# User-Centered Survey of Immersive Analytics

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## Introduction

Several immersive data visualization approaches and systems have been developed and explored recently to benefit users in various domains, to understand the underlying data. We survey the Immersive Analytics (IA) literature from the user's perspective rather than a systemic lens. We relate the user's desired level of understanding of the data to its technical qualities. We investigate previous literature to understand how different technologies, levels of interaction (passive consumption / active interaction), data representations (concrete / abstract), collaborative features, and user study design have been used to benefit the users.

**We want to understand:**

What kind of technical implementation might be appropriate to enable the user to understand the data to a low or high level, and

What kinds of user studies have been conducted to develop or improve IA systems to meet user needs.

We analyze our corpus to investigate how existing visualization systems have been implemented, and with what purpose they were created. We have chosen to categorize the corpus by whether the main purpose of the system was to present the data to the user for a low level of understanding, or to allow the user to analyze the data at a deeper level and gain a high level of understanding. Through these relationships, the reader might be able to derive a combination of technical qualities that would work for a desired level of understanding for users of their visualization system.

**Research questions:**

1  How are the user's needs in terms of level of understanding (high or low) related to the technical qualities of data visualizations (active interaction or passive consumption; abstract or concrete representation; presence or absence of collaborative features) in the IA literature?
2  What types of user studies have been conducted in previous empirical studies? How have these studies been conducted and documented to understand the user's needs?
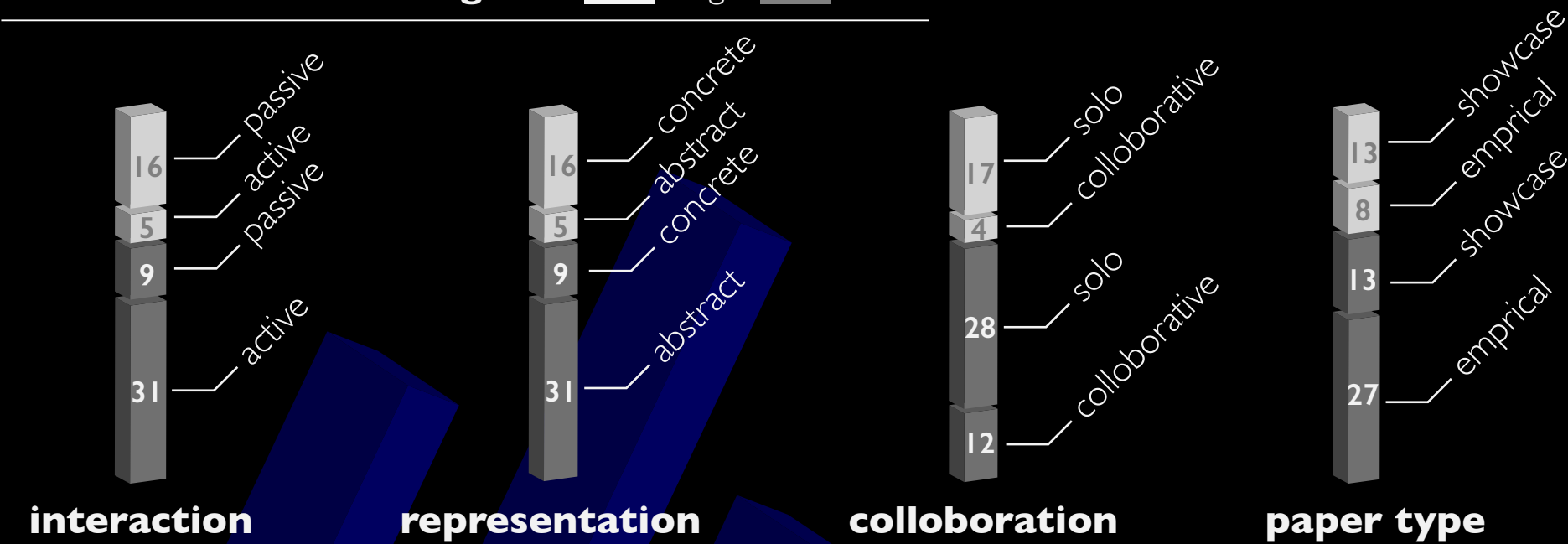
## Methodology

For this preliminary review, we took an unstructured approach to literature discovery. The researchers on the team searched databases pertinent to their own expertise for the terms ("data visualization" AND "virtual reality") OR "immersive analytics". Most papers we found discussed visualizations as a tool that could be used in any domain. These domain-agnostic papers made up 28.6% of our corpus. The next most popular domains were sciences (15.9%), medicine (9.5%), and archaeology (9.5%). The venues with the highest representation are IEEE VR (19.1%), TVCG (16.2%), VIS (4.4%) and VRST (4.4%). We expanded our search by reading papers referenced in the initial corpus. Of the 64 papers analyzed for this review, 43 were from 2015 or later, and the earliest paper was from 1993. The corpus we analyzed is publicly accessible, including keyword distribution, domain, year of publication, and the venue at https://bit.ly/IAbibliography.

## Preliminary Results

In our analysis, we focus on the relationship between the desired level of understanding of the data (low / high) and its technical qualities (four categories):

1  **level of interaction:** passive consumption (observing the data) vs. active interaction (manipulation and control of data)
2  **type of representation:** concrete (visual representation akin to the physical manifestations of the data) vs. abstract (representation stands for the property of the things being visualized)
3  **collaborative features:** collaborative (multiple users) vs. solo (individuals)
4  **paper type:** empirical (evaluation through user study) vs. showcase (display of the work)



level of understanding:  low ▢  high ▣

| interaction | representation | colloboration | paper type |

interaction: 16 passive, 5 active, 9 passive, 31 active
representation: 16 concrete, 5 abstract, 9 concrete, 31 abstract
colloboration: 17 solo, 4 collaborative, 28 solo, 12 collaborative
paper type: 13 showcase, 8 empirical, 13 showcase, 27 empirical

### User Study Types

We identified two kinds of user studies; exploratory and informal (studies without clear report of the process) vs. structured user studies (use methods and tools to evaluate and improve usability).
**Methods and tools:** Evaluation methods and tools included usability questionnaire, think aloud, task completion (quality and/or quantity), SUS questionnaire, and exit questionnaire. However, many papers did not document the tools they used.
**Constructs in user study results:** The reviewed papers reported constructs like task completion time, usability and presence, the level of precision, reduced abstraction, interface user experience, educational aspect, the impact of the system, and subjective results.

## Limitations/ Future Work

For this review, we conducted an unstructured search of the visualization literature in order to build our corpus of 64 IA papers. This was in large part due to the ambiguous nature of the definition of Immersive Analytics. Our corpus was exclusively extracted from academic venues, disregarding technical demonstrations on personal blogs, or professional applications in the industry. We would like to include such contributions in future work as well as exploring how collaborative analysis and interaction with data are implemented in IA. We would like to dive deeper into the correlation between the collaborative environment and technologies, interaction style, type of the data, and the purpose of the study. Furthermore, collaboration often necessitates that people from different environments or disciplines work together to achieve a common goal.

## Conclusion

This investigation will benefit designers, developers, and practitioners who want to implement immersive visualizations from a User-Centered Design perspective, and help Immersive Analytics researchers get a better understanding of the gaps in the current literature and explorations. Our hope is that our paper can spark conversation around the importance of User-Centered Design within the Immersive Analytics domain.