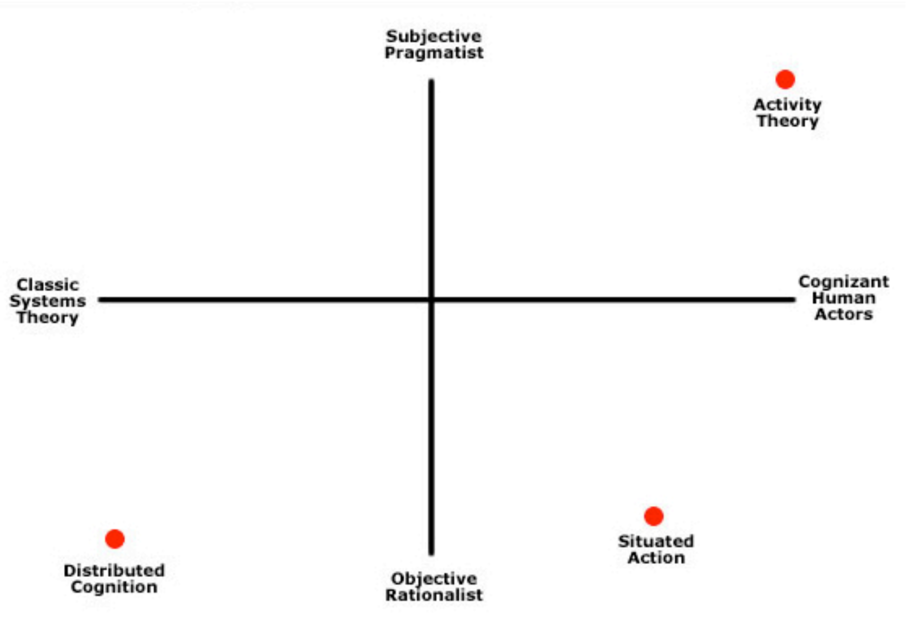


Figure 3.2: Comparison of postcognitivist theories.
Source: Indiana University School of Informatics (2007)

In terms of interactivity, traditional cognitive science focuses on user-system interaction, where interaction itself is modeled mainly as simple input and output channels. Postcognitivist theories in turn do not focus merely on interaction between people and technology but take into account the objects in the world with which subjects are interacting via technology in a social context.

In the next chapter, the nature of *interactivity* itself will be analyzed from different perspectives.

3.2 Interactivity

Now that we have peeled off the last layer, we arrive at the core – the complex and multi-faceted phenomenon of *interactivity*. We want to explore what interactivity actually is, find out details about its nature and how it might help us to accomplish tasks easier. The terms “interactivity”, “interaction”, and “interact” are ubiquitously used nowadays. We talk about interactive media, interactive software, interactive books, etc. But a concise definition of interactivity is hardly ever given. Basically, the focus will be on the nature of interactivity when people are dealing with visual tools on computer systems. However, this will be done in the broader context of people interacting with tools in general. For that matter, we will take on several perspectives based on InfoVis, HCI, and Cognitive Science.

Earlier the example of paper maps vs. Google Maps was presented. In this context, it was argued that paper maps are static in its very nature because their content is not manipulable. Google Maps, in turn, are highly interactive since we are able perform a broad range of actions on the representation and change and manipulate its contents. To lift it onto the level of media, we would say that paper is static and the WWW is interactive. But what if we cut and fold the paper map? Isn’t that also interaction? And what if we use a paper map to find a certain street? We are obviously interacting with the world but where does the interactivity reside? In our tools? In us human beings? Albeit it sounds easy to define interactivity, we can see that we thought we might know what it is, but when digging deeper, the concept dissolves like water between our fingers.

Referring to the map example, InfoVis and Visual BI experts state that interactivity is one powerful concept that enables us to improve analysis processes in many ways. Some studies (Saraiya et al. 2006) also report that this is the case but research on describing WHY and HOW this is the case and the mechanisms behind it, is largely missing.

In order to be able to grasp the concept of interactivity, we follow the path of Stromer-Galley (2004, p. 391ff) who argues that we have to tackle interactivity from two perspectives – *interactivity-as-product* and *interactivity-as-process*. In the first view, interactivity is seen as a property of the medium itself, whereas in the second, interactivity is conceptualized as intangible concept of a process. These two views shall be used as starting points for further investigation.

3.2.1 Interactivity-as-Product

In this section, we will focus on interaction between humans and the computer system with a particular focus on InfoVis. In the tradition of InfoVis, interactivity is mainly seen as a property of the tool in terms of the elements offered for user interaction. InfoVis emphasizes the role of interactivity already in the early definition of Card et al. (1999, p. 7) while it is stated that interaction support is just as important as the visual representation itself. Ware (2004, p. 176) states that

> "[t]he ideal cognitive loop involving a computer is to have it give you exactly the information you need when you need it. This means having only the most relevant information on screen at a given instant. It also means minimizing the cost of getting more information that is related to something already discovered"

According to Spence (2007, p. 136),

> "[i]nteraction between human and computer is at the heart of modern information visualization and for a single overriding reason: the enormous benefit that can accrue from being able to change one's view of a corpus of data. Usually that corpus is so large that no single all-inclusive view is likely to lead to insight. Those who wish to acquire insight must explore, interactively, subsets of that corpus to find their way towards the view that triggers an 'a ha!' experience".

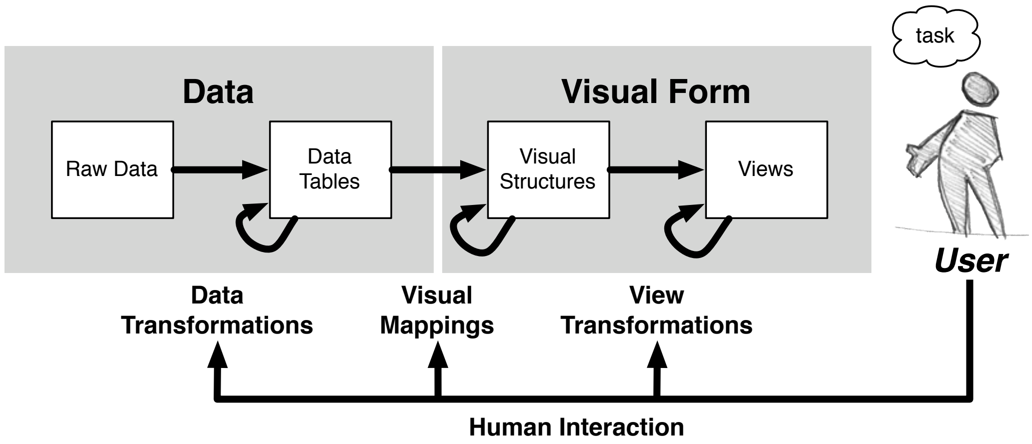
However, while the enormous benefits of being able to change one's view are often stated, there is hardly ever an answer to the question of what these benefits actually are as well as how and why they work.

A well known way of conceptualizing InfoVis is the *Information Visualization Reference Model* developed by Card et al. (1999). It describes InfoVis as a multi-step process that transforms raw data into visual representations for users with certain tasks and offers points of interaction (figure 3.3). In this model, human interactivity is conceptualized as *points of influence* on certain transformation processes. Following this, interactivity in visual methods could be defined as whether such points of influence are present, which allow for an active discourse with the data.

In this regard, InfoVis is mostly concerned with the way interaction is carried out. This refers to interaction techniques like zooming and panning or interaction styles such as *direct manipulation*.

Ways of Interaction

Over the years, different *interaction styles* have been developed in HCI, such as command line or graphical "point-and-click" interfaces as listed in (Preim 1999, p. 137). Of particular importance to InfoVis is the interaction style of *direct manipulation*.



Raw Data: idiosyncratic formats
Data Transformations: Mapping raw data into an organization appropriate for visualization
Data Tables: relations (cases by variables) + metadata
Visual Mappings: Encoding abstract data into a visual representation
Visual Structures: spatial substrates + marks + graphical properties
View Transformations: Changing the view or perspective onto the visual presentation
Views: graphical parameters (position, scaling, clipping, ...)
Human Interaction: User influence at any level

Figure 3.3: Information Visualization Reference Model.
Source: cmp. Card et al. (1999, p. 17)

Direct Manipulation was developed in the mid 1980s (cmp. Hutchins, Hollan & Norman 1985, Shneiderman 1983) and builds upon the principle of "physical" manipulation of graphical objects on the screen. The difference between command line and direct manipulation interfaces might best be described by the analogy of driving a car. Steering wheel, accelerator, and brake pedals are means of interaction that can be operated physically while immediate feedback is provided (e.g., the car turns right when we turn the steering wheel to the right). Now imagine you have a keyboard for controlling a car where you would have to type in commands like "turn right", "brake", or the like. Considering this, the advantages of direct manipulation become clearer.

According to Hutchins et al. (1985, p. 311), a major point of importance of direct manipulation is the fact that it gives a feeling of directness of manipulation. Reducing the information processing distance between the user's intentions and the facilities provided by the machine, makes the interface feel more direct by reducing the effort required by the user to accomplish goals. It is assumed that this feeling of directness results from the commitment to fewer cognitive resources as Hutchins et al. (1985, p. 317) point out. The basic principles of direct manipulation are

- Visual representation: Objects to be dealt with are directly visually represented on the interface.
- Rapid, incremental, reversible actions: Interaction consists of chains of actions upon the

visually present objects that are reversible.

- Pointing instead of typing: Objects are manipulated directly using a mouse or other pointing device rather than indirectly via commands.
- Immediate, continuous feedback: During interaction with objects, the objects are continuously visible and provide instantaneous feedback on the result of an operation.

From a cognitive point of view, there are two main aspects of directness – *distance* and *engagement*. Norman (1988, p. 45ff) describes two types of distances, which he termed *gulf of execution* and *gulf of evaluation*, which are part of his execution-evaluation cycle shown in Figure 3.4. Starting from a goal, an intention is formed, an action plan is formed and the plan is executed in order to cause a change in the world. This chain from one's goal to a change in the world is called *gulf of execution*. Upon a change in the world, the system state is perceived, interpreted, and evaluated, which leads to further goals. Looking at it from this direction, it is called *gulf of evaluation*. Direct manipulation helps to bridge these gaps with less effort and "[t]he better the interface of a system helps bridge the gulfs, the less cognitive effort needed and the more direct the resulting feeling of interaction" (Hutchins et al. 1985, p. 318).

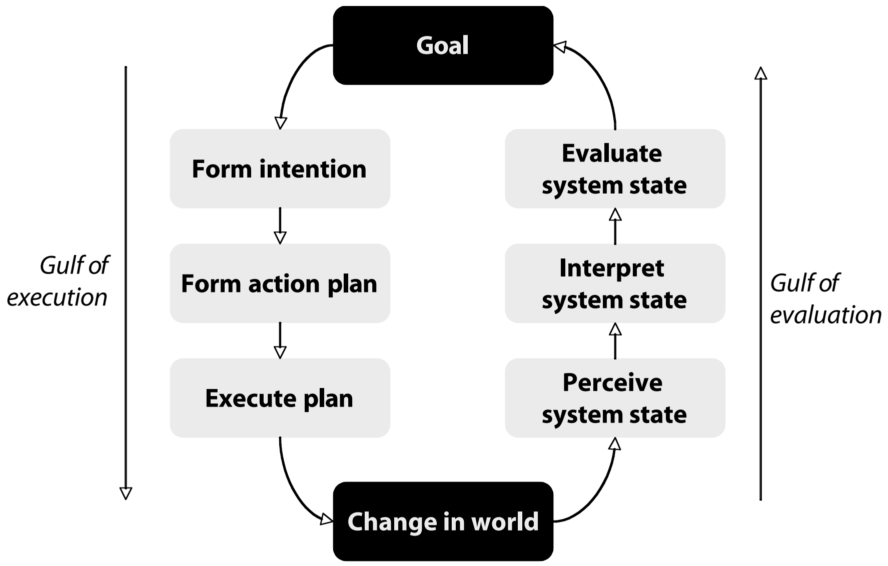


Figure 3.4: Norman's execution-evaluation cycle.
Source: cmp. Norman (1988, p. 45ff)

Engagement, the second main aspect of direct manipulation, refers to "a feeling of first-personness, of direct engagement with the objects that concern us" (Hutchins et al. 1985, p. 318). This provides a feeling of control that is generally perceived positively in contrast to communication with an intermediary.

To signal that a tool or medium provides means for interaction, artifacts include *triggers*, *placeholders*, and *entry points* points in order to decrease the gulfs of evaluation and execution. The conceptualization of these means follow the idea of *affordances* used by Norman (1988,

p. 9f). They can be characterized as perceivable properties of a system that provide clues of its use. For example, a mouse wheel provides the cue that it can be turned. In differentiating affordances further, “a trigger is something that prompts an activity, something that tells you that you need to do something” (Susi 2005, p. 2111, cmp. Dix, Ramduny-Ellis & Wilkinson 2004), for example an alarm in a calendar. According to Dix, Ramduny-Ellis & Wilkinson (2004, p. 388f), placeholders are cues that tell you *what* to do, for example in a to-do list, and Kirsh (2001, p. 305) describes entry points as providing cues for entering an information space, for example a popup window that tells you that you have mail.

Instrumental Interaction Domain objects are often not manipulated directly but via instruments as mediators between users and domain objects. Beaudouin-Lafon (2004, p. 17) calls this *instrumental interaction* where “interaction instruments are user interface components that transform user actions into commands for domain objects” (Kaptelinin & Nardi 2006, p. 83) (see Figure 3.5). Hence, a differentiation is made between domain objects and interaction instruments.

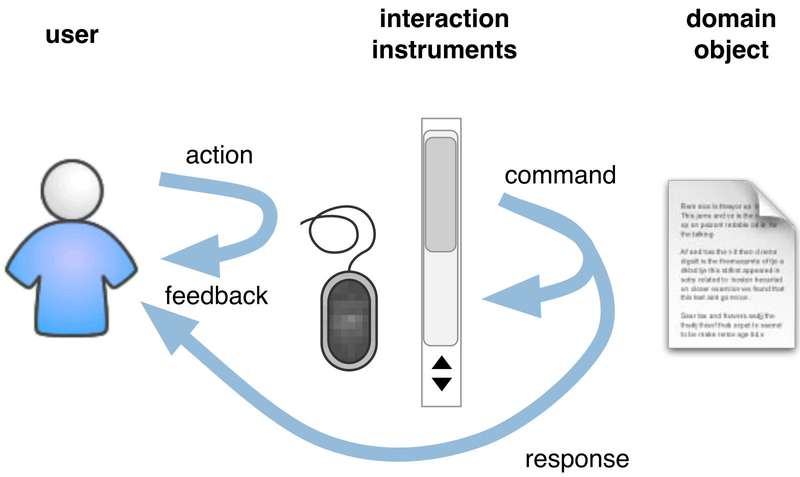


Figure 3.5: Instrumental Interaction – user interface components transform user actions into commands for domain objects.
Source: cmp. Beaudouin-Lafon (2004, p. 17)

Interaction Devices In a usual work setting today, typing and pointing devices (keyboard and mouse) are used as input and display devices or printers are used as output for human-computer interaction. Apart from that, other devices and specialized hardware like joysticks, styluses, tablets, data gloves, helmets, or caves might be used to interact. Moreover, also non-physical interaction via speech recognition, eye-movement recognition or electrical signals of nerves or the brain might be used.

Interaction Techniques Most research work conducted on interaction in the area of InfoVis is concerned with the concrete *interaction techniques* available. Preim (1999) defines it as "a means provided by a system to conduct an interaction task."[1] (Preim 1999, p. 525, transl. by the author). Interaction techniques usually do not encompass hardware. As already mentioned, a couple of attempts have been made to categorize interaction techniques. Two of them will be presented now; the first one is more general and originated from HCI and the second one is focused on InfoVis.

Raskin (2000, p. 104) identified the following set of elementary operations:

- indication: Feedback of the system that the user knows at all times to what object the system thinks s/he is pointing.
- selection: distinguishing from other contents; either single objects, regions, or composites (union of selections).
- activation: triggering actions.
- modification/usage.
  - generation: new object(s).
  - deletion: removing object(s).
  - movage: insertion in one place and deletion from another.
  - transformation: manipulating object(s).
  - copy: duplication of object(s).

When considering InfoVis methods, more powerful interaction techniques, such as zooming and panning or distortion method,s have been developed, which do not fit well into the conceptualization by Raskin (2000, p. 104). In a recent attempt in the InfoVis community, Yi et al. (2007, p. 1226ff) proposed the following categorization:

- select: mark something as interesting; e.g., brushing
- explore: show something else; e.g., navigation
- reconfigure: show a different arrangement; e.g., swap x and y axis of a scatterplot
- encode: show a different representation; e.g., switching to a different visualization method
- abstract/elaborate: show more or less detail; e.g., details on demand
- filter: show something conditionally; e.g., dynamic queries

[1] Translated from the German original version by the author: "Von einem System bereitgestellte Möglichkeit, eine Interaktionsaufgabe auszuführen." (Preim 1999, p. 525)

- connect: show related items; e.g., linking

A well known example for interaction techniques from the category of filtering are *Dynamic Queries*:

> "Dynamic queries, enabled through simple filtering controls such as sliders, offer an enormous advantage when exploring data. These query devices represent a big leap in usability, although I suspect that we will see continued evolution of such user interfaces to the point that we do not even notice them, but interact with them entirely intuitively" (Few 2007).

Few also describes the benefits of dynamic queries to BI by stating that "[...] in most BI software you would have to define the range, submit the query, and wait for the results; but with this slider, we can adjust the range dynamically and see the results change in the graph as we do so" (Few 2007). Figure 3.6 shows an example of a dynamic query applied to the visualization that was introduced in the previous chapter.

To the right of the scatterplot visualization, two *range sliders* are used for filtering trunk volume and car price, and a set of checkboxes is used for selecting brands. In this example all cars of brands other than Kia, Mercedes, and Volvo that cost less than 27,400 and have a trunk volume between 504 and 695 cm^3 are selected. Dynamic queries are also an example for *instrumental interaction* while the filter widgets are the interaction instruments that transform user actions into commands for scatterplot visualization (the domain object).

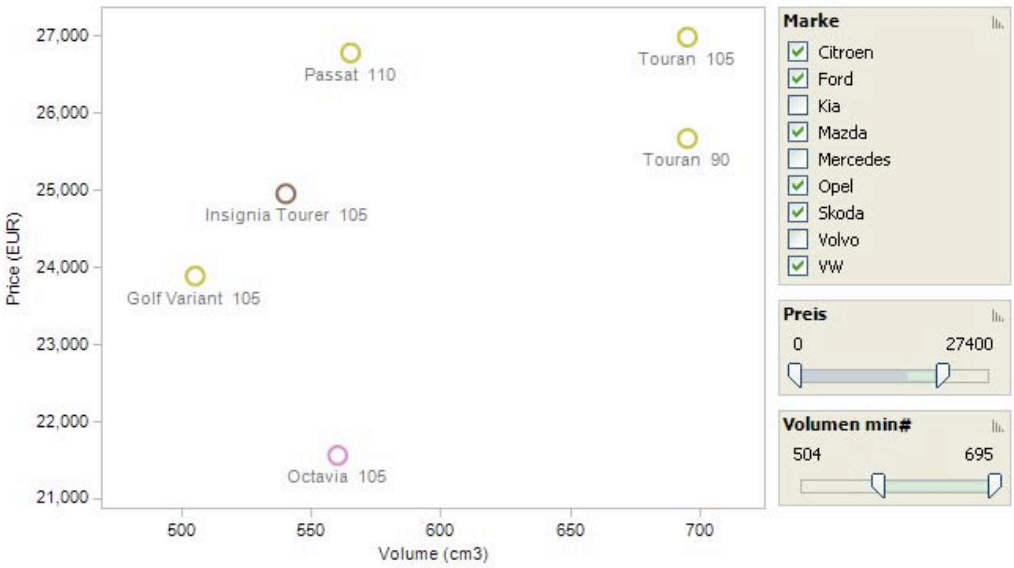


Figure 3.6: Dynamic Query Example – Two *range sliders* are used for filtering trunk volume and car price and a set of checkboxes is used for selecting brands.
Source: author

Interactivity is not simply a yes/no property of a tool or medium, but there are different degrees of interactivity as described in the next section.

Degree of Interactivity

Steuer (1992, p. 78) defines the degree of interactivity as "the extent to which users can participate in modifying the form and content of a mediated environment in real-time", which means that the degree of interactivity is determined by the interaction techniques present in an interface. For example, an interface that only allows for zooming and panning has a lower degree of interactivity than one that additionally provides highlighting and dynamic querying.

So far we have investigated interactivity from a product-oriented view, i.e., interactivity is seen as a property of the tool or medium per se independent of the actual use. The second point of view of interactivity as a process will be presented in the next chapter.

3.2.2 Interactivity-as-Process

Not the features of a tool or medium are the focus of interest in interactivity-as-process, but the process of active discourse of users with the data. Therefore, also the user's tasks, goals as well as the interaction context is taken into consideration. As reported by Kaptelinin & Nardi (2006, p. 11), the use of tools is deeply rooted in human development and even precedes the use of language.

The postcognitivist theories presented in the previous section mainly follow this approach and focus on the process of interaction itself – activities of people using technology. In traditional HCI, the more narrow view of user-system interaction is taken.

While this attempt is much richer with regard to including aspects related to users, the interactivity of artifacts themselves is not an issue. Consider for example the activity of driving a nail into a wall with a hammer. In this activity, a person is interacting with a tool (the hammer) as well as the environment while the tool itself is not manipulable but rather used to manipulate the world.

Moreover, this view also implies that interactivity is highly context-dependent. For example, when the person with the hammer and the nail stands in a room of metal walls, the interactivity of driving the nail in a wall with a hammer cannot be exerted (cmp. Laurel 1993, p. 21).

In addition, every process of perception can be considered as interaction with the environment. Visual perception itself is a dynamic process and does not work just like a digital camera. Quite on the contrary, visual perception is a highly dynamic process that is determined by many internal factors such as attention, focus or experience, as Ware (2004, p. 20ff) describes. Therefore, we interact with our environment through the very process of visual perception, and things that are not relevant in our visual field are suppressed and, thus, not perceived. An example for such a phenomenon is in-attentional blindness, where certain layers of action are not seen because visual attention is focused on other parts of a scene. Simons & Chabris (1999, p. 1059ff) describe an experiment where a gorilla is walking through a scene of basketball players without being noticed by observers that are asked to count the number of passes between players in the foreground.

After the presentation of the notions of interactivity-as-product and interactivity-as-process, the question regarding the value of interactivity is investigated.

3.2.3 The Value of Interactivity?

> "I don't know what percentage of our time on any computer-based project is spent getting the equipment to work right, but if I had a gardener who spent as much of the time fixing her shovel as we spend fooling with our computers, I'd buy her a good shovel. At least you can buy a good shovel."
>
> Erasmus Smums, cited in (Raskin 2000, p. xi)

Liu et al. (2008, p. 1081) claim that "attention needs to be given to what users achieve by using interaction techniques rather than how the techniques provided by InfoVis systems work." This is a question that is quite hard to answer. First, theoretical evidence is presented, which is found in literature and second, a few results of empirical studies are presented to show a user's point of view.

According to Hutchins et al. (1985, p. 321ff) who refer to direct manipulation in particular, interactivity reduces the cognitive load by enhancing the expressiveness of the interface language (possible inputs and outputs) and minimizing the gulfs of execution and evaluation. Furthermore, externalization of information is beneficial. Norman (1993, p. 43ff) argues that perceptual processing of external information is more efficient than processing internally represented information. Combining these two issues, interactive external representations can be handled with ease largely on a perceptual and physical manipulation level, for example dragging a file icon to a trash bin on the screen to delete a file. In contrast to that, in a command-line interface, one would have to know which command to use and its exact syntax as well as the name of the file and its location. This information would have to be remembered and retrieved because it would mostly not be perceived readily on the screen. Furthermore, Sundar (2007, p. 88) says that "Ultimately, the real value of interactivity is that it gives the user the ability to serve as a source, and not just a receiver, of communication."

Another question is the quality of an interactive system. The importance of quality is outlined by Raskin (2000, p. xix):

> "If a system's one-on-one interaction with its human user is not pleasant and facile, the resulting deficiency will poison the performance of the entire system, however fine that system might be in its other aspects."

He also defines the quality standard of a *humane interface* as "An interface [that is] is responsive to human needs and considerate of human frailties" (Raskin 2000, p. 6). Shneiderman & Plaisant (2004, p. 59ff) propose a balanced checklist of criteria to assess the value of interactivity. These criteria consist of technological aspects (system functionality and reliability) as well as user criteria (time to learn, speed, rate of user error, etc.).

Only recently, a small amount of studies has focused on the value of interactivity. A study carried out by Richards (2006) on an interactive learning environment with varying degrees of interactivity shows that there is a "greater preference for the interactive session and prevailing belief that interactivity is better than none" (Richards 2006, p. 65). However, the study does not indicate that better learning had been achieved when interactivity was involved. He concluded that "basic knowledge about a domain may be best gained passively, but that knowledge about how to behave and what questions to ask in that domain are best gained through active involvement" (Richards 2006, p. 59). In the study conducted by Saraiya et al. (2006, p. 453f) users preferred inferior visualizations with interaction over superior static visualizations. Furthermore, they argue that visual representations provide only an initial direction to the data and its meaning, but through the combination of visual representations and appropriate interaction mechanisms, the users achieve insights into the data.

3.2.4 Summary & Discussion

> "We humans are in love with our tools because they help us become more than we are, to overcome our limitations and extend the boundaries of what is possible to do with our brains and bodies."
>
> Jean-Louis Gassee (1991), cited in Laurel (1993, p. 213)

Richards (2006, p. 59) states that "interactivity is far more than a technical feature involving the user clicking on buttons or selecting options." It is a multidisciplinary study focusing on the form of communication where control is the key. In summary, one can conclude that generally speaking, the term interactivity is highly overused and underdefined.

What we can discern from the literature is that there is a positive effect of interactivity for exploration and analysis in visual interfaces mainly due to

- the reduction of cognitive load (reducing the gulfs of execution and evaluation),
- higher engagement (feeling of being in control / first-personness), and
- a higher expressiveness of the user interface language (richer possibilities for input and output).

But how this effect can be achieved and designed properly as well as how varying degrees of interactivity influence it, is largely unknown. Only one un-specific note concerning the influence of the degree of interactivity could be found in the work of Sundar (2007, p. 87): "too much choice can create dissonance and undermine the sense of personal control by overwhelming, rather than empowering, users."

After investigating cognitive models and theories as well as the specific area of interactivity, a brief summary of the theoretical part will be given.

3.3 Theory Roundup

"HCI is not the science of user interfaces, just as astronomy is not the science of telescopes. HCI needs interfaces to create interaction, and we should focus on describing, evaluating and generating interaction, not interfaces."
Beaudouin-Lafon (2004, p. 21)

According to Beaudouin-Lafon (2004, p. 17), interaction models should be

- descriptive: the ability to describe a wide range of existing method,
- evaluative: enable the assessment of multiple design alternatives, and
- generative: help in designing new methods.

Most of the theories and models presented in this chapter are mainly descriptive. A model that has also significant evaluative and generative aspects is GOMS. However, this model works at a very low level and is impractical for many larger projects. Most other models and theories are very powerful in explaining situations and activities involving humans and artifacts. However the exact influence of the degree of interactivity of artifacts and their power or value cannot be discerned from them.

In the empirical part of this thesis, we will approach the notion of interactivity from a user's point of view by assessing the perceived value and role of interactivity in the specific context of Visual Business Intelligence.

Chapter 4

Method

“Everything that can be counted does not necessarily count;
everything that counts cannot necessarily be counted”
Sign in Albert Einstein’s office, cited in Carpendale (2008, p. 40)

As discussed in the previous chapters, there are no empirical studies available that investigate the role and value of interactivity in the context of InfoVis. Only one study by Saraiya et al. (2006) is available which provides some insight, but interactivity was treated only as side-issue. Most of the work investigating interactivity is focused on interaction techniques or building taxonomies thereof, for example (Yi et al. 2007) or (Shneiderman 1996). The value of interactivity hasn’t been investigated from a performance, nor from a value point of view in the context of InfoVis. Because of this lack of initial direction, it seems important to avoid any restrictions concerning breadth and depth of possible answers via standardized questionnaires. From a methodological point of view, this work is based on qualitative semi-structured interviews. This allows for getting an overview of the interviewee’s main foci without being too constraining.

In a first step, IT managers of Austrian businesses, who are responsible for introducing and maintaining the BI infrastructure in their company, were asked to present and explain visual methods that they use. This group of persons has been selected because they know the BI tools in use very well and have knowledge about their respective users. Moreover, these persons are presumably more knowledgeable in estimating the possible value or impact of introducing more interactivity in their BI landscape. Furthermore, IT managers of large businesses of more than 1000 employees were invited as interview partners as, on the one hand, it is believed that there is a higher probability of BI system and visual methods usage in larger corporations, and on the other hand, there is a higher number of users of such systems. The industry sectors have not been restricted; quite on the contrary, a more heterogeneous set of sectors is considered beneficial in order to retrieve a broader view of general BI system usage. A minimum number of five participants was the goal for the empirical study. The interview partners were selected by contacting a number of IT managers who fit into the characteristics described above via email, using a one-page info sheet that described the planned study.

The questions asked and issues discussed in a semi-structured interview were informed by cognitive and post-cognitive models and theories. Specifically, the analysis goals, use-cases, constraints, frequency of use in general, as well as the perceived role and value of interactivity in particular, have been investigated. The goals of the empirical study were to investigate the following subjects:

- Which visual methods are currently applied and what are they used for?
- Are these methods paper or computer-based and are they static or interactive?
- How are the visual methods used?
- How important are visual methods for business data analysis and for decision-making?
- What does interactivity mean to the person interviewed?
- What value is ascribed to interactivity?

An interview guideline was prepared that consists of four parts (see Appendix A.1 for the complete interview guideline):

1. Introduction
2. Visual methods - general
3. Interactivity in visual methods
4. Demographic data

The interviews were held in person or via telephone in March 2009. Based on this, the role and value of interactive features were assessed by analyzing the interviews conducted. All interviews were audio taped and fully transcribed by the author. The interview transcripts can be found in Appendix A.2[1]. The transcripts were analyzed qualitatively along a coding scheme. For an interview analysis, a data-driven coding approach was pursued that was derived directly from the data via qualitative interpretation by the author (cmp. Carpendale 2008, p. 40). The coding scheme was derived incrementally by first identifying and annotating themes in logically connected chunks of text by the author. In a second step, the identified low-level themes were grouped and organized hierarchically based on topic and similarity in order to structure the identified themes. This resulted in a hierarchical coding scheme. In the following, the top level structure of the resulting coding scheme is listed (see Appendix A.3 for the complete coding scheme):

- BI
  advantage, application example, area, current state, definition, for whom, problem, tool

[1]The transcript and citations of interview partner 6 (IP6) are omitted in this thesis by request of the interview partner.

- business area
  operational, tactical, strategic
- interactivity
  advantage, as-a-process, critical area, currently in use, description, future, groupware, importance, interoperability of applications, personal attitude towards, task, technique, usage, user attitude
- user
  demand for more, development, not happy with current state, to be involved
- user interface
  excel based, table
- visualization
  about users, advantage, application area, critical area, for whom, frequency of use, future prediction, gadgets, idea, personal attitude towards, problem, quality, recommendation, task, technical, technique, use, use case, user attitude, user point of view

After that, the empirical findings are discussed and contrasted with scientific models and theories.

Chapter 5

Empirical Study

Between March 9, 2009 and March 19, 2009, six interviews with IT-Managers of Austrian businesses were conducted. The interview length ranged between 30 and 45 minutes, with one interview taking considerably longer comprising of 74 minutes. The interviews were conducted either at the workplace of the interview partners (4), the office of the author (1) or via telephone (1). The company of four interview partners are located in Vienna, one in Salzburg and one in Tyrol. All interviews were audio-taped and held in form of an oral dialogue. Generally, no examples or computer demos were used, neither by the interviewer (I) nor by the interview partners (IP). Only one interview partner demonstrated the running system of the respective enterprise to the interviewer.

In the upcoming section, a short overview regarding the interview partners and their work are given. After that, detailed results of the qualitative analysis are presented.

5.1 Interview Partners

A brief overview of the main demographic characteristics of all interview partners is given in table 5.1.

Nr.	Sex	Age	Job area	Hierarchical level	Size of enterprise	Sector	Education	Years of experience	Main tasks	Visualization use
1	m	30-34	Misc/IT	Team/group leader	5000-9999	Health	Professional education	9	monthly data loading; complete BI infrastructure	no
2	m	35-39	Misc/IT	Division manager	1000-4999	Media	University-entrance diploma	12	implementation of BI and data warehouse solutions	yes, limited
3	m	35-39	Misc/IT	Team/group leader	>10000	Production	Master craftsman	10	data gathering, data modeling, data analysis	yes
4	m	30-34	Misc/IT	Team/group leader	1000-4999	Mechanical engineering	Master in Applied Sciences	8	system & user administration and help desk	yes, limited
5	m	35-39	IT/Org	Expert	1000-4999	Finance	University degree	5	contract management system	only one
6	m	55-59	IT/Org	Team/group leader	>10000	Finance	University-entrance diploma	19 (Infomgmt.) - 4 (BI)	Data gathering, data quality	no

Table 5.1: Demographic overview of interview partners.
Source: own empirical study

All six interviewed IT-managers are male and between 30 and 39 years old (5), with one interview partner being 55-59 of age. Most of the interview partners (IPs) are at the level of team/group leaders (4). One IP is an IT expert and one IP is a division manager. All interview partners work in companies with more than 1000 employees (1000-4999 in three cases, 5000-9999 in one case, and more than 10000 in two cases). The industrial sectors within which IPs work are relatively heterogeneous: health, media, production, mechanical engineering, and financial market (2). All IPs have more than four years of experience in the field of BI, with the majority having about 10 years of experience. Generally, the use of visual methods in BI is not very widespread and quite limited. This area will be discussed in more detail in the following section.

5.2 Summary of Interviews

The following interview summary is structured along the three main themes BI, visualization and interactivity, which also determined the main structure of the interviews.

5.2.1 Business Intelligence

As an introductory question, the interview partners were asked to elaborate their understanding of the area of Business Intelligence in general. Concerning this, two groups of answers can be identified. The first group is more technology-oriented, whereas the second group is more concept-oriented. For the first group of technology-oriented definitions, the IPs described BI as flexible storage, retrieval and querying of business relevant data where large amounts of data can be aggregated in a meaningful way, or as IP4 puts it:

> "Processing of huge amounts of data, that are analyzed and in the end used for something or where there is a large amount of dimensions, where the point of intersection of the different dimensions provides the relevant information. And aggregation is the actual topic."[1] (Interview 4, line 37ff, transl. by the author)

IP3 emphasizes the role of data analysis and querying:

> "Business Intelligence is an area, where I try to process data in a way to retrieve it again for statistical analysis, for data mining, with high-performance and highly aggregated. If I have to put it differently, I always say, yes, we are a huge graveyard of data which processes things in a way that users are able to quickly retrieve important data."[2] (Interview 3, line 25ff, transl. by the author)

[1]Translated from the German original version by the author: "Aufbereitung von großen [...] Datenmengen, die man analysiert und im Endeffekt irgendetwas daraus macht oder wo man eine große Anzahl von verschiedenen Dimensionen hat, wo sich aus dem Schnittpunkt der verschiedenen Dimensionen eigentlich die richtige Information ergibt. Und die Aggregation daraus eigentlich da das Thema ist." (Interview 4, line 37ff)

[2]Translated from the German original version by the author: "[...] Business Intelligence [...] ist ein Bereich, wo ich versuche, Daten so aufzubereiten um sie [...] für statistische Auswertungen für Data Minings, performant,

Three of the six IPs put forward a more concept-oriented view concerning BI, where they describe it as a transformation of data into information, knowledge, and decisions. IP5 formulated it quite concise as:

> "We have a lot of data, huge amounts of data and how can I get Information out of that? That would be BI for me."[3] (Interview 5, line 87ff, transl. by the author)

IP2 and IP6 are going two steps further and explain BI's ultimate goal as gaining knowledge and make correct decisions:

> "[...] being able to gain insight into the company [...] make correct decisions or decisions that are as correct as possible under difficult circumstances, in a short amount of time, and facing continuous change also of the environment."[4] (Interview 2, line 49ff, transl. by the author)

As a main application area for BI, controlling and particularly the area of financial reports was pointed out most often. Apart from this budgeting, quality management, contract management, personnel planning, marketing, sales, and customer relationship management (CRM) were mentioned.

In line with controlling and financial reporting as main application area, the BI method mentioned most often, was reporting. Moreover, data warehousing, data modeling, analysis, data mining, OLAP (on-line analytical processing), ROLAP (relational on-line analytical processing), dashboarding, scorecarding, and decision support were mentioned as BI methods used by the interview partners.

From a software infrastructure point of view, the product Cognos was stated most often followed by SAP. Other products that were mentioned are Business Objects, Hyperion, Microsoft, Marketing Manager, Micro Strategy, Oracle, and Siebel Analytics.

Advantages & Problems of BI

The majority of perceived advantages of BI are related to the technology-oriented understanding of BI mentioned above. These advantages are:

- a common data basis (across the company),
- the ability to deal with large amounts of data,
- allowing quick queries and comparison of alternatives,

hochaggregiert wieder herzubekommen. Wenn ich es sonst noch so sagen würde, sage ich immer, ja wir sind ein großer Datenfriedhof der die Sachen so aufbereitet, dass die User damit wieder schnell zu wichtigen Informationen kommen." (Interview 3, line 25ff)

[3] Translated from the German original version by the author: "Wir haben viele Daten, Unmengen Daten und wie mache ich daraus Informationen? Das wäre sozusagen das BI für mich." (Interview 5, line 87ff)

[4] Translated from the German original version by the author: "[...] dadurch einen Einblick ins Unternehmen zu bekommen [...] unter schwierigen Umständen, in kurzer Zeit bei ständiger Veränderung, auch von der Umwelt, richtige oder möglichst richtige Entscheidungen treffen zu können." (Interview 2, line 49ff)

- the possibility of customized views for users,
- the common layout and wording in reports across the company, and
- it represents the basis for fact-based decision making.

With regard to data modeling and querying, the idea of ad-hoc querying in contrast to pre-defined reports was emphasized by IP4 among others:

> "Data modeling from a multidimensional point of view with the cube concept, that includes this ad-hoc topic very prominently in contrast to relational models."[5] (Interview 4, line 32ff, transl. by the author)

The main problem areas observed by the interview partners are

- data,
- interoperability,
- performance, and
- under-utilization.

Regarding the first problem area of data, the interview partners mentioned three specific types. First, the problem of data timeliness – IP5 mentions the problem that data is entered into the system much too late due to organizational barriers and therefore, reports generated by the BI system are worthless, because they refer to data that is not up-to-date:

> "[...][T]he main reason was that up to now, these (products) were entered into the system with a delay. [...] Sales had a contract that provided the profit-margin needed for this month, and this contract could not be seen. For him, everything was red."[6] (Interview 5, line 154ff, transl. by the author)

Second, some of the data needed for certain user groups is simply not available at all and third, the quality of the data itself is often very low. Another problem area identified by multiple interview partners is a technical obstacle: the lack of interoperability between different applications. Multiple software applications are often in use within one company and, due to the lack of interoperability, it is often cumbersome for users to carry out a certain task that might involve two or three different systems, which are not interconnected properly. Also related to the technical infrastructure, IP5 mentioned the system performance in the sense of a sometimes low system reliability:

[5] Translated from the German original version by the author: "Datenmodellierung aus dieser mehrdimensionalen Sichtweise mit diesem Würfelgedanken, der einfach im Unterschied zu relationalen Modellen diese ad-hoc ganz stark hineinbringt." (Interview 4, line 32ff)

[6] Translated from the German original version by the author: "[...] der Hauptgrund war, dass eben bisher diese (Produkte) so zeitverzögert praktisch im System erfasst worden sind. [...] Der Vertrieb hat einen (Vertragsart)-vertrag gehabt, der hat ihm für das Monat den Deckungsbeitrag gebracht, den er gebraucht hat und den hat er nicht gesehen. Für ihn war alles rot." (Interview 5, line 154ff)

> "Sometimes reports are generated fast, sometimes slowly, and sometimes not at all. This means start over again, now let's look that we get the performance under control, that report generation gets stable, that when I hit the button, I get the report. I had this scenario two weeks ago because of different circumstances, again unfortunate circumstances, the data basis was not available, meeting with the customer, I had promised this report, the sales representative had to go to the customer and say, I am sorry, we do not have the report, we did not make it, very unpleasant."[7] (Interview 5, line 263ff, transl. by the author)

Moreover, IP4 describes a problem related to users of BI systems: The power of the available tools is often underutilized. This means that in principle, BI tools often have features and functionalities that are not used at all.

After summarizing the interview results concerning BI in general, visual methods in the context of BI are discussed in the following chapter.

5.2.2 Visualization

In general, the use of visual methods in BI is very limited in the corporations of the interview partners. Only one IP reports regular usage of visual methods. Two IPs report limited application, one reports that only one visualization is in use, and in the companies of the two remaining IPs, no visualization is in use at all. Three IPs report that a possible reason for not using visualization might be found in corporate culture, personal taste, as well as trust.

> "And those people who work with the data on a daily basis, most of them are convinced by the numbers – they want to see the number, want to see details about it, because these are also numbers many people have in their mind."[8] (Interview 1, line 427ff, transl. by the author)

> "Of course it also depends on the type of person, if somebody is visually oriented, this plays a crucial role."[9] (Interview 5, line 221ff, transl. by the author)

[7]Translated from the German original version by the author: "Die Berichte kommen derzeit manchmal schnell raus, manchmal sehr langsam, manchmal gar nicht, nochmal anstarten, so jetzt schauen wir einmal, dass wir die Performance hinbekommen, dass die Berichte immer rauskommen, wenn man auf den Knopf drückt und zu dem Zeitpunkt, wo man sie braucht. Ich hab vor zwei Wochen wieder den Fall gehabt, aus verschiedensten Gründen, eben wiederum unglückliche Umstände, die Datenbasis war nicht da, Kundentermin, ich habe den Bericht versprochen, der Vertriebsmann muss zum Kunden gehen, sagen, tut mir leid, ich habe den Bericht nicht, wir haben es nicht geschafft, äußerst unangenehm." (Interview 5, line 263ff)

[8]Translated from the German original version by the author: "Ahm, und die Leute die dann tagtäglich mit den Daten arbeiten hat man wirklich gemerkt, die meisten sind einfach von der Zahl überzeugt - die wollen die Zahl sehen, wollen die vertiefend darstellen, weil das sind auch Werte, die haben sehr viele Leute im Kopf." (Interview 1, line 427ff)

[9]Translated from the German original version by the author: "Es hängt natürlich auch vom Typ davon ab, ob jemand visuell überhaupt orientiert ist, das spielt da sicherlich eine Rolle." (Interview 5, line 221ff)

Another possible reason identified by the IPs is that data problems are often more severe as mentioned in the previous section. And without the necessary data basis that is correct and complete, visualization does not make sense.

> "The biggest problem of users and information consumers is not the way how these data are translated into information and how they are represented, but whether the data is correct or not."[10] (Interview 2, line 570ff, transl. by the author)

As reported by the IPs, the currently most prevalent form of data representation is a table format and visual methods are only at the beginning.

> "Extremely often I see the generation of lists, which means the way how this could be represented differently is obviously only in its infancy."[11] (Interview 2, line 188ff, transl. by the author)

Quite interestingly, IP4 reports the use of dashboards on paper for his own business unit in the entrance area of the building.

> "[...] Downstairs in the foyer, which we passed, we put it on the wall that everybody can see, aha, we now have carried out a project [...]"[12] (Interview 4, line 262f, transl. by the author)

Advantages & Critical Areas

When asked for the advantages of visual methods, the interview partners identified six main areas:

- allow for understanding large amounts of complex data,
- easier for making comparisons,
- see relationships,
- see dynamic changes and trends,
- save time, and
- make daily work more attractive.

[10] Translated from the German original version by the author: "[...] das größte Problem haben Anwender und [...] Informationskonsumenten nicht mit der Art und Weise, wie diese Daten zu Informationen transformiert werden und dargestellt werden, sondern, ob sie jetzt stimmen oder nicht stimmen." (Interview 2, line 570ff)

[11] Translated from the German original version by the author: "[...] ich sehe aber auch [...] extrem viel, ja, Erzeugung von Listen, das heißt die Art und Weise, wie man das anders darstellen könnte, steckt offensichtlich noch vielerorts in den Kinderschuhen [...]." (Interview 2, line 188ff)

[12] Translated from the German original version by the author: "[...] [U]nten in dem Eingangsbereich, den sie gesehen haben, hängen wir das aus, damit man sieht, aha wir haben jetzt ein Projekt gemacht [...]". (Interview 4, line 262f)

The first four advantages are more content-oriented, whereas the last two refer to organizational advantages. In the context of understanding large amounts of data, the power of visualization was mainly seen in gaining a quick overview and furthermore, making better decisions.

> "For me, the basic advantage of visual methods is that I can quickly gain an overview of the numbers."[13] (Interview 5, line 288f)

> "[...] [L]et's use our other half of the brain, that one, that reacts to visual representations and helps me to make quicker and better-informed decisions"[14] (Interview 2, line 519ff, transl. by the author)

Regarding work attractiveness, IP5 states:

> "That is surely nice to work with and makes everyday work more colorful and friendly. Also a cultural effect for work in a way that I do not always have to stick to the numbers."[15] (Interview 5, line 304ff, transl. by the author)

About the potential of dangers and disadvantages connected to visualizations, the IPs mentioned foremost

- possible information distortion and
- manipulation potential, as well as
- the importance of choosing the appropriate technique.

Moreover, the danger of

- making unintentional changes in the data,
- selecting the right data,
- corporate culture,
- user acceptance,
- user skills,
- the power of pictures, and
- possible distraction

[13] Translated from the German original version by the author: "Der grundsätzliche Vorteil von visuellen Methoden für mich ist, das ich mir sehr rasch einen Überblick über Zahlen verschaffen kann." (Interview 5, line 288f)

[14] Translated from the German original version by the author: "[...] [N]utzen wir doch endlich unsere andere Gehirnhälfte, nämlich die, die vielleicht auch sehr gut auf graphische Darstellungen reagiert, damit ich noch schneller und noch vernünftiger entscheiden kann." (Interview 2, line 519ff)

[15] Translated from the German original version by the author: "Und das ist sicher auch nett zum Arbeiten und macht den Arbeitsalltag etwas bunter und auch freundlicher. Auch ein gewisser kultureller Effekt so für das Arbeiten, das ich nicht immer nur auf den Zahlen klebe. (Interview 5, line 304ff)"

were mentioned. With regard to the issue of manipulation potential and possible information distortion, IP5 stated:

> "The disadvantages would be that I can disguise things easily. By using the usual tricks, via shortening, via logarithmic representations [...]"[16] (Interview 5, line 318ff, transl. by the author)

Going in the same direction, when visualization methods are primarily used, the possible danger of the power of pictures, i.e., blindly trusting pictures without questioning the facts, could arise as described by IP4 and IP5:

> "[...] If I am not clear about what to present and I miss certain explanatory notes and a framework that led to that statement or kind of presentation, I am quickly able to communicate false information, but I have a hard time to get that out of the heads because many people do memorize facts much stronger visually and then you have to discuss endlessly in order to make them understand that there was precondition xy for that image or, no, that is taken as truth and I think that is a danger."[17] (Interview 4, line 279ff, transl. by the author)

Apart from choosing the appropriate visualization technique, the critical area of choosing the right data was also mentioned:

> "[...] Visualization often is not taking away the problem with the data in the back, what do I need? [...] And this is often underestimated."[18] (Interview 3, line 308ff, transl. by the author)

Interestingly, IP2 points out a possible downside of the advantage of making work more attractive as mentioned in the previous section. Using visual methods might also have negative effects in form of distraction.

> "[...] the danger of drifting off into gaming. [...] Yes, because of just concentrating on visualization and presentation and using ways of presentation, one is distracted from the central issue which is analysis [...]"[19] (Interview 2, line 357ff, transl. by the author)

[16]Translated from the German original version by the author: "Die Nachteile wären, dass ich natürlich Dinge verschleiern kann wunderbar. Durch die üblichen Tricks, durch Verkürzungen, durch logarithmische Darstellungen [...]" (Interview 5, line 318ff)

[17]Translated from the German original version by the author: "[...] wenn ich jetzt nicht klar bin, in dem, was ich darstelle und es fehlen mir gewisse Anmerkungen und Rahmenbedingungen, die zu dieser Aussage oder zu dieser dargestellten Form führen, dann kann ich schnell eigentlich falsche Informationen transportieren, die ich aber aus den Köpfen nie wieder wegbringe, weil sich viele Leute die Sachen auch visuell viel stärker merken, und dann kannst du ewig diskutieren, bis die einmal verstanden haben, dass ja da noch Voraussetzungen xy für dieses Bild entstanden sind oder da sind, nein, das wird schon als Wahrheit genommen und das ist glaube ich eine Gefahr." (Interview 4, line 279ff)

[18]Translated from the German original version by the author: "[...] die Visualisierung nimmt mir oft die Problematik nicht weg, ah, wo ich sage, die Daten im Hintergrund, welche brauche ich denn? [...] Und das wird meistens unterschätzt." (Interview 3, line 308ff)

[19]Translated from the German original version by the author: "[...] die Gefahr ins Spielen abzudriften. [...] Ja, eben, dass man vor lauter Visualisierung und Darstellung von und Nutzung von Darstellungsmöglichkeiten nicht mehr zum Eigentlichen kommt, nämlich zur Analyse [...]." (Interview 2, line 357ff)

Tasks & Techniques

Visualization techniques that were mentioned explicitly are bar charts, cockpits, highlighting, pie charts, and traffic lights. Only one IP mentions the use of maps for data representation. Star graphs were mentioned as the only multivariate visualization technique. IP4 states that the choice for the technique might also be determined by the personal taste of the users.

> "I'd say it like this, it is known that certain persons in the company expect a special type of report design, you know they like, where they get into quickly, what makes sense. And that determines the design and how it is applied, but it is not specified upfront. But one usually knows what is received in which way and based on that, types of diagrams are chosen, whether I use 100% scales or absolute values, etc."[20] (Interview 4, line 187ff, transl. by the author)

From a task point of view, visual methods are mainly used for presentation, while analysis and exploration where cited as side issues.

> "Because actually, from my point of view [...], these possibilities of visualization [...] are mostly used for general distribution, for communication, but not for gaining insights."[21] (Interview 2, line 243ff, transl. by the author)

When looking into the future, IP5 and IP6 think that focusing on visual exploration and analysis would have a high potential:

> "I am convinced that this is received well. Simply because there are many visually determined persons, the portion is higher as of purely auditory, digitally determined persons, when looking at it this way. I can imagine that this is received very well." [22] (Interview 5, line 454ff, transl. by the author)

In the sense of visual support for different business tasks, application areas were identified in operational, tactical, as well as strategic tasks. From a software point of view, Microsoft Excel has been mentioned by all interview partners as being used by users in their companies for different data analysis and also visualization tasks.

[20] Translated from the German original version by the author: "Ich sag einmal so, es ist bekannt, welche Berichtsgestaltung gewisse Leute im Unternehmen erwarten, was ihnen gefällt, wo sie schnell darauf einsteigen, was schlüssig ist. Und aus dem ergibt sich dann in der Gestaltung, wie man das einsetzt, aber es ist nicht vorgegeben. Aber de facto weiß man ja, was wie ankommt und anhand dessen richtet sich, welche Diagramme jetzt verwendet werden, ob ich jetzt, was weiß ich, 100% Verteilungsskalierungen nehme oder ob ich Absolutwerte nehme usw." (Interview 4, line 187ff)

[21] Translated from the German original version by the author: "Denn tatsächlich aus meiner Sicht [...] werden diese Visualisierungsmöglichkeiten [...] mehrheitlich nur für die Weitergabe, also für die Kommunikation eben erzeugt, aber nicht für den eigenen Erkenntnisgewinn." (Interview 2, line 243ff)

[22] Translated from the German original version by the author: "Also ich bin überzeugt davon, dass das gut ankommt. Einfach weil es sehr viele visuelle Menschen gibt, der Anteil ist höher als jetzt bei reinen auditiv, digitalen Menschen sag ich einmal, wenn man von der Ecke kommt. Ich kann mir vorstellen, dass das sehr gut ankommt."(Interview 5, line 454ff)

Users & Application Areas

When asked about user groups that use or would benefit from visual methods in BI, senior managers and controllers were mentioned most often. Moreover, middle and lower management, sales, software development departments, and customers were identified as further user groups.

According to the majority of the interview partners, visual methods are received positively by users or are believed that they would be if introduced. On the one hand, according to the interview partners, users do not actively ask for visual methods but mainly think in terms of tables.

> "Usually they come to me and say 'I need a table'. [...] If I visualize the table and show them what is possible, they are mostly very enthusiastic [...]"[23] (Interview 3, line 329ff, transl. by the author)

On the other hand, IP1 reports that parts of the BI solutions used have functionalities to generate diagrams but no one uses them.

> "In principle, he could even generate a diagram for that data, yes. I realize, that this is not used because I can analyze it, but the possibility is there."[24] (Interview 1, line 550ff, transl. by the author)

An area identified for being particularly suitable for visualization techniques is to present continuously changing data. Moreover, customer relationship management, resource planning, and warehouse management were identified as potential application areas for visual methods.

An obstacle often mentioned in the implementation of visual methods in BI is that IT managers claim that users do not know what they want, which was mentioned by IP2 and IP3:

> "[...] There is this big problem that I see, that you have a very hard time to get out of the users what they want to see [...]"[25] (Interview 2, line 191ff, transl. by the author)

> "[...] I think the reason is that one says I do not know what I need, I do not know which information I need and I above all, I do not know what knowledge I want to generate."[26] (Interview 2, line 191ff, transl. by the author)

[23] Translated from the German original version by the author: "Prinzipiell kommen sie mit der Frage - ich brauch eine Tabelle. [...] Wenn man es dann anders visualisiert und ihnen zeigt, welche Möglichkeiten es gibt, dann sind sie meistens hellauf begeistert [...]" (Interview 3, line 329ff)

[24] Translated from the German original version by the author: "Er könnte sich hier sogar [...] ein Diagramm erzeugen lassen, für diese Daten, ja. Ich sehe, dass das nicht verwendet wird anhand dessen, weil ich es auswerten kann, aber die Möglichkeit besteht." (Interview 1, line 550ff)

[25] Translated from the German original version by the author: "[...] da ist die große Problematik, wie ich sie sehe, dass man es wahnsinnig schwer hat, aus den Usern herauszubekommen, was sie wirklich sehen wollen [...]" (Interview 3, line 59ff)

[26] Translated from the German original version by the author: "[...] es begründet sich glaub ich damit, das man sagt, ich weiß gar nicht, was ich brauche, ich weiß gar nicht welche Informationen ich benötige, und ich weiß schon gar nicht, was für ein Wissen ich generieren möchte [...]" (Interview 2, line 191ff)

With regard to this problem, IP2 points out the importance of training for users.

> "This will lead to confusion, especially if it is not explained properly and no proper training and mental preparation are planned [...]."[27] (Interview 2, line 558ff, transl. by the author)

In the next section, a summary regarding the questions and answers on interactivity will be presented.

5.2.3 Interactivity

When asked to describe what interactivity is, most interview partners focus on the areas of getting details on demand as well as so-called drill-down, a very prominent concept in BI that describes the ability to go down to details of aggregated values. The concept of details-on-demand was reported by IP5:

> "Well, interactive would be something like, I click on a diagram, for example, and then the detailed report pops up."[28] (Interview 5, line 332f, transl. by the author)

A very formal account on interactivity was given by IP4:

> "Well, the spontaneous interaction with a diagram or the presented information at the time of observation and immediate feedback via an update."[29] (Interview 4, line 313ff, transl. by the author)

Apart from these definitions, which go along with what was presented in theory, interactivity is also seen as mediation of user to user communication (groupware), as interoperability between applications and also as the possibility for data input by users. This illustrates that there is no common understanding of the concept of interactivity among IPs.

Similar to visualizations in general, the usage of interactivity in particular is very limited.

> "[...] In principle, it is used, but only by very few people [...]"[30] (Interview 1, line 585, transl. by the author)

Most visual methods are reported to be static and interactivity itself as well as analysis is mostly secondary.

[27] Translated from the German original version by the author: "Dann wird das zu Verwirrung führen, speziell wenn man das nicht ordentlich erklärt, keine ordentlichen Maßnahmen der Schulung und der mentalen Hinführung [...] einplant [...]." (Interview 2, line 558ff)

[28] Translated from the German original version by the author: "Naja, interaktiv wäre, ich klick auf eine Grafik zum Beispiel und dann geht mir ein Detailbericht auf." (Interview 5, line 332f)

[29] Translated from the German original version by the author: "Na ja, das spontane interagieren mit der Grafik oder mit der dargestellten Information zum Zeitpunkt der Betrachtung mit unmittelbarer Rückmeldung durch eine Aktualisierung." (Interview 4, line 313ff)

[30] Translated from the German original version by the author: "[...] prinzipiell, es wird genutzt, nur von einem sehr sehr geringen Kreis [...]" (Interview 1, line 585)

> "I think it is secondary at the moment because in my experience the topic analysis in general is secondary at the moment [...]"[31] (Interview 2, line 495ff, transl. by the author)

When considering interactivity in tabular representation, IP1 reports that user defined data cubes are used only by very few users, but they use it extensively.

Advantages & Critical Areas

The advantages of interactivity mentioned most often are

- flexibility and
- its potential to save time.

In terms of flexibility, IPs mentioned that interactivity allows to retrieve exactly the information the user wants, and at the same time, the necessary amount of pre-defined reports decrease.

> "This means, I go back and do not try to anticipate the information requirement, [...] that is most probably not correct anymore tomorrow because of the dynamics of the company and its environment but I delegate the decision 'What information do you need?' to the user, who is able to get the information that he needs via interactivity."[32] (Interview 2, line 480ff, transl. by the author)

> "In order to get the right information and is not confined to the aggregated level where one is stuck in the end."[33] (Interview 4, line 299f, transl. by the author)

The potential of interactivity as a time saver is explained by the fact that no one else has to be asked and no specialized reports have to be developed. This implies that decisions can be made more quickly.

> "Well, it is simply the speed. That I can go somewhere quickly, I do not need to go somewhere else, open something else, but I can quickly switch between drill-up, drill-down, drill-through is also available, I am able to quickly be there where I want to be."[34] (Interview 5, line 382ff, transl. by the author)

[31] Translated from the German original version by the author: "Ich glaub, es ist noch ein Nebenschauplatz, weil nach meiner Wahrnehmung [...] überhaupt das Thema Analyse [...] noch ein Nebenschauplatz ist [...]" (Interview 2, line 495ff)

[32] Translated from the German original version by the author: "Das heißt, ich geh zurück und versuche nicht den Informationsbedarf zu antizipieren, [...] der dann wahrscheinlich morgen gar nicht mehr stimmt, aufgrund der Dynamik des Unternehmens und der Umwelt, die auf das Unternehmen einwirkt, sondern ich gebe die Entscheidung, "Was ist dein Informationsbedarf?" an den Anwender, der dann durch die Interaktivität die Möglichkeit hat, sich das zu holen, die Information, die er eben dafür braucht." (Interview 2, line 480ff)

[33] Translated from the German original version by the author: "Damit man richtig die Information bekommt und nicht auf der aggregierten Ebene bleibt und im Endeffekt dann wieder ansteht." (Interview 4, line 299f)

[34] Translated from the German original version by the author: "Naja, das ist also einfach die Geschwindigkeit. Das ich schnell wo bin, ich muss nicht wieder rausgehen, woanders hingehen, etwas anderes aufmachen, sondern ich kann schnell zwischen den, von drill-up, drill-down, drill-through gibt es dann ja auch noch, kann ich mir das schnell irgendwo einfach sein, wo ich hin will." (Interview 5, line 382ff)

> "Exactly this is, for example, one of the big advantages, that I am able to make decisions more quickly. And if I apply interactivity and start from a good background, highly aggregated, that I am able to go to problem cases quickly and do not need to search anywhere [...]."[35] (Interview 3, line 409ff, transl. by the author)

Additionally, the help of interactivity in

- dealing with complexity,
- the facilitation of comparing alternatives and scenarios, as well as
- its positive effect for a deeper understanding with the result of making better informed decisions

were mentioned as advantages of interactivity. Apart from these content-related advantages, IP5 and IP6 identified positive effects on work and creativity as similarly stated in the section about visualization.

On the potentially negative effects of interactivity, the interview partners mentioned

- distraction,
- higher costs,
- the need of more resources,
- that interactivity is more difficult to control,
- security issues, and
- user acceptance.

Distraction was also mentioned in connection with visualization in general and is seen as the danger of getting lost in details when having interactive visual tools. At the same time, IP4 puts this into perspective by considering it as a process of learning:

> "Getting lost in detail, where one loses track of the main goal because [...] but no, I would not consider this as an disadvantage. It is probably something, you have to learn, to control yourself."[36] (Interview 4, line 380ff, transl. by the author)

[35] Translated from the German original version by the author: "Genau, das ist zum Beispiel einer der größten Vorteile, dass ich schneller Entscheidungen treffen kann. Und wenn ich Interaktion einsetze und [...] auf einem [...] guten Background starten kann, hochaggregiert, dass ich schnell auf Problemfälle hinarbeiten kann [...] und nicht mich erst durchsuchen muss [...]." (Interview 3, line 409ff)

[36] Translated from the German original version by the author: "Verheddern im Detail, wo man im Endeffekt das Grundziel aus den Augen verliert, weil man sich, [...], nein aber täte ich jetzt nicht als Nachteil sehen. Das muss man wahrscheinlich lernen, ja von selber steuern." (Interview 4, line 380ff)

The issue of higher costs is explained by a higher degree of implementation effort as well as a higher effort for managing security issues. This also relates to the problem of security, with the questions of who can see which details and what levels of interactivity are available for which user or group raised and these problems need to be solved. Moreover, a potential problem of interactivity is that it is more difficult to control because of an increased freedom for users. Furthermore, a higher amount of system resources is needed when providing interactivity in visual methods, which has negative effects on system performance as a whole.

> "Maybe the report runtime at most because on the aggregated level I am considerably faster and if system response time is getting worse because the data resolution has to be higher, then this would be a disadvantage."[37] (Interview 4, line 382ff, transl. by the author)

Finally, user acceptance was mentioned as a potentially critical area of interactivity, which might also turn into resistance.

> "And if it really is beneficial for the consumer from an information content and handling point of view, the information consumer, it means change and therefore bad and therefore there is resistance."[38] (Interview 2, 561ff, transl. by the author)

Users & Application Areas

On the one hand, most IPs reported that users would react positively to interactivity or would most probably react positively if they knew more about interactivity.

> "And from a tool point of view [...] it is very popular [...] to interactively work with theses diagrams."[39] (Interview 2, line 225ff, transl. by the author)

On the other hand, users are reported to not actively ask for interactivity. IP3 explains that users that do not know what interactivity is, are satisfied with what they currently have, but users who have already experienced interactivity, want more.

> "[...] Well, all users who do not know interactivity, are happy. [...] All users that have already seen what is possible by using interactivity want more [...]."[40] (Interview 3, line 449ff, transl. by the author)

[37]Translated from the German original version by the author: "Maximal vielleicht die Berichtslaufzeit - weil auf der aggregierten Ebene bin ich ja im Bericht wesentlich schneller und wenn durch diese Interaktivität die Antwortzeit des System wesentlich darunter leidet, weil er dahinter von der Auflösungsdichte her wesentlich genauer sein muss, dann wäre das für mich schon ein Nachteil." (Interview 4, line 382ff)

[38]Translated from the German original version by the author: "Und selbst wenn es wirklich vom Informationsgehalt her und von der Verwendung her ein Gewinn ist für den Konsumenten, den Informationskonsumenten, es ist eine Umstellung und daher ist es schlecht und daher wird sich dagegen gewehrt." (Interview 2, 561ff)

[39]Translated from the German original version by the author: "Und tooltechnisch [...] ist es sehr beliebt, [...] interaktiv mit diesen Diagrammen arbeiten zu können." (Interview 2, line 225ff)

[40]Translated from the German original version by the author: "[...] also alle User die die Interaktivität noch nicht kennen, sind zufrieden. [...] Alle User, die bereits gesehen haben, was mit Interaktivität sonst noch geht, ah, wollen dann mehr [...]." (Interview 3, line 449ff)

Furthermore, almost all IPs think that interactivity can be beneficial. From a usage point of view, interactivity is seen as applicable for the tasks of

- communication,
- data input,
- explaining and finding causes,
- exploring alternatives, and
- detecting outliers.

The interaction techniques that were mentioned to support these tasks were most often

- drill-down and
- details-on-demand

as already stated above.

Besides this,

- configuration or the ability to change values and parameters,
- navigation in large information spaces, and
- grouping and filtering

have been mentioned.

When asked about the future development regarding interactivity in Visual BI, most IPs stated that this is not an issue for them. Only one of the interview partners stated that his company will actually invest more to put such methods into use.

After summarizing the interview contents along the lines of BI, visualization and interactivity, insights that can be derived from this will be presented and discussed in the next chapter.

Chapter 6

Results & Discussion

Following Bowett (2008) and other definitions stated in Section 2.1, BI's main purpose is seen as supporting complex decision-making processes via transformation of data into knowledge and decisions. Moreover, the issue of fact-based decision making has been identified as one of the main advantages. However, as IP6 mentions, many business decisions are still made by gut feeling, even if the data was there. The question is: Why is this the case? There are two possible reasons for this: First, data that is available might not be accessible in a way to support decision making. Second, the lack of more widespread usage of BI might be more deeply rooted in corporate culture or personal taste of the responsible managers. In the first case, interactive visual methods could be a way to improve the current situation. The second issue of corporate culture is going to be discussed later in this section.

Currently, the main application field of Business Intelligence is reporting in the sense of static presentation of data in reports, either as printable documents or electronically. Visual exploration and analysis, in turn, are not very important in current practice. They are mainly performed on an individual level using MS Excel as front-end.

Interestingly, trust among users towards visualizations seems to be lower than trust towards numbers as reported by the interview partners. As a possible reason for this, IPs mention the manipulative potential of visual representations where data might be distorted, whether intentionally or unintentionally, while a number stands for itself. This might also be caused by not enough knowledge about how visualizations work and how good quality charts could be designed. This possibly causes the fear of being manipulated without realizing it.

Interactivity and visualizations are reported to be generally two steps ahead. Specifically, visualization of data is seen as a potentially beneficial area but not considered very important in practice. A possible reason reported by the IPs is that still much more fundamental issues need to be tackled in the context of BI at the moment. These more fundamental issues are identified as data-related and form the basis of all further processing.

6.1 Visualization

A visualization metaphor that is often used in the context of BI is that of an airplane cockpit, hence also the term “management cockpit” that is used for dashboards in BI. In this metaphor, managers see themselves as pilots who have to control the flight route using different instruments and controls in the cockpit. However, visualization use in practice seems to be still far from this notion and in a very early stage. Long lists and tables are usually in use today. A possible reason for this, which was often mentioned in the interviews, is that users do not know what is possible in terms of visual methods and therefore think in terms of numbers, tables, and reports. This issue will also be discussed in the sections about users and corporate culture below. Visual support is often present only in the form of coloring text and table cells when certain value thresholds are exceeded. Furthermore, it is questionable whether the cockpit metaphor is suitable for Visual Business Intelligence. Airplane cockpits are very well suited for current data display and control but much less for visual exploration and analysis tasks.

Another aspect of visualization commonly used is traffic light coloring using green for OK and red for not OK. This might be problematic for users as color blindness is quite common – about 8% of the male and 0.4% of the female population have some kind of color vision deficiency (cmp. Snowden, Thompson & Troscianko 2006, p. 154ff), which makes red-green essentially indistinguishable for the affected individuals.

From a task point of view, visualization is mostly used for presentation tasks but not for gaining insights or interacting. According to our interview partners, who think that visualization is well suited for analysts, this situation will change in the future which follows the predictions in (Centrifuge Systems 2008). However, in general, visualization often seems to be too far in the future, due to more severe problems at the data side still prevalent.

6.2 Interactivity

Because of the fact that visualization in general is not used broadly in practice, interactivity in visual methods is even less an important topic today. However, the interview partners had many ideas about possible uses and benefits of interactivity and also believe that users would react positively if they knew more about the possibilities of interactivity. This corresponds to the observation of the study carried out by Richards (2006, p. 65) that was conducted in a different context.

The fact that interactivity in visual methods is relatively unknown among users is rather surprising because its very idea is relatively old and was already emphasized by Bertin (1981, p. 5) 30 years ago:

> “[...] it is the internal mobility of the image which characterizes modern graphics. A graphic is no longer drawn once and for all; it is constructed and reconstructed (manipulated) until all the relationships which lie within it have been perceived.”

Interactivity in BI is mostly seen in the context of aggregated values and the ability to drill-down into details or getting details on demand, for example related documents. In Section 3.2 the two theoretic perspectives of interactivity-as-product and interactivity-as-process are presented. Most of the interview partners put forward aspects of interactivity-as-product focusing on product characteristics. However, one interview partner explicitly emphasized interactivity-as-process in discussing different groups of users and why they interact under which premises. Apart from that, other aspects of interactivity were emphasized, namely interactivity in the sense of providing opportunities for data input by users, interactivity as means for computer-mediated communication, and in the sense of interoperability of applications. Particularly, the last topic of interoperability between applications seems interesting and not discussed by theoretic models up to now.

As presented in Section 3.2.4, two reasons for the positive effect of interactivity given in theory are the reduction of cognitive load (reducing the gulfs of execution and evaluation) and a higher expressiveness of the user interface language (richer possibilities for input and output). Both these reasons were also recognized as benefits of interactivity in the empirical study. The reduction of cognitive load is largely seen as helping to make decisions more quickly and as saving time. The higher expressiveness of the user interface language is described as helpful in dealing with complexity and gaining a deeper understanding of the data.

The third reason for the positive effect of interactivity is seen in theoretical approaches in higher engagement (feeling of being in control / first-personness). This was also recognized in the empirical study and interview partners claimed that increased use of interactivity and visual methods would create a more interesting and attractive working environment for employees. Furthermore, it was stated that this would enhance the creativity of employees tremendously. Shneiderman (2002, p. 17) emphasizes the importance of creativity and describes the relationship between humans and tools.

> “An ambitious goal for the new computing is to support your creativity in many domains: sciences and the arts, composing and performing, and work and entertainment. Computers won’t ever have Aha! moments; only people are capable of experiencing that joy. However, computers will support your access to previous work, consultation with peers and mentors, rapid generation and exploration of proposed solutions, and dissemination within the field.”

Creativity and interactivity are highly interconnected, as Fischer & Giaccardi (2007, p. 28) note:

> “Although creative individuals are often thought of as working in isolation, much of our intelligence and creativity results from interaction with tools and artifacts and from collaborating with other individuals.”

This notion of creativity and interactivity is also related to the concept of being in the *flow* introduced by psychologist Csikszentmihalyi (Csikszentmihalyi 1991, p. 71ff). The term “flow” denotes an engaging experience and a level of immersion that is achieved by the user when experiencing a system. Arriving at this experience can be eased by providing means for seamless interactivity with tools and artifacts.

6.3 Users

Initially, our interview partners identified top management as the main user group for visual methods in BI, on the one hand, and customers, on the other hand. When considering different visualization tasks, lower and middle management were also identified as a user group, who would mainly benefit from visual exploration and analysis tasks. This is in contrast to senior managers, who mainly deal with presentation tasks.

A prominent problem claimed by all interview partners is that users do not know what they want. Two aspects were mentioned for this issue. First, users are hardly able to articulate what data they need and what tasks they need to perform. Second, users frequently do not have any idea of how the data should be represented. Therefore, the majority of users do not know about the possibilities of visual methods but react usually positively when they get to know them.

Moreover, IT personnel is mostly concerned with data and tool issues in BI systems and much less trained in questions of data representation. This might be a reason why the usage of visual methods in BI is relatively low.

6.4 Corporate Culture

Apart from not knowing what is possible in terms of visual methods, users tend to stick to work habits they have employed and are largely defined by a certain corporate culture. In the area of usability engineering, this issue has been acknowledged by Norman (1996, p. 235):

> "I have come to recognize that industry faces numerous problems that are outside of the scope of the traditional analyses of design. In particular, there are management and organizational issues, business concerns, and even corporate culture."

Derived from this, a lesson learned might be that corporate culture is a crucial factor that needs to be considered when developing visual methods in general, not only with regard to users themselves, but also with regard to their domain and environment.

6.5 Future Ideas

A very interesting approach towards interactivity and visual methods was mentioned by two of the interview partners. They imagined systems that do not necessarily display all data or variables but focus on those that strongly differ from their expected value or action. These adaptive systems would allow managers to focus on important areas while avoiding the need for observing all available variables and searching for the ones that need action.

6.6 Questions

To wrap up the discussion of the results of the empirical study, answers will be given to the questions imposed as goals for the study in Chapter 4.

Which visual methods are currently applied and what for? According to the interview partners, the application of visual methods in BI is generally not widespread. The main technique for representing data is in tables and numbers. Visual aids that are used in connection with tables are text and cell coloring when certain value thresholds are exceeded. Visualizationis mainly used as an additional way of representing tabular data in reports. The most often used visualization techniques are standard diagrams like bar charts, line charts, pie charts, and traffic lights. Which technique is used depends largely on the BI tool at hand, personal taste, and corporate culture.

Application areas identified as useful for applying visual methods are foremost controlling, followed by budgeting, quality management, contract management, personnel planning, marketing, as well as sales and customer relationship management.

Are these methods paper- or computer-based and are they static or interactive? Most applied visual methods are computer-based but static or have very little interactivity.

How are the visual methods used? Visual methods are mainly used for presentation tasks in the investigated companies, which mean visual presentation of results for communicating them to other individuals. Currently, analysis and exploration tasks are secondary only. However, this area is seen as beneficial for better business results and also higher employee satisfaction. From a business point of view, visual methods are or are believed to be applicable in operational, tactical as well as strategic tasks.

How important are visual methods for business data analysis and for decision-making? Visual methods are seen to be two steps ahead of current practice in BI. Today, more basic problems of data gathering, data modeling, and data quality are prevalent and visualization is secondary only.

What is the understanding of interactivity? Interactivity is mostly understood as a means for drill-down (navigating from aggregated overviews to detailed data) and details-on-demand (getting details for an item of interest, such as related document) by the interviewed IT managers. Apart from that, interactivity is also seen as interoperability between applications and as a means to allow for data input by users.

How is interactivity valued? Reportedly, users are generally positive about interactivity in visualizations when they get to know it but there is usually no demand for more interactivity. The interview partners of our empirical study stated that users that do not know interactivity are happy with what they have, but users who have seen and experienced interactivity, want more. The interviewed IT managers in the field of BI generally have a positive view about interactivity and acknowledge that there are many benefits such as supporting a deeper understanding for making well-informed decisions but also a couple of potentially negative and critical aspects were mentioned.

6.7 Validity

As mentioned already, this empirical study can only be a first step towards exploring and understanding the multi-faceted phenomenon of interactivity in Visual Business Intelligence. Its purpose is to shed some light on the users' perspectives and their understanding of visualization and interactivity. In lieu of in-depth empirical as well as theoretical work that concentrates on this issue, a qualitative approach was chosen to obtain a broader understanding of the topic from a user's point of view. However, due to the fact of the limited amount of participants, the acquired and presented results should be taken with caution. The results reflect the opinions and conceptualizations of six individuals who are experts in the field of Business Intelligence. Therefore, they cannot be generalized without reservation. However, no major contradictions where encountered among the interview partners which suggests at least some potential for broader validity of the obtained results. Moreover, the selected group of interview partners cannot be characerized as the classical end-users. Therefore, the opinions of the interview partners may differ from those of classical end-users without IT background and have to be put into perspective.

In the upcoming chapter, a conclusion is given, and ideas for possible future work are presented.

Chapter 7

Conclusion & Future Work

As pointed out in Section 2.2, Information Visualization as part of Visual Business Intelligence strongly emphasizes the importance of interactivity. However, until now, interactivity as subject matter on its own is treated as secondary issue in research. How and why interactivity is beneficial for gaining insight and making decisions, is mostly left in the dark. Therefore, cognitive theories and models were investigated to find out whether those can give an answer to this question. However, interactivity is not explicitly accounted for or modeled in these theories. Scientific evidence on the value and role of interactivity in knowledge crystallization and decision-making processes is scarce.

In order to better understand interactivity in visual methods, an empirical study was carried out in the context of Business Intelligence. Six qualitative interviews with IT experts of large Austrian companies have been conducted and analyzed. Unfortunately, in the companies of the interview partners, the use of visual methods in general is very low in the field of BI and the use of interactivity in visual methods is even lower. However, a number of interesting insights were gathered in the study.

Three of these aspects are corporate culture, work attractiveness, and creativity. Corporate culture appears to have a big influence on work practices and determines largely how work is done and problems are solved in a work environment. With regard to work attractiveness, interactive visual methods are believed to have a positive influence on daily work practice as reported by the interview partners. This is also connected to a special focus on the creativity of employees that can be used to achieve better business performance. All of these aspects describe a shift from a strict top down regime, where not only targets are preset but also the exact processes, to a more flexible approach that leaves more room for flexibility in employees. This also emphasizes the view of interactivity-as-process where not only the interactivity of a digital artifact is considered but a larger system of actors, artifacts, culture, and the processes in between.

Moreover, the issue of trust seems to play an important role in the attitude towards visual methods. Trust in diagrams is reported to be lower than trust in numbers, and visual methods are often considered as nice to have as add-ons to make reports more flashy than as a tool for visual exploration or analysis.

Furthermore, according to the interview partners, interactivity and visual methods are often not known to users and, therefore, no demand is created from the user side.

In Section 1.2, a set of three hypotheses was formulated:

Most visual methods currently applied in Business Intelligence are static or employ only very limited forms of interactivity. This first hypothesis is supported by the findings of the empirical study. The use of visual methods is very limited in general and the majority of the used visualizations are static as reported by the interview partners.

Increasing the interactivity of visual methods is desired by users. The answer to this hypothesis is twofold. On the one hand, IT managers that were interviewed in the course of the study state that they would like to see more interactivity in visual methods themselves. On the other hand, it became apparent that the concept of interactivity in visual methods is not really known among end-users. This also means that interactivity is not actively asked for by end-users.

According to users, interactivity aids information and knowledge gains in business data analysis. The results of the empirical study show that the interviewed IT managers see interactivity as beneficial to gain information and knowledge. Similar to the previous hypothesis, end-users of the respective companies are reported to share this view but only if they have already experienced interactivity. Besides the perceived benefits, also critical aspects and disadvantages were identified.

Finally, an answer will be given to the main research question that inspired this work:

What is the perceived value and role of interactivity in visual methods for business data analysis? Interactivity in visual methods is generally associated with positive effects both from a theoretic and practical point of view. Many benefits are identified in connection to interactivity, and most importantly for the business context, interactivity is associated with supporting a deeper understanding of data for making well-informed decisions by the interview partners. However, from a theoretical point of view, empirical evidence for these benefits is very thin. On the downside, interactivity is associated with potential problems of distraction, high technical demands, and possibly user resistance. In current practice of BI, the role of interactivity in visual methods seems to be a secondary issue only and other more relevant problems, which are mainly data-related, need to be solved first.

As already mentioned in Chapter 6, the results of the empirical study are based on six qualitative interviews and therefore, the degree to which these findings can be generalized is limited in several respects. Hence, the presented results have to be put into perspective and cannot reflect the opinions of BI users in general. Much more, the presented findings can be seen as important starting points and issues to be investigated in-depth in the future.

Future Work

Overall, the findings of the empirical study are largely in-sync with theory but theory and practice do not quite connect to each other yet.

First, there is a clear need for empirical studies to investigate the role, advantages, and disadvantages of interactivity in order to provide hard facts as empirical basis.

Second, more focus is needed on considering interactivity-as-process, towards users, their domains and why interactivity is used for which goals.

Third, the question of trust depending on the form of representation needs to be investigated thoroughly to be able to answer the question why trust in diagrams is apparently lower than trust in numbers.

Fourth, from a theoretical point of view, cognitive theories and models need to be enriched to explicitly account for the role of interactivity in order to be able to capture and predict the role and influence of interactivity.

Fifth, the added value of both visual methods and interactivity needs to be demonstrated to users. This might be done via examples, empirical evidence, and, probably most successfully, through business success stories.

Sixth, and probably most important for stakeholders, the impact of the increased use of visual methods and interactivity on business needs to be investigated and shown clearly.

The goal of this thesis was to shed some light on the concept of *interactivity* in the context of Visual Business Intelligence. As a first step, the involved areas of Business Intelligence (BI), Information Visualization (InfoVis), and Visual Business Intelligence were presented. Furthermore, the central aspect of interactivity was tackled first from a theoretical point of view by investigating different cognitive theories and models as well as the state of the art in research about interactivity itself. Second, the current state of affairs of interactivity and visual methods in BI in practice was investigated by conducting an empirical study in form of qualitative interviews.

This work can only be a start towards more research about interactivity. Overall, Visual Business Intelligence and the role of interactivity are extremely interesting and rich topics that will grow in importance in the future.

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List of Abbreviations

BI	Business Intelligence
CRUM	Computational-Representational Understanding of Mind
DSS	Decision Support System
EIS	Executive Information System
ESS	Executive Support System
HCI	Human-Computer Interaction
ICT	Information & Communication Technology
InfoVis	Information Visualization
I/O	Input/Output
IT	Information Technology
MIS	Management Information System
MSS	Management Support System
OR	Operations Research
PIM	Personal Information Management

Appendix A

Empirical Study Material

The material of the empirical study was prepared in German. Therefore, the whole upcoming section is written in German.

A.1 Interview Guideline

Interviewleitfaden

Visuelle Methoden im Bereich Business Intelligence: Rolle von Tabellen, Diagrammen und Grafiken im unternehmerischen Alltag

Datum:

Name:

Firma:

Uhrzeit:

Intro

- Begrüßung
  - Hinweis Aufnahmegerät, Anonymität der Befragung
  - Hinweis, dass die anonymisierten Ergebnisse dem Interviewten zur Verfügung gestellt wird.
  - Hinweis Struktur mitschreiben+"Zeitprotokoll-Timecode"
  - Wie lange schon im Bereich BI tätig?
- Konzentration auf Visuelle / Graphische Methoden der Business Intelligence
  - Diagramme/Grafiken
  - Tabellen
  - *Evt. Beispiele zeigen*

Zur Person / BI allgemein

1. Was sind ihre Hauptaufgabengebiete?
   a. Seit wann beschäftigen sie sich mit BI?
2. Was verstehen sie unter Business Intelligence?
   a. Was gehört zu BI?
3. Welche Methoden der BI werden bei ihnen angewendet?

Visuelle Methoden allgemein

WAS

4. Welche visuellen/graphischen Methoden werden für Business Intelligence bei ihnen angewandt?
5. Können sie bitte eine handvoll Beispiele nennen?
6. Sind diese Methoden papier-basiert oder computer-basiert?

WOFÜR

7. Für welche Aufgaben werden visuelle Methoden verwendet?
   Stichworte: Exploration, Analyse, Präsentation
8. Für wen sind die Ergebnisse gedacht?
   Stichworte: Die Personen, die es ausarbeiten selber; Vorgesetzte / Management / Vorstand
   a. Welche Erwartungen gibt es auf seiten dieses Zielpublikums?
9. Welche Fragen oder Probleme werden typischerweise mit visuellen/graphischen beantwortet bzw. gelöst?
10. In welchen unternehmerischen Bereichen werden visuelle/graphische Methoden hauptsächlich eingesetzt?
    Stichworte: operativ, taktisch, strategisch

WIE

11. Wie wird damit gearbeitet? / Gibt es typische Analyseszenarien? (Use-cases)
12. Wie oft werden diese Methoden eingesetzt?

REFLEXION

13. Wie beurteilen sie den Nutzen von visuellen/graphischen Methoden in BI?

14. Welche Vor- und Nachteile gibt es bei den eingesetzten Methoden? / Welche Einschränkungen gibt es?
15. Gibt es aus ihrer Sicht Wünsche/Verbesserungsmöglichkeiten?

ERFAHRUNG

16. Wie werden visuelle/graphische Methoden von den BenutzerInnen in ihrem Unternehmen aufgenommen?
17. Werden visuelle/graphische Methoden aktiv verlangt/nachgefragt?

Interaktion in visuellen Methoden

WAS

18. Was verstehen sie unter Interaktivität bzw. Interaktion in Zusammenhang mit Tabellen, Diagrammen und Grafiken?
    ggf. Input: Vorstellung Interaktion / Direkte Manipulation - Demo
19. Welche Rolle hat Interaktivität? / Was kann man damit tun?
20. Sind die meisten der bei ihnen eingesetzten visuellen Methoden statisch (fix vorgegeben) oder interaktiv manipulierbar?

REFLEXION

21. Ist Interaktion für sie sinnvoll im Bereich visueller Methoden? Wozu könnte Interaktivität beitragen?
22. Wie wichtig ist aus ihrer Sicht Interaktivität bei visuellen Methoden?
23. Was sind aus ihrer Sicht Vorteile von Interaktion?
    Stichworte: Schneller? bessere Ergebnisse?
24. Was sind aus ihrer Sicht Nachteile von Interaktion?
25. Welchen Wert hat Interaktion für sie?
    Würden sie Geld investieren, um interaktive Werkzeuge zu bekommen?

ERFAHRUNG

noch nicht eingesetzt bzw. sehr eingeschränkt:

26. Sind die BenutzerInnen in ihrem Unternehmen mit statischen / vordefinierten Sichten zufrieden oder wären sie aus ihrer Sicht an interaktiven Möglichkeiten interessiert?
27. Wird Interaktivität aktiv nachgefragt?

bereits eingesetzt:

28. Wie wird Interaktivität in visuellen/graphischen Methoden von den BenutzerInnen in ihrem Unternehmen aufgenommen?
29. Wie würde aus ihrer Sicht noch mehr Interaktivität wahrscheinlich aufgenommen werden?

Demographische Daten

Geschlecht? m ❑ w ❑

Alter? / Geburtsjahr?

Funktionsbereich?

- ☐ Finanz- / Rechnungswesen
- ☐ Controlling
- ☐ Marketing
- ☐ Vertrieb / Verkauf / Kunden-betreuung
- ☐ Einkauf
- ☐ Logistik/Transport
- ☐ Organisations- / Unternehmensentwicklung
- ☐ Kommunikation
- ☐ Produktion
- ☐ Forschung & Entwicklung
- ☐ Qualitätsmanagement
- ☐ Personalbetreuung / -administration
- ☐ Personalentwicklung / Ausbildung
- ☐ Projektmanagement
- ☐ Stab
- ☐ Verwaltung/Sekretariat
- ☐ Sonstige

Hierarchieebene?

- ☐ Vorstand / Geschäftsführung / Unternehmensleitung
- ☐ Bereichsleitung
- ☐ Filial- / Niederlassungsleitung
- ☐ Abteilungsleitung
- ☐ Team- / Gruppenleitung
- ☐ Referent / Experte
- ☐ Mitarbeiter / Sachbearbeitung
- ☐ Sonstige

Unternehmensgröße?

- ☐ 1-49 MA
- ☐ 50-99 MA
- ☐ 100-499 MA
- ☐ 500-999 MA
- ☐ 1000-4999 MA
- ☐ 5000-9999 MA
- ☐ 10000 oder mehr MA

Branche?

- ☐ Agrarwirtschaft
- ☐ Architektur
- ☐ Automobil-industrie
- ☐ Bau & Bergbau
- ☐ Beratung
- ☐ Chemie/Pharma
- ☐ Druckindustrie
- ☐ Elektrotechnik
- ☐ Energie
- ☐ Finanzwirtschaft
- ☐ Forschung & Entwicklung
- ☐ Gesundheits-wesen
- ☐ Gastronomie
- ☐ Handel
- ☐ Immobilien
- ☐ Maschinenbau
- ☐ Medien
- ☐ Öfftl. Dienst
- ☐ Software
- ☐ Telekommuni-kation
- ☐ Tourismus
- ☐ Transport
- ☐ Werbeindustrie
- ☐ Sonstiges

Ausbildung? (höchster Abschluss)

- ☐ Keine
- ☐ Volksschule
- ☐ Hauptschule
- ☐ Matura
- ☐ Berufsausbil-dung
- ☐ Meister
- ☐ Bachelor
- ☐ FH-Studium
- ☐ Uni-Studium
- ☐ MBA
- ☐ Promotion
- ☐ Habilitation
- ☐ Sonstiges

A.3 Coding Scheme