



ADQDA: A Cross-device Affinity Diagramming Tool for Fluid and Holistic Qualitative Data Analysis

Jiali Liu, James R Eagan

► To cite this version:

Jiali Liu, James R Eagan. ADQDA: A Cross-device Affinity Diagramming Tool for Fluid and Holistic Qualitative Data Analysis. Proceedings of the ACM on Human-Computer Interaction , 2021, 5 (ISS), pp.19. 10.1145/3488534 . hal-03370011

HAL Id: hal-03370011

<https://imt.hal.science/hal-03370011>

Submitted on 7 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

ADQDA: A Cross-device Affinity Diagramming Tool for Fluid and Holistic Qualitative Data Analysis

JIALI LIU, LTCl, Télécom Paris, Institut Polytechnique de Paris, France

JAMES R. EAGAN, LTCl, Télécom Paris, Institut Polytechnique de Paris, France

Affinity diagramming is widely applied to analyze qualitative data such as interview transcripts. It involves multiple analytic processes and is often performed collaboratively. Drawing on interviews with three practitioners and upon our own experience, we show how practitioners combine multiple analytic processes and adopt different artifacts to help them analyze their data. Current tools, however, fail to adequately support mixing analytic processes, devices, and collaboration styles. We present a vision and prototype ADQDA, a cross-device, collaborative affinity diagramming tool for qualitative data analysis, implemented using distributed web technologies. We show how this approach enables analysts to appropriate available pertinent digital devices as they fluidly migrate between analytic phases or adopt different methods and representations, all while preserving consistent analysis artifacts. We validate this approach through a set of application scenarios that explore how it enables new ways of analyzing qualitative data that better align with identified analytic practices.

CCS Concepts: • **Human-centered computing** → **Interactive systems and tools**; • **Information systems** → **Collaborative and social computing systems and tools**.

Additional Key Words and Phrases: affinity diagramming, qualitative data analysis, sensemaking, cross-device interaction, multi-surface interaction, collaboration

ACM Reference Format:

Jiali Liu and James R. Eagan. 2021. ADQDA: A Cross-device Affinity Diagramming Tool for Fluid and Holistic Qualitative Data Analysis. *Proc. ACM Hum.-Comput. Interact.* 5, ISS, Article 489 (November 2021), 19 pages. <https://doi.org/10.1145/3488534>

1 INTRODUCTION

Affinity diagramming (also known as the KJ method [36]) is a spatial clustering technique where analysts manually move around and group individual data items based on their similarity or relevance to a shared topic[6]. It has been applied for a wide variety of tasks in different domains, such as Human-Computer Interaction (HCI), anthropology, and management[6, 43, 57, 60]. It is generally applied for three kinds of purpose [32]: to elicit diverse input, such as in brainstorming or project planning; to organize data into known categories; and to analyze data, where people exploit spatial organizations to help them make sense of unstructured and seemingly fuzzy qualitative materials, such as interview transcripts. This work focuses on this last category.

Many activities are involved in building such understanding from collections of data: analysts need to closely examine original materials; make highlights or annotations while reading; extract related pieces of information to put them in space; experiment with different kinds of arrangements to explore conceptual alternatives; they might also build higher level diagrams to abstract the emerged concepts, etc. Fig. 1 shows a real analysis environment customised to support various

Authors' addresses: Jiali Liu, LTCl, Télécom Paris, Institut Polytechnique de Paris, Paris, France, jiali.liu@telecom-paris.fr; James R. Eagan, LTCl, Télécom Paris, Institut Polytechnique de Paris, Paris, France, james.eagan@telecom-paris.fr.

© 2021 Association for Computing Machinery.

This is the author's version of the work. It is posted here for your personal use. Not for redistribution. The definitive Version of Record was published in *Proceedings of the ACM on Human-Computer Interaction*, <https://doi.org/10.1145/3488534>.



Fig. 1. An example analysis using paper, where the user has customised the environment to support various analytic activities and representations in qualitative sensemaking. Source: Sarah Scarsbrook.¹

activities and representations with paper tools¹. The overall sensemaking process is highly iterative [52], where analysts switch back and forth between different analysis phases and views, such as to refine their mental models, collect additional evidences, or test alternative hypotheses [42]. The analysis artifacts could also hold various connections. For example, a participant’s quote in a sticky note might make little sense without its context in a transcript. Current tools, however, tend to treat the analysis activities and artifacts as discrete pieces. Transitioning between these phases involves too much friction, effectively linearizing this iterative process. For example, refining codes in the source data might break the existing layout in any corresponding affinity diagrams.

Qualitative data analysis is characterized as a dynamic, intuitive, and creative work [4]. Many additional factors may come into play: whether the analyst is working alone or collaborating with others; what kinds of analytic methods they prefer; whether they are working in the same location or from remote work sites; the tasks they are engaged in; or available devices. When working on a common analysis project, different collaborators might adopt different tools, methods, and data representations, and they might tackle the analysis from different perspectives [41, 61]. Even a single user often needs to adopt different conceptual methods or transition between different contexts, such as when appropriating different devices in the office and from home, etc.

Current tools focus on specific aspects of affinity diagramming, but do not address the holistic process of qualitative data analysis. Choosing one tool often means compromising the other factors stated above. For example, many continue to prefer the traditional paper approach due to its ability to be spread out in available space to extend the “space to think” [2]. Yet, it is difficult to share remotely, search the context of a quote snippet, or manage different diagrams [32, 35]. Digital affinity diagramming tools, such as Affinity+ [14] or Miro², focus on the clustering tasks without considering other analytic phases such as coding. Qualitative data analysis tools, such as MaxQDA³ or NVivo⁴, support diagramming analysis in conjunction with coding practice, but are often desktop-based and limited to a single user, single device.

In this paper, we present a vision and proof-of-concept system ADQDA (Affinity Diagramming for Qualitative Data Analysis), a cross device, collaborative affinity diagramming tool for a fluid, holistic sensemaking process. In our vision, users may seamlessly transition between different analytic phases or adopt various methods and representations, all while preserving consistent analysis artifacts. Users may work alone or adopt different collaboration styles depending their situated needs. They may use any appropriate available digital devices as they fit their tasks at hand. For example, they may use their wall in conjunction with a laptop, phone, or tabletop as they need space to think [2] or to display related information. ADQDA applies the concept of shareable

¹<https://theartsjournal.net/2019/03/28/the-coding-cave/>, accessed 10 Sep 2021.

²<https://miro.com/>

³<https://www.maxqda.com/>

⁴<https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home>

dynamic media [40] in multi-surface environments to allow the dynamic distribution of different devices across multiple users and tasks. Changes are synchronized live across devices to all users. To facilitate a seamless transition between different analysis activities and representations, ADQDA preserves a consistency between related artifacts as they arise in the process. We further design various multi-surface interaction techniques to reduce the cognitive demand of users when iterating between different analytic views, and offer awareness mechanisms to solve potential cognitive breakdowns of collaborators. The contributions of this work are:

- a design space for affinity diagramming tools for qualitative data analysis, drawn from our own experience and from interviews with practitioners,
- a vision for fluid, holistic, cross-device qualitative data analysis that reflects the iterative nature of sensemaking of qualitative data across multiple analytic phases;
- a proof-of-concept prototype, ADQDA, implemented as a distributed web-based system using Webstrates [40], and
- a series of demonstrative scenarios that show how ADQDA realizes this vision and can potentially facilitate richer, deeper qualitative data analyses.

2 RELATED WORK

2.1 Affinity Diagramming Practices & Tools

Type of tasks. The term affinity diagrams captures a variety of practices, with different purposes and procedures [32]. By investigating real-world affinity diagramming practices with 13 participants, Harboe and Huang found that, when used “To Analyze Data,” such as from surveys, field interviews and observations [1, 10, 42, 50], it tends to be more cognitively intensive with relatively large numbers of notes and a longer duration [32]. ADQDA focuses on affinity diagramming for qualitative data analysis, where the notes in a diagram are extracted from already exist materials. Many current digital diagramming systems, such as AffinityTable [27] or Affinity+ [14], focus on brainstorming-like scenarios where the notes depict ideas that are generated as a part of the process.

Extending space to think. When dealing with increasing numbers of notes, space constraints are often a problem [32, 35, 43]. With paper tools, people often appropriate available space, such as by spreading out to other walls or tables [35, 43]. Digital tools, however, “... [are] thought to restrict users to the confines of a pre-determined space such as a desktop instead of using any and all space available to them” [35]. Some diagramming tools, such as Miro² or MURAL⁵, use an infinite canvas to facilitate an ever-expanding diagram, but remain limited to a single window’s viewport. The AffinityTable [26] combines two large displays, one vertical one horizontal, yet they play a fixed role in the analysis process. The MindMap [44] supports ad hoc combination of personal phones to build shared mind maps during brainstorming. Different strategies are adopted under space constraints, such as only working on one part of a diagram at a time or omitting less important ones, which can hinder the analysis [32, 38]. ADQDA, instead, allows users to extend the space by adding in additional available displays and flexibly combining them to suit for their analysis tasks at hand.

Transitioning between analysis activities & representations. Sensemaking is an iterative process, where analysts switch back-and-forth between different analysis activities and phases [52]. Affinity diagramming as a specific sensemaking technique inherits this nature [6]. Current tools, however, rarely consider the holistic process, bringing friction to such transitions. For example, Harboe et al. found their participants spent as much time just copying highlights to sticky notes as on the analytic task itself [32]. Tools can help transform paper notes to digital ones [26, 39] or vice versa [34]. Tools like Paper++ [45], PapperlappApp [30, 31], and Affinity Lens [58] apply a hybrid

⁵<https://www.mural.co/>

approach that interweave the physical representations and digital power. Much of today's data are collected initially in digital forms, transforming directly between digital systems is also required.

Many current digital diagramming tools consider scenarios where inputs are primary ideas—as in brainstorming—rather than data items extracted from documents. Additional tools, such as word processors, need to be integrated in the process. Transitioning data from one system to another is often more cumbersome than just using import, export functionality. This disconnection could lead to cognitive breakdowns or otherwise hinder the analysis. Judge et al. [35] observed that “Even if interview transcripts are available to users, as the number of notes increases, it becomes impractical to look up the meaning and context of notes.” They suggested to attach snippets of original transcript to the notes. ADQDA aims at facilitating various kinds of transitions by applying different linking mechanisms, cross-device interaction techniques, and awareness mechanisms.

Collaboration. Affinity diagramming is often performed collaboratively [6, 35, 54]. The number of users can range from a small group of two, to a group of more than twenty [32, 43]. Paper tools constrain users to a shared location. The GKJ [46] system automatically digitizes paper affinity diagrams to facilitate later sharing. Digital tools, such as Distributed Designers' Outpost [25] or Miro² support remote collaboration on the same diagram, and provide extra awareness mechanisms such as shared cursors or shadows of the remote collaborator for presence. ADQDA aims to support flexible collaboration modes. Analysts can work alone or collaborate with colleagues either in the same location or from remote places. ADQDA further allows asymmetric collaboration, where multiple analysts can work on different phases and views while maintaining a consistent analysis.

2.2 Various Sensemaking Approaches & Tools

Affinity diagramming, as a specific sensemaking technique might be used together with other approaches, such as coding, which is more structured and embedded in documents [16, 22, 55]. Two common analytic strategies are often applied: open coding—also called substantive coding or grounded coding—as an inductive form of analysis, emphasizes gradually identifying themes and concepts that emerge from data to construct new theories [13, 18, 19]; and closed coding—also called a priori coding or template coding—takes a deductive approach where codes are created beforehand based on certain theoretical frameworks or pre-existing knowledge and are used to frame the data into a coherent construct [21, 37].

In practice, practitioners often blend the two into different variations as suitable for their own analysis needs. For example, they may begin with a set of *a priori* codes based on interview questions and iteratively add to them as new themes emerge. Elliott observed “the most pragmatic researchers will typically use both in a single research project” [24]. Blair found that a combination of these two can reduce confirmatory bias since they “speak to, and counter, one another” [8]. Chandrasegaran et al. [17] showed how the processes of Grounded Theory [20] parallels Pirolli and Card's sensemaking model [52], where analysts iteratively switch between bottom-up (from data to theory) and top-down (from theory to data) activities. Both coding and diagramming or a mix of the two could be adopted to these models based on concrete projects.

Commercial computer-aided qualitative data analysis software, such as MaxQDA³, ATLAS.ti⁶, and NVivo⁴, support both coding and diagramming. Despite providing rich functionalities, such as using machine learning to identify potential interesting themes, they impose a certain analytic sequence, often linearized with coding before diagramming. They are also limited to a desktop-based, single-user model. ATLAS.ti Cloud⁷ provides web-based live collaboration, yet it does not support diagramming. ADQDA allows users fluidly blending diagramming and coding across all

⁶<https://atlasti.com/>

⁷<https://atlasti.com/2019/02/26/live-collaboration-in-atlas-ti-cloud/>

analysis stages. Analysts thus can adopt flexible approaches depending on their mental models and contextual needs.

2.3 Artifact Ecologies in Collaborative Sensemaking Activities

Real-world analytic processes are often dynamic, with users arbitrarily joining in any analytic task among a network of activities [32, 43]. Bødker and Klokmoose's Human-Artifact Model emphasizes studying heterogeneous devices as part of an artifact ecology where "one can dynamically interplay with others and with users' web of activities" [9, 15].

Interactive surfaces, such as mobile phones, tablets, laptops, tabletops, and wall-sized displays, are becoming increasingly accessible and pervasive in our daily life. Different types of devices have their own affordances and technical capabilities in terms of form, size, input modalities and precision. Brudy et al. [11] classify diverse devices as Ad-hoc/Mobile, Semi-fixed and Fixed, based on their degree of support for dynamic changes and reconfiguration. Scharf et al. [56] categorize these devices based on ownership, access, and distance. These characteristics make different type of devices more suited to certain collections of tasks and interactions, and are often combined as an ecosystem for complex tasks and knowledge work [15]. Smaller devices offer better mobility, portability and privacy [29], are often used at a personal scale and can mediate the interactions with large displays in multi-surface environments; larger displays, by contrast, allow simultaneous access and can present more information, often acting as a shared sensemaking space [5, 12, 33].

Built on the concept of shareable dynamic media, Klokmoose et al. introduced Webstrates [40], a malleable, collaborative environment, where each user can dynamically modify and extend the environment from within. Badam et al. developed Vistrates on top of Webstrates and demonstrated how heterogeneous devices can be flexibly combined to support dynamic activities around data visualization [3]. ADQDA, built on Webstrates as well, focuses on the device ecology in the context of qualitative data analysis using affinity diagrams.

3 DESIGN SPACE ON QUALITATIVE SENSEMAKING

Drawing from our own experience and interviews with practitioners, we present a design space that helps to describe the various kinds of activities, methods, and artifacts in qualitative sensemaking, and to understand the painpoints analysts suffer. Drawing upon the analysis and design space, we present our vision for qualitative analysis tools.

3.1 Informal Interviews

As researchers in the HCI field, we have used affinity diagramming as a principal analysis method for taxonomic or interview-based studies published at flagship HCI conferences. One author has experience spanning 15+ years with the method, using both paper and digital tools. We further conducted informal interviews with two HCI researchers and a sociologist with rich experience using affinity diagrams. Figure 2 demonstrates the type of analysis tasks they described and the methods and tools used.

In our interviews, participants shared photos, videos, or websites of affinity diagrams generated in their past projects. We further walked through the process used to generate them. The goal of the interviews was to better understand how our participants used affinity diagramming in their research and to tease out potential painpoints they had experienced. We then showed them an initial version of ADQDA with rudimentary support for creating basic affinity diagrams on a wall-sized display. It included the basic abilities to import notes or images, collaboratively organize them on a multitouch wall (or with a mouse and scrollbars on a desktop computer), and add textual annotations. (The primary affinity diagram view shown in fig. 5(2) is based on this initial version.) This part of the interview was aimed at helping participants to project themselves into

Participant	Domain	Types of tasks	Raw materials	Extract notes from raw materials	Methods applied	Tools used
P1	Sociologist	Cluster social network diagrams	Images	No	AD	Paper, Wall-sized interactive display
P2	HCI	Interview-based studies	Interview transcripts	Yes	Coding + AD	Paper, Wall-sized interactive display
P3	HCI	Identify meaningful categories	Texts & Images	No	AD	Paper, Miro
Authors	HCI	Taxonomic or interview-based studies	Interview transcripts	Yes	Coding + AD	Paper, Wall-sized interactive display

Fig. 2. The type of analysis tasks and the raw materials our practitioners cope with using affinity diagramming, and the methods, tools engaged (AD: Affinity Diagramming).

the experience of conducting digital affinity diagramming on a wall-sized display, even if they had used different tools for their own analyses.

As fig. 2 shows, when applying affinity diagramming to analyze qualitative data, the notes in a diagram come in two forms: those being extracted from their original contexts, such as notes containing participants' quotes from interview transcripts, and those as independent data items, such as the sociologist's diagrams. We observed that they share some similarities. For example, practitioners in both cases explored multiple different ways to cluster their data, yet the former case involves the extra conceptual method of coding with its additional analysis activities and challenges. Our contribution primarily focuses on this case, where affinity diagramming and coding are combined.

3.2 Design Dimensions

We identify five dimensions in such analytic processes that help describe the various aspects engaged in qualitative sensemaking: (A) analysis phases, (B) conceptual methods, (C) analytic lens (D) modes of collaboration, (E) and types of devices used.

(A) Analysis Phases. Along the horizontal axis shown in fig. 3 are the core analytic phases: (1) extract related data items from raw materials (this phase is omitted in cases like P1 and P3), (2) assign data items into categories (often called codes), and (3) draw connections between categories to form higher-level concepts.

Some analysts may perform open coding (starting from the first phase and moving right). Others may perform closed coding (starting from right and moving left). Frequently, the two are mixed. No matter the strategy applied, users may seamlessly flow between these different phases in arbitrary order. For example, codes or concepts could be updated as more data items are extracted (e. g., transition from phase 1 to 2 or 3); insights derived in one coding system could trigger the creation of another focused on a specific concept (e. g., loop inside phase 2) or could trigger a new pass over the raw transcripts (i. e., from phase 2 to 1); the emergence of new concepts or hypotheses could lead to collecting more data (e. g., from phase 3 to 1), such as conducting additional or follow-up interviews, etc.

(B) Conceptual Methods. While we focus on using affinity diagrams to analyse data, we have seen practitioners mix the two conceptual methods—coding and diagramming—in a flexible way during different phases of their analysis. As in fig. 3, coding processes (in blue) represent analysis activities which are more structured. Such coding often entails highlighting text segments in the documents (phase 1); annotating highlights with keywords or tags (phase 2); and organizing or structuring

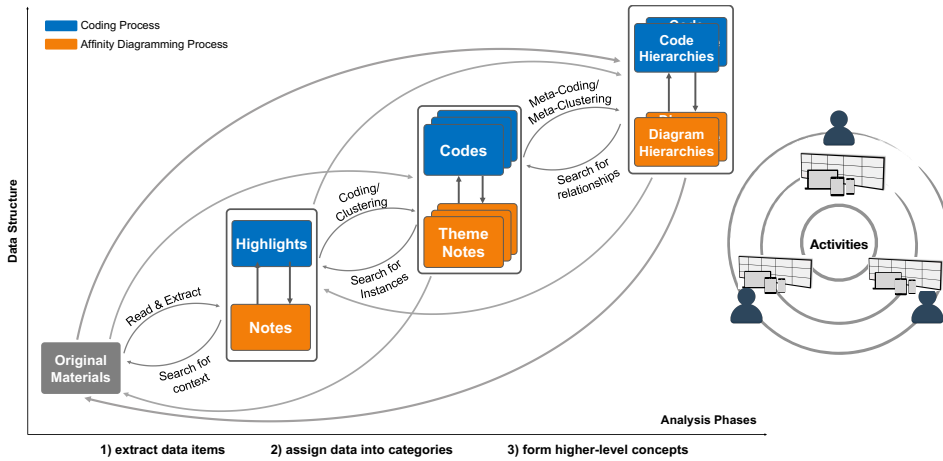


Fig. 3. A design space for sensemaking tools: (A) analysis phases, along the x-axis; three primary analytic phases for qualitative data analysis; and (B) conceptual methods, such as coding (in blue) and affinity diagramming (in orange) as complementary methods for analysis. (C) Analytic Lens, multi-faceted analysis shown as stacks of coding systems or affinity diagrams. The links between phases and representations show the transitions and iterations between them during the sensemaking process. (D) modes of collaboration and (E) types of devices. Users arbitrarily join in any analytic task among a web of activities, and appropriate pertinent device for situated tasks.

those codes, such as into a hierarchy (phase 3). Affinity diagramming processes (in orange) are more spatially-oriented analysis activities, where the analyst uses “space to think” [2]. Data is extracted from their source and transformed into notes that can be arranged spatially (phase 1). Analysts cluster these notes into groups, often with theme notes to summarise the abstract ideas of a cluster (phase 2). These theme notes can be further clustered to form higher level concepts, resulting in hierarchical diagrams (phase 3).

Coding and diagramming enable different kinds of complementary analyses, and both contribute to the cognitive interpretation of the data. In coding, ideas can be quickly recorded while reading. Highlights and margin codes are embedded in raw materials, maintaining their surrounding context. Diagramming, on the other hand, frees the analyst from the structure of the source document, helping to explore alternative connections and categorizations of the data—at the cost of this context. The placement of notes or the distance between them can convey extra conceptual messages.

Instead of following a certain analysis sequence, such as generating first level codes using coding while higher level concepts using diagramming, we found that participants (P2, Authors) often mix them in a more flexible way. For example, when discovering a new theme during diagramming, P2 described coming back to re-code the source transcripts to look for more occurrences that might have been missed. The choice of methods also depends on their situated contexts, such as using coding when working on the train and switching to diagramming when in the office.

(C) *Analytic Lens*. We found that analysts may need to view data through more than one lens, such as testing the fit of different ways of structuring the data [55] (P1); structuring the data from the perspective of different analytic questions (e. g. strategies involved vs. tools used etc.) [10] (and P2); or partitioning the analysis across individual participants [42]. These analytic practices result in multiple coding schemas or multiple affinity diagrams. We represent them as stacks of coding systems or affinity diagrams in our design space in fig. 3. These diagrams often hold various kinds

	Analytic Phases & Conceptual Methods (A & B)				Analytic lenses (C)	Collaboration modes (D)		Devices (E)
	Supports coding documents	Supports diagramming on large surfaces	Maintains coherence in transition across analytic phases	Maintains coherence between coding and diagramming	Maintains coherence across alternate analyses of data	Supports real-time remote collaboration	Supports asymmetric collaboration	Can dynamically extend interactive space with new devices
Distributed-Designer's Outpost		✓				✓		
Affinity+		✓						○ (Phones, tablets are used as ephemeral input devices)
Miro		○ (desktop-size viewport of infinite canvas)				✓		
MaxQDA	✓		○ (One-way, linear; New codes break existing diagrams)	○ (One-way, linear; New codes break existing diagrams)				
Paper	✓	✓						✓ (In terms of physical spaces)
ADQDA	✓	✓	✓	✓	✓	✓	✓	✓

Fig. 4. A comparison between different affinity diagramming and qualitative data analysis tools. Orange: diagramming-centric tools. Red: coding-diagramming tools. Symbol ✓: well-supported in the system. Symbol ○: partially supported, or cumbersome.

of relationships based on the users' mental model. For example, analysts might want to put two diagrams side-by-side to compare them or to synthesize them into a new diagram.

(D) Modes of Collaboration. In real-world practices, the analysis practices could be highly dynamic in terms of number of collaborators and their mode of collaboration. Based on our interviews and experience, some analysts might partition the data to work on distinct subsets at a given time; others may work on a first level diagram while a colleague simultaneously works on a higher level diagram; some use coding while others use diagramming. They may engage in the same or different phases or activities, using the same or different conceptual methods, in the same location or from distributed work sites, using various coordination strategies adapted to their mode of collaboration.

(E) Device Types. Different types of devices play unique and crucial roles in supporting different analytic tasks within the sensemaking process. Coding interview transcripts might make most sense when using a keyboard and mouse or a digital pen, whereas affinity diagramming may be more natural when using a touch display. Depending on the context, users should be able to adopt any appropriate and available device for the task at hand. Moreover, just as paper tools can be spread to walls and tables when analysis requires “space to think”, users should be able to combine different types of available digital displays to extend the space for analysis.

3.3 Painpoints—Or: What Current Tools Lack in This Space

The identified design space helps us to understand where current tools lack support. To demonstrate, we pick four representative systems of their types: Affinity+ [14], a research prototype for digital affinity diagramming; Distributed-Designer's Outpost [25], a digital whiteboard supports remotely organising notes in space; Miro², a commercial online collaborative whiteboard platform; and MaxQDA³, a commercial computer-assisted qualitative data analysis software (fig. 4).

Analysis Phases & Conceptual Methods. Current tools tend to require users to choose a certain analytic method (e. g. affinity diagramming or coding) or follow a specific analytic sequence (usually coding to get lower level concepts, then affinity diagramming to discover higher level concepts). Current digital diagramming tools benefit from the extra space of a large, interactive display to cluster notes, but any coding must typically be performed in another tool, with their associated import, export, and data munging challenges. Tools do support both, as MaxQDA, seem to assume

that users perform coding before diagramming. Changes made in coding alter the spatial positions of affinity diagrams. As one user in one of MaxQDA's own tutorial videos comments, "when MaxQDA brought the new coding results into the project, it re-sorted all the groups into alphabetical order for reasons I don't entirely understand."⁸

Analytic Lens. Diagramming-centric tools focus on scenarios where collaborators engage in a same shared diagram. While most tools allow the creation of multiple diagrams from the same data, they are typically treated as independent diagrams. As such, iteratively going back to a different phase of analysis, such as re-coding the data, would require manually updating the diagrams accordingly. MaxQDA provides rich model templates in MAXMaps, and does support associating multiple diagrams to the same data, but, only allows one active diagram at a time. In addition to the desktop-size limitation, it does not support tasks such as putting two diagrams side-by-side to compare them.

Modes of Collaboration. Tools like Affinity+ or paper constrain collaboration to a co-located space. Tools that support distributed, real-time collaboration, such as Distributed-Designer's Outpost and Miro, break this constraint, but assume collaborators all work on the same diagram. In MaxQDA and Nvivo, collaboration is done by passing work between team members. These tools can not be flexibly adapted to different collaboration needs, such as asymmetric collaboration where users might simultaneously work on the same analysis session but with different methods or views.

Device Types. In diagramming-centric tools, analysis activities often take place in a large, shared display, such as wall-sized display or tabletop, or on an infinite canvas as in Miro and Mural; small personal devices, such as phones, tablets, are often used as ephemeral devices for collecting input, but they do not extend the diagramming space. Most QDA tools, on the other hand, mainly focus on a desktop-based, single-user model. Though users can bring in a secondary screen to extend the analysis, it must run on the same machine and often only support one open window of each type at a time. We are not aware of any other tools besides paper that supports the ready addition of extra available displays to extend the analysis across phases and representations.

3.4 A Vision for Qualitative Sensemaking Tools

We envision digital tools can support qualitative data analysis as a fluid, holistic process, where users can seamlessly migrate between different analytic phases or adopt various analytic methods and representations, all while preserving consistent analysis artifacts. In our vision, users may work alone or adopt different collaboration styles that suit their context. They may appropriate any available devices as they are suited to the analysis tasks at hand (and conversely adapt their analytic methods to the devices at hand). In an ideal world, the barriers to following the arrows in Fig. 3 should be intrinsic to the analytic process or to the affordances of available hardware, not imposed by the constraints of the software used.

4 ADQDA SYSTEM

To demonstrate our vision, we design and implement a proof-of-concept prototype, ADQDA⁹ (Affinity Diagramming for Qualitative Data Analysis), a collaborative, distributed web-based system using Webstrates [40].

⁸<https://www.youtube.com/watch?v=qK7juDLnrUw>, accessed 10 Sep 2021.

⁹The source code: <https://github.com/jiali77/ADQDA>.

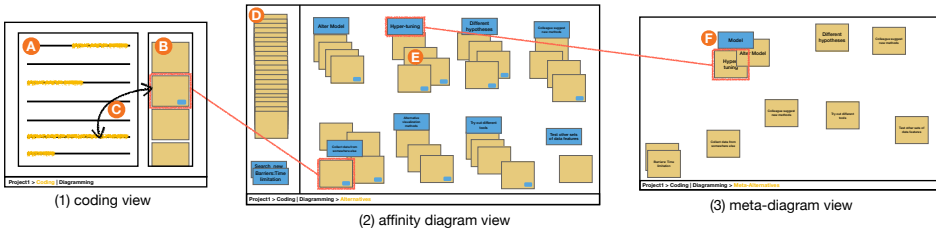


Fig. 5. The main components of ADQDA and the links between them: (1) coding view, (2) affinity diagram view, (3) meta affinity diagram view.

4.1 Main Components

ADQDA consists of three main views: (1) a coding view, (2) an affinity diagram view, and (3) a meta-diagram view, as shown in fig. 5.

Coding View. By default, the system opens the coding view, which contains the document under analysis (fig. 5A) and a “notes panel” (fig. 5B). To import a document, user clicks the “import” button and paste their text into the window that popped up. User navigates through documents using the document list and highlights content while reading. Once an excerpt get highlighted in the document, a corresponding note is automatically generated in the “notes panel”. Long clicking or touching a highlight will navigate to the corresponding note and vice versa (fig. 5C). Double-clicking/tapping on this note (fig. 5B) lets the user tag the note with an existing (autocompleted) code or by entering a new one. When accessed on a mobile phone, the display is adapted to focus on the document, showing only highlights until clicked.

Diagramming View. Users can switch the current view to an existing affinity diagram or create a new one using the navigation menu at the bottom. Multiple diagrams can be created by giving each a unique name. As shown in fig. 5(2), an affinity diagram can contain two types of notes: standard *notes* (colored in yellow) containing data extracted from the source document; and *theme-notes* (colored in blue) containing user-assigned messages, often keywords that describe a given cluster in the diagram. Users can create theme-notes by double-clicking/tapping on the diagram background. All notes can be dragged around in space as in physical affinity diagrams. The theme-notes together with the notes grouped around it form clusters (fig. 5E). Every cluster can be moved as a unit by activating a toggle on its theme note. Moving a note within a 10 pixel tolerance of a cluster adds it, and moving it away removes it from a cluster. The corresponding note is tagged/untagged with the cluster’s theme note, which is displayed in both the note and its corresponding coding view. When the content of a theme note is updated, all related tags are synchronized to the updates as well.

Meta-Diagramming View. Meta-diagrams are used to perform higher-level analyses. In the meta-diagram view, standard notes are hidden by default, and (blue) theme-notes become standard (yellow) notes to be clustered under *higher-level theme-notes* (fig. 5(3)). Long-pressing the empty space in any diagram background brings up a pie menu, where users can choose to go to another diagram in the same analysis hierarchy. For example, choosing the “up-arrow” option in a basic affinity diagram redirects the current page to its corresponding meta-diagram (if there is any) or automatically generates a new one; choosing the “down-arrow” in a meta-diagram redirects to its lower-level diagram.



Fig. 6. Analysts work in different contexts across the analysis processes with ADQDA, e.g., (a) coding in a laptop (b) collaborative diagramming in a wall-sized display (c) collaboratively developing multiple diagrams from different analytic lens, with mobile phone(s) to check notes' contexts.

4.2 Distributing Views across Users & Devices

In ADQDA, each view can have multiple same or different instances opened in heterogeneous displays and can be manipulated by multiple users both synchronously or asynchronously. Developed as a web application, users can access it through a single URL link and then choose a desired view using the navigation menu. Multiple instances of the same view are synchronized, such as moving a note in one affinity diagram causes that note to move in the diagram opened on another device. A name tag appears below the note to indicate who is currently moving it.

We list a few examples to demonstrate how ADQDA could be appropriated under different situations. A single user can code the data with her laptop and arrange the notes on a larger screen (figure 6a); multiple users can collaborate on a same affinity diagram using a wall-size display (figure 6b); or multiple users can work on individual affinity diagrams by adopting multiple displays at hand and put them side-by-side to compare (figure 6c).

4.3 Iterating between Analytic Phases

ADQDA automatically generates a note for each highlight in each existing diagram in real time. These notes are further linked to their source documents, and to those in other diagrams. In a diagram, users can click the “show me more” menu on a note to open it in the corresponding transcript on a pre-registered device, such as a phone or tablet. Additional devices can be registered by navigating to the session’s URL on the new device. As shown in fig.7, when long pressing a note, either in diagram view or coding view, it will highlight in all views to help users locate a specific note in multiple places. Multiple views can be opened simultaneously on different devices, allowing users to make comparisons by simply switching their attention from one display to another.

Considering diagrams in different hierarchical levels, by default, information generated in one hierarchy level is hidden in another level, but can be acquired on demand: In the basic affinity diagram, users can turn on “show meta info” mode to examine corresponding meta cluster information. A tag will appear on the theme-note if it is clustered to a higher-level theme. In a meta-diagram, users can expand notes to reveal the individual notes they collect at the lower level. This expansion preserves the spatical arrangement in the lower level to maintain spatial cognition [35]. However, users can not edit the clusters across different levels.

4.4 Mapping Coding and Diagramming

In ADQDA, to maintain analysis coherence and consistency—notes and highlights, tags and theme-notes, and hierarchical codes and meta-diagrams—are treated as different views of the same entity. The system maintains a bijection between coding concepts and their equivalent diagramming concepts, as described below.

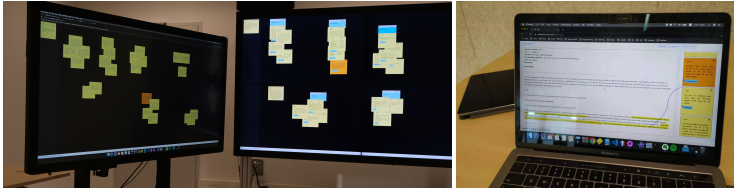


Fig. 7. Two different affinity diagrams on two large displays, and a coding view opened in a laptop. Long press a note in any of them highlights notes with same content in the others.

Mapping Diagramming Activities to Coding: In diagramming view, grouping a note to a given cluster tags that note with its theme, and removing it from the cluster untags it. These add or deletion of tags are synchronised in the coding view. If a same note has been clustered in different diagrams, it thus has multiple tags. These tags are all revealed in the coding view. While when viewed in a diagram, the note only appears in its own cluster(s); tags from other diagrams are not shown to avoid distraction. Deleting a note from a diagram removes it from that view, but does not remove it from other views. Whereas deleting it in the coding view removes it in all diagrams.

Mapping Coding Activities to Diagramming: Though notes and highlights, and theme-notes and codes are conceptually equivalent, they are not identical. Affinity diagrams are inherently spatial, whereas tags/codes are not. Coding an excerpt does not provide spatial information necessary to determine its notes' position in a diagram. It is possible to algorithmically position such notes, but this spatial arrangement also plays a part in the user's mental model.

To deal with this asymmetry, we introduce two design concepts: "messy pile" and "inbox, outbox". The "messy pile" is a region in the left of each diagram (fig. 5D). When an excerpt gets highlighted, a note containing same content is created in the "messy pile" of all existing diagrams. When users create a new tag/code, the system prompts the user to indicate which, if any, diagram the tag should apply and creates a new theme note in the "messy pile" of that diagram. In ADQDA, each theme-note has an "inbox" and an "outbox", as shown in fig. 8 (left). If a note is tagged to a theme from the coding view, it will be put in the theme-note's "inbox" in a thumbnail format. Similarly, if a note is removed from that theme from coding view, it will be put in the theme-note's "outbox". Users can drag these thumbnails into a specific position in the cluster or just choose "drop in" option to let the system automatically puts the note(s) in the cluster. In this way, users can distinguish the updates caused by coding, and can choose between automation and manual allocation of notes' positions.

The "inbox, outbox" concept not only addresses the asymmetric mapping problem, but also helps the user keep track of changes in other views or by other collaborators. For example, a user might re-tag a snippet in the coding view but not realize that will alter its associated diagrams.

4.5 Implementation

We build ADQDA on top of Webstrates [40] using standard web technologies (HTML, JavaScript, CSS). Webstrates provides web page synchronization, thus allows multiple users collaboratively edit a document in real time. The key mechanism in ADQDA is called *transclusion*, a technique of dynamic embedding documents within another. Fig. 8 (right) shows the document transclusion structure in ADQDA. Based on a user's choice, the "ADQDA UI" dynamically transcludes required web page (coding, diagram, meta-diagram) as current active view. These views further injects scripts and style rules to control the look and behavior based on the specific analysis content stored in the Database pages (e. g. position of notes, cluster information).

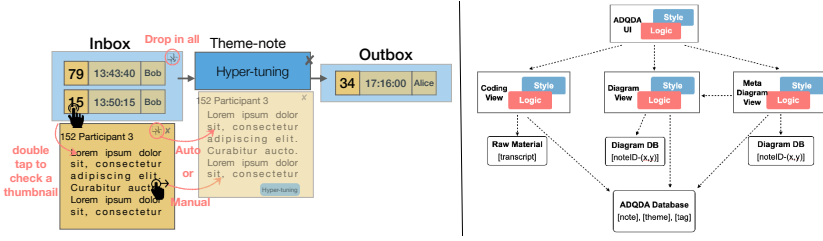


Fig. 8. Left: The “inbox, outbox” of a theme note. Users can track the updates caused by coding. They can expand a thumbnail to check the note, and manually drag it to the cluster or choose “drop in” to let the system automatically assign the position. Right: The transclusion structure for ADQDA in implementation.

5 DEMONSTRATION SCENARIOS

In this section, we use a set of application scenarios to probe the utility and novelty of the ADQDA prototype. These scenarios present “design rationale, a vision of what could be, expected scenarios of use, reflections, [and] case studies”, which Greenberg and Buxton argue are more appropriate forms of validation [28] for this kind of work.

Scenario 1. Appropriating Digital Devices. Alice and Bob meet in a lab room to analyze interview transcripts. The room has a wall-sized interactive display, an interactive table, and Alice and Bob’s own laptops, phones, and tablets. They each open the transcripts on their laptops and begin coding them in ADQDA. They highlight pertinent snippets of the transcripts while they read. After going through a few participants, Alice moves to the wall while Bob continues to code transcripts. She loads the URL for their analysis session and creates a new affinity diagram, which automatically contains the extracted snippet in a pile in the corner of the display. While she organizes these snippets, Bob’s new snippets continue to be added to pile. Meanwhile, Charles, working from his office in another city, joins the analysis by opening Alice’s diagram on his laptop. They work collaboratively, following each other’s notes as they move around in real time on the shared diagram, Alice using her fingers and Charles his mouse. Charles decides he would rather not pan around in the diagram, so he walks down the hall to his studio and opens the diagram on its interactive board.

Discussion: This scenario illustrates multiple users working in different places and with different types of devices using ADQDA. The users are able to choose the available devices best suited to their task at hand, extending the environment or switching devices by merely opening the shared session URL and choosing the shared artifact (transcripts or diagrams) to work on.

Scenario 2. Iterative Sensemaking. Joining Alice on the wall, Bob realizes he is not sure of the meaning of one of the notes. He uses the menu on the note to send it to his phone, which he had previously registered with the session by opening its URL. His phone displays the pertinent transcript focused on the selected snippet. Meanwhile, Alice is not sure that a note is in the right category. She sends it to her tablet, finding in the transcript that the underlying meaning was misinterpreted without its surrounding context. She continues to read the rest of the transcript to make sure that the other snippets have not been similarly misconstrued. In the transcript, the diagrams’ category labels appear as tags on each snippet (Figure 5a), so she can make sure that each tag makes sense. She re-tags several misidentified snippets and adds a few more snippets as she identifies new themes that had not emerged before.

Meanwhile, Bob and Charles continue working on their shared diagram. Alice’s new notes now appear in the uncategorized pile on the diagram, while each of the notes she has re-tagged in the transcripts now appears in its new theme’s “inbox” and its old theme’s “outbox” (Figure 8).

Collectively, they walk through each of the items in inbox to make sure that they agree with this new categorization before either dragging the note into place in its new cluster, letting the system do so automatically, or sending it back to its old cluster.

Discussion: This scenario shows how analysts can smoothly iterate between different phases of analysis using ADQDA, from coding to diagramming and back again, throughout a given analysis session. Each analytic artifact reveals different contextual information through its spatial construct that the analyst needs to be able to fluidly navigate as the analysis evolves. Similarly, different analyses may be better suited to different devices, whether ephemeral in nature or more focused.

Scenario 3. Creating alternative analysis. Some days later, Alice, Bob, and Charles decide to re-analyze the data, focusing on how participants use their artifacts rather than just on the types of artifacts under study. Alice creates a new affinity diagram from the same set of transcripts, which loads all of the notes into the initial pile. The three of them collectively build their new diagram, Alice and Bob in their lab and Charles in his home office. Once the diagram has taken shape, Alice and Bob gather around the table in their lab and load the initial diagram. As they select notes in the new diagram, they highlight in the initial one, helping them to compare the relationship between the different analyses. Charles does not have a board in his home office, so follows along in the transcripts view on his tablet. As Alice and Bob highlight notes in their diagram, the corresponding snippet highlights in Charles' view, showing any alternative tags it may have from the other diagrams.

Discussion: This scenario shows how analysts can carry out parallel analyses of their data from different analytic lenses, but still maintain a link between them. The analysts can treat these analyses as independent, focusing on just the one, as we see in the first part of the scenario, or they can compare across them, as in the second part. To help facilitate such comparison, the different users can bring in the different available devices to extend the space for their analysis. Similarly, they can collaborate asymmetrically, as when Charles works along from the transcript view.

Scenario 4. Developing Higher-level Concepts with Meta-Diagrams. Alice, Bob, and Charles agree that both diagrams reveal essential facets of the collected data. Alice and Bob begin a meta-analysis of the first diagram, looking for higher level concepts. They create a new meta-diagram, which transforms theme notes from the first diagram into regular notes in the new diagram. They further import the theme notes from the second diagram, allowing them to combine the themes from both analyses into a single higher-order analysis. As Alice is combining two notes into a common theme, she wants to make sure she is correctly interpreting the theme's label. She first expands the note to reveal its associated snippets to confirm before them grouping the two themes together. Meanwhile, Charles continues refining the second diagram on the board in his studio. To ensure a shared understanding of both diagrams and to follow along as his themes are organized into new higher-level concepts, Charles turns on the "show meta info" mode.

Discussion: The first part of this scenario illustrates how users can transition between analytic phases, while still maintaining links to higher or lower levels of abstraction. The second part of the scenario illustrates how multiple users can simultaneously iterate on different analyses at different levels of abstraction.

Summary. Through these scenarios, we show the importance of a holistic approach to qualitative data analysis. Different tools might exist to solve specific aspects of the analysis, from coding to affinity diagramming and meta-analysis, but if they do not support multiple analytic phases, methods, and lenses, then they introduce barriers that inhibit iterative analysis. Similarly tools should support diverse artifact ecologies. While different tools exist that address parts of these

phases, we argue that their combination is greater than the sum of their parts. ADQDA provides a rudimentary proof-of-concept implementation of the design space, but as the scenarios show, enables types of analysis and collaboration configurations that are impossible or cumbersome with current tools. As such, it raises the ceiling by enabling new collaborative analyses and lowers the threshold by reducing interactive viscosity across transitions [48, 49].

6 DISCUSSION

6.1 Qualitative Sensemaking as A Holistic Process

Affinity diagramming, when used to analyze qualitative data, differs from creative tasks in its procedures and characteristics. Rather than generating [26], analysts start with examine existing materials like interview transcripts. An extra conceptual method of coding could be introduced to the process, adding additional analysis activities and challenges.

Qualitative data analysis generally involves a wide variety of analysis activities that make up a part of the holistic process of sensemaking, as shown in fig. 3. Many current tools either focus on specific parts of this design space, a specific ordering or sequence to them, or specific types of analysis. Most of our participants did not explicitly make significant iterations between coding and diagramming. This could be due to the different types of qualitative analysis involved. P2 and the authors do make such iterations, but also perform coding-based analysis. P1 and P3, on the other hand, did not perform a specific coding phase. Beyond differences in analytic contexts, we suspect this lack of iterations between coding and diagramming is also likely due to the fact that current tools make that so hard to do. P2 does, but had to wrestle with many pragmatic hurdles to accomplish such analysis chains. We (the authors) do combine these phases frequently in our own analyses and created many features of ADQDA to “scratch our own itch.”

ADQDA takes a holistic approach to data analysis, aiming to maintain links across all parts of the data and analytic artifacts. Other approaches oriented around more specific-purpose tools could potentially provide a viable alternative solution, but would require advances in robust re-usable representations of the data and working analysis artifacts to streamline data exchange across these tools (similarly to the way Unix tools are readily combinable with the `|` operator).

6.2 Limitations

Prototype Limitations. The primary focus of the ADQDA prototype is to support transitions between analysis phases and methods and create ad-hoc cross-device analysis environments for the tasks at hand. As such, support for coding and affinity diagrams could be considered minimum viable product: it provides basic support for coding textual transcripts and for rearranging snippets and groups of snippets, clustering, and annotating snippets in affinity diagrams.

Richer interactions for multi-touch gestures [59], provenance and history tracking [14], or large-scale interaction techniques such as Bring and Go [47] or portals [7], etc.. are not currently implemented. There are currently no additional visualisations or color coding to convey, for example, the stability of clusters or to reinforce participant numbers or participant roles (e. g., managers vs. executives vs. workers).

While the implementation is designed with collaboration as an explicit design goal, there is little support for in-system coordination. All such coordination must currently be done out-of-band using teleconferencing or using ad-hoc social conventions (such as jiggling a note for a shared focus). Finally, ADQDA is implemented using Webstrates [40], a research prototype environment. It can handle around a hundred simultaneous connections and tens of simultaneous edits to the same shared document. It is built on web technologies with their associated constraints.

Conceptual Limitations. Beyond the technical limitations of the current prototype, there are also conceptual limitations in the current approach and design, especially related to collaboration, device heterogeneity, and conceptual compatibility between different views.

Our system supports various collaboration modes, multiple users can be colocated or remote, on the same device or different devices, simultaneously or asynchronously. Conceptually, however, different interactions are better suited to each of these scenarios. For example, a technique that work well to highlight a given note across multiple views for a single user might distract or confuse other users. Different incompatible interaction techniques might be better suited to multiple users working on the same wall vs. multiple users collaborating across distant walls. Furthermore, the various collaboration scenarios might also rely on different kinds of awareness mechanisms [23, 53].

Similarly, the different views are currently only minimally adapted to the constraints of the device [51]. For example, displaying a wall-sized diagram on a smaller display such as a laptop or a smartphone currently uses a mix of panning and zooming. It is both useful and possible, but awkward. Moreover, it assumes that the relative dimensions of the canvas will not vary across devices. For input, touch and click events are currently treated as equivalent, but little additional support is currently made to handle the different input modalities of different devices.

Finally, the underlying design of the approach assumes that it is possible to define a consistent mapping to maintain dynamic links between all related analysis artifacts. For example, a note in a transcript must maintain a link to its snippet in an affinity diagram, but under certain scenarios such a bijection may be untenable or impossible to maintain across different layers of abstraction.

7 CONCLUSIONS

We present a design space and a vision for collaborative, cross-device support for affinity diagramming in qualitative data analysis. In it, users may work alone or in collaboration across the different activities and representations of qualitative data analysis. The different phases of analysis, from coding to organizing individual observations into concepts, associating and categorizing related concepts should all fit into an iterative sensemaking process, where different phases of analysis can be started or resumed as makes sense for the individual analyst. Users may migrate between different interactive devices such as phones, tablets, tables, boards, and walls as they see fit for the analytic task at hand. Moreover, they can combine these devices to work in conjunction.

We have presented a proof-of-concept implementation, ADQDA, that implements this vision using Webstrates [40]. In it, joining a shared analysis session involves simply opening its URL on the desired device and choosing the desired view to display. We use this tool to demonstrate such collaborative qualitative data analysis using affinity diagrams.

ACKNOWLEDGMENTS

We thank our interview participants for their time and valuable input. We thank Nadia Boukhelifa for sharing knowledge and experience in qualitative data analysis, and Marc-Emmanuel Perrin for building the first version of digital diagramming tool. We thank anonymous reviewers for their constructive feedback. This work is supported by Digiscope (ANR-10-EQPX-26-01) and Institut Mines-Télécom (Futur & Ruptures project Data Expression).

REFERENCES

- [1] Robert Amar, James Eagan, and John Stasko. 2005. Low-level components of analytic activity in information visualization. In *IEEE Symposium on Information Visualization, 2005. INFOVIS 2005*. IEEE, 111–117.
- [2] Christopher Andrews, Alex Endert, and Chris North. 2010. Space to think: large high-resolution displays for sense-making. In *Proceedings of the SIGCHI conference on human factors in computing systems*. ACM, 55–64.

- [3] Sriram Karthik Badam, Andreas Mathisen, Roman Rädle, Clemens N Klokmoose, and Niklas Elmqvist. 2018. Vistrates: A component model for ubiquitous analytics. *IEEE transactions on visualization and computer graphics* 25, 1 (2018), 586–596.
- [4] Tehmina Basit. 2003. Manual or electronic? The role of coding in qualitative data analysis. *Educational research* 45, 2 (2003), 143–154.
- [5] Michel Beaudouin-Lafon, Stephane Huot, Mathieu Nancel, Wendy Mackay, Emmanuel Pietriga, Romain Primet, Julie Wagner, Olivier Chapuis, Clement Pillias, James Eagan, et al. 2012. Multisurface interaction in the wild room. *Computer* 45, 4 (2012), 48–56.
- [6] Hugh Beyer and Karen Holtzblatt. 1998. *Contextual design: defining customer-centered systems*. Vol. 1. Morgan kaufmann.
- [7] Anastasia Bezerianos and Ravin Balakrishnan. 2005. View and space management on large displays. *IEEE Computer Graphics and Applications* 25, 4 (2005), 34–43.
- [8] Erik Blair. 2015. A reflexive exploration of two qualitative data coding techniques. *Journal of Methods and Measurement in the Social Sciences* 6, 1 (2015), 14–29.
- [9] Susanne Bødker and Clemens Nylandsted Klokmoose. 2012. Dynamics in artifact ecologies. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*. ACM, 448–457.
- [10] Nadia Boukhelifa, Marc-Emmanuel Perrin, Samuel Huron, and James Eagan. 2017. How data workers cope with uncertainty: A task characterisation study. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 3645–3656.
- [11] Frederik Brudy, Christian Holz, Roman Rädle, Chi-Jui Wu, Steven Houben, Clemens Nylandsted Klokmoose, and Nicolai Marquardt. 2019. Cross-Device Taxonomy: Survey, Opportunities and Challenges of Interactions Spanning Across Multiple Devices. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, 562.
- [12] Frederik Brudy, Steven Houben, Nicolai Marquardt, and Yvonne Rogers. 2016. CurationSpace: Cross-Device Content Curation Using Instrumental Interaction. In *Proceedings of the 2016 ACM International Conference on Interactive Surfaces and Spaces*. ACM, 159–168.
- [13] Antony Bryant and Kathy Charmaz. 2007. *The Sage handbook of grounded theory*. Sage.
- [14] Edwin R Burtner, Richard A May, Randall E Scarberry, Ryan R LaMothe, and Alexander Endert. 2013. Affinity+: Semi-structured brainstorming on large displays. In *Powerwall international workshop on ultra-high-resolution displays, CHI '13 Extended Abstracts*. ACM, 6.
- [15] Susanne Bødker and Clemens Nylandsted Klokmoose. 2011. The human-artifact model: An activity theoretical approach to artifact ecologies. *Human-Computer Interaction* 26, 4 (2011), 315–371.
- [16] Sheelagh Carpendale, Søren Knudsen, Alice Thudt, and Uta Hinrichs. 2017. Analyzing qualitative data. In *Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces*. ACM, 477–481.
- [17] Senthil Chandrasegaran, Sriram Karthik Badam, Lorraine Kisselburgh, Karthik Ramani, and Niklas Elmqvist. 2017. Integrating visual analytics support for grounded theory practice in qualitative text analysis. In *Computer Graphics Forum*, Vol. 36. Wiley Online Library, 201–212.
- [18] Kathy Charmaz. 2014. *Constructing grounded theory*. sage.
- [19] Juliet Corbin and Anselm Strauss. 2014. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications.
- [20] Juliet M Corbin and Anselm Strauss. 1990. Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative sociology* 13, 1 (1990), 3–21.
- [21] Benjamin F Crabtree and William F Miller. 1992. A template approach to text analysis: developing and using codebooks. (1992).
- [22] Ian Dey. 2003. *Qualitative data analysis: A user friendly guide for social scientists*. Routledge.
- [23] Paul Dourish and Victoria Bellotti. 1992. Awareness and coordination in shared workspaces. In *Proceedings of the 1992 ACM conference on Computer-supported cooperative work*. 107–114.
- [24] VF Elliott. 2018. Thinking about the coding process in qualitative data analysis. *Qualitative Report* 23, 11 (2018).
- [25] Katherine M. Everitt, Scott R. Klemmer, Robert Lee, and James A. Landay. 2003. Two Worlds Apart: Bridging the Gap between Physical and Virtual Media for Distributed Design Collaboration. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*. Association for Computing Machinery, New York, NY, USA, 553–560. <https://doi.org/10.1145/642611.642707>
- [26] Florian Geyer, Ulrike Pfeil, Jochen Budzinski, Anita Höchtl, and Harald Reiterer. 2011. Affinitytable-a hybrid surface for supporting affinity diagramming. In *IFIP Conference on Human-Computer Interaction*. Springer, 477–484.
- [27] Florian Geyer, Ulrike Pfeil, Anita Höchtl, Jochen Budzinski, and Harald Reiterer. 2011. Designing reality-based interfaces for creative group work. In *Proceedings of the 8th ACM conference on Creativity and cognition*. ACM, 165–174.
- [28] Saul Greenberg and Bill Buxton. 2008. Usability evaluation considered harmful (some of the time). In *Proceedings of the SIGCHI conference on Human factors in computing systems*. ACM, 111–120.

- [29] Jens Grubert, Matthias Kranz, and Aaron Quigley. 2016. Challenges in mobile multi-device ecosystems. *mUX: The Journal of Mobile User Experience* 5, 1 (2016), 5.
- [30] Gunnar Harboe. 2017. *PapperlappApp: augmenting paper-based affinity diagrams*. Ph.D. Dissertation. University of Zurich.
- [31] Gunnar Harboe, Gelek Doksam, Lukas Keller, and Elaine M Huang. 2013. Two thousand points of interaction: augmenting paper notes for a distributed user experience. In *Distributed User Interfaces: Usability and Collaboration*. Springer, 141–149.
- [32] Gunnar Harboe and Elaine M Huang. 2015. Real-world affinity diagramming practices: Bridging the paper-digital gap. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems*. ACM, 95–104.
- [33] Tom Horak, Sriram Karthik Badam, Niklas Elmqvist, and Raimund Dachsel. 2018. When David meets Goliath: Combining smartwatches with a large vertical display for visual data exploration. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 19.
- [34] Tero Jokela and Andrés Lucero. 2014. Mixednotes: A digital tool to prepare physical notes for affinity diagramming. In *Proceedings of the 18th International Academic MindTrek Conference: Media Business, Management, Content & Services*. 3–6.
- [35] Tejinder K Judge, Pardha S Pyla, D Scott McCrickard, Steve Harrison, and H Rex Hartson. 2008. *Studying group decision making in affinity diagramming*. Technical Report. Department of Computer Science, Virginia Polytechnic Institute & State University.
- [36] Jiro Kawakita. 1991. The original KJ method. *Tokyo: Kawakita Research Institute* 5 (1991).
- [37] Nigel King. 1998. Template analysis. (1998).
- [38] Scott Klemmer, Mark Newman, Ryan Farrell, Raecine Meza, and James A Landay. 2000. A Tangible Evolution: System Architecture and Participatory Design Studies of the Designers' Outpost. *NCSTRL. UCB/CSD-00 1117* (2000).
- [39] Scott R. Klemmer, Mark W. Newman, Ryan Farrell, Mark Bilezikjian, and James A. Landay. 2001. The Designers' Outpost: A Tangible Interface for Collaborative Web Site. In *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology (UIST '01)*. Association for Computing Machinery, New York, NY, USA, 1–10. <https://doi.org/10.1145/502348.502350>
- [40] Clemens N Klokmoose, James R Eagan, Siemen Baader, Wendy Mackay, and Michel Beaudouin-Lafon. 2015. Webstrates: shareable dynamic media. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*. ACM, 280–290.
- [41] Ida Larsen-Ledet, Henrik Korsgaard, and Susanne Bødker. 2020. Collaborative Writing Across Multiple Artifact Ecologies. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–14.
- [42] Jiali Liu, Nadia Boukhelifa, and James R Eagan. 2019. Understanding the Role of Alternatives in Data Analysis Practices. *IEEE transactions on visualization and computer graphics* 26, 1 (2019), 66–76.
- [43] Andrés Lucero. 2015. Using affinity diagrams to evaluate interactive prototypes. In *IFIP Conference on Human-Computer Interaction*. Springer, 231–248.
- [44] Andrés Lucero, Jaakko Keränen, and Hannu Korhonen. 2010. Collaborative use of mobile phones for brainstorming. In *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services*. 337–340.
- [45] Paul Luff, Christian Heath, Moira Norrie, Beat Signer, and Peter Herdman. 2004. Only touching the surface: creating affinities between digital content and paper. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work*. 523–532.
- [46] Motoki Miura, Taro Sugihara, and Susumu Kunifuji. 2011. GKJ: Group KJ method support system utilizing digital pens. *IEICE transactions on information and systems* 94, 3 (2011), 456–464.
- [47] Tomer Moscovich, Fanny Chevalier, Nathalie Henry, Emmanuel Pietriga, and Jean-Daniel Fekete. 2009. Topology-aware navigation in large networks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2319–2328.
- [48] Brad Myers, Scott E. Hudson, and Randy Pausch. 2000. Past, present, and future of user interface software tools. *Transactions on Computer-Human Interaction* 7, 1 (2000), 3–28. <https://doi.org/10.1145/344949.344959>
- [49] Dan R Olsen Jr. 2007. Evaluating user interface systems research. In *Proceedings of the 20th annual ACM symposium on User interface software and technology*. ACM, 251–258.
- [50] Thomas Olsson, Else Lagerstam, Tuula Kärkkäinen, and Kaisa Väänänen-Vainio-Mattila. 2013. Expected user experience of mobile augmented reality services: a user study in the context of shopping centres. *Personal and ubiquitous computing* 17, 2 (2013), 287–304.
- [51] Seonwook Park, Christoph Gebhardt, Roman Rädle, Anna Maria Feit, Hana Vrzakova, Niraj Ramesh Dayama, Hui-Shyong Yeo, Clemens N Klokmoose, Aaron Quigley, Antti Oulasvirta, et al. 2018. AdaM: adapting multi-user interfaces for collaborative environments in real-time. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 184.

- [52] Peter Pirolli and Stuart Card. 2005. The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis. In *Proceedings of international conference on intelligence analysis*, Vol. 5. McLean, VA, USA, 2–4.
- [53] Arnaud Prouzeau, Anastasia Bezerianos, and Olivier Chapuis. 2018. Awareness Techniques to Aid Transitions between Personal and Shared Workspaces in Multi-Display Environments. In *Proceedings of the 2018 ACM International Conference on Interactive Surfaces and Spaces*. 291–304.
- [54] Christian Remy, Gunnar Harboe, Jonas Frich, Michael Mose Biskjaer, and Peter Dalsgaard. 2021. Challenges and Opportunities in the Design of Digital Distributed Affinity Diagramming Tools. In *European Conference on Cognitive Ergonomics 2021*. 1–5.
- [55] Johnny Saldaña. 2015. *The coding manual for qualitative researchers*. Sage.
- [56] Florian Scharf, Christian Wolters, Michael Herczeg, and Jörg Cassens. 2013. Cross-Device Interaction Definition, Taxonomy and Applications. (2013).
- [57] Raymond Scupin. 1997. The KJ method: A technique for analyzing data derived from Japanese ethnology. *Human organization* (1997), 233–237.
- [58] Hariharan Subramonyam, Steven M Drucker, and Eytan Adar. 2019. Affinity Lens: Data-Assisted Affinity Diagramming with Augmented Reality. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, 398.
- [59] Edward Tse, Saul Greenberg, Chia Shen, Clifton Forlines, and Ryo Kodama. 2008. Exploring True Multi-User Multimodal Interaction over a Digital Table. In *Proceedings of the 7th ACM Conference on Designing Interactive Systems (DIS '08)*. Association for Computing Machinery, New York, NY, USA, 109–118. <https://doi.org/10.1145/1394445.1394457>
- [60] Susan M Winchip. 2001. Affinity and interrelationship digraph: A qualitative approach to identifying organizational issues in a graduate program. *College Student Journal* 35, 2 (2001), 250–250.
- [61] T Wynn. 1993. Layers of thinking in tool behavior. In (KR Gibson and T. Ingold Eds.) *Tools and Cognition in Human Evolution*.