D-Tour: Semi-Automatic Generation of Interactive Guided Tours for Visualization Dashboard Onboarding

Vaishali Dhanoa, Andreas Hinterreiter, Vanessa Fediuk, Niklas Elmqvist, Eduard Gröller, Marc Streit

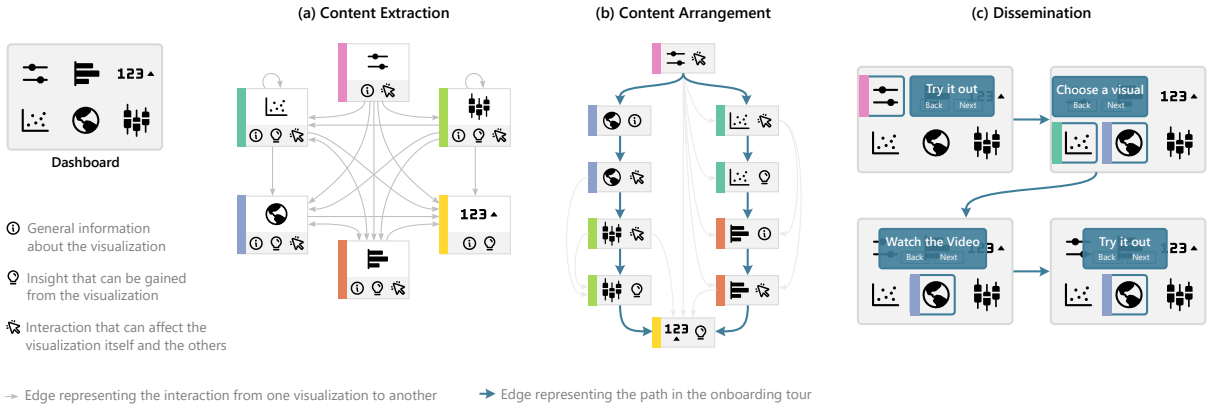

Fig. 1: **Authoring and disseminating interactive dashboard tours.** Our workflow for crafting semi-automated onboarding experiences while preserving user agency. The content in a given visualization dashboard is extracted and converted into (a) a component graph and arranged into (b) an interactive dashboard tour, which is then (c) shared with the end-users.

Abstract—Onboarding a user to a visualization dashboard entails explaining its various components, including the chart types used, the data loaded, and the interactions available. Authoring such an onboarding experience is time-consuming and requires significant knowledge and little guidance on how best to complete this task. Depending on their levels of expertise, end users being onboarded to a new dashboard can be either confused and overwhelmed or disinterested and disengaged. We propose *interactive dashboard tours* (*D-Tours*) as semi-automated onboarding experiences that preserve the agency of users with various levels of expertise to keep them interested and engaged. Our interactive tours concept draws from open-world game design to give the user freedom in choosing their path through onboarding. We have implemented the concept in a tool called D-TOUR PROTOTYPE, which allows authors to craft custom interactive dashboard tours from scratch or using automatic templates. Automatically generated tours can still be customized to use different media (e.g., video, audio, and highlighting) or new narratives to produce an onboarding experience tailored to an individual user. We demonstrate the usefulness of interactive dashboard tours through use cases and expert interviews. Our evaluation shows that authors found the automation in the D-Tour Prototype helpful and time-saving, and users found the created tours engaging and intuitive. This paper and all supplemental materials are available at https://osf.io/6fbjp/.

Index Terms—Dashboards, onboarding, storytelling, tutorial, interactive tours, open-world games.

1 INTRODUCTION

Visualization dashboards—collections of charts, graphs, and other visual elements that provide users with a comprehensive overview of information—have become one of the most popular forms of visualization used in business [1,43]. Introducing an end user to a dashboard they have not seen before is known as *onboarding* [16, 51], during which the dashboard and its visualizations, purpose, and data are presented. Proper onboarding can enhance both use and adoption of dashboards by giving an overview of the data, visuals, and interactions, and filling the users' knowledge gaps [7, 11, 58]. However, not all onboarding experiences are created equal—short of a personalized meeting between end user and the dashboard author, the most effective onboarding method is a guided tour of the dashboard components [10]. However, crafting such guided tours is labour-intensive and time-consuming because of a lack of tooling and standardization. Furthermore, once created, the tour remains static and cannot easily be adapted to a new end user with different skills and expertise, let alone to a new dashboard.

Here, we propose *interactive dashboard tours* (D-Tours) as an effective approach to designing dashboard *onboarding experiences* that preserve user agency while employing presentation techniques drawn from data-driven storytelling and open-world video games. A D-Tour is based on a sequence of dashboard components that are extracted semi-automatically from a dashboard. Similar to open-world games such as *Elden Ring* (2022) and *Hogwarts Academy* (2023), the presentation sequence is not linear but maintains the user's freedom in navigating the tour while keeping vital knowledge dependencies between components. In practice, this means that the user maintains agency in choosing when to view components, within author-defined constraints on the content. For example, certain Key Performance Indicators (KPIs) must be vis-

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ited first or multiple components must all be visited.[1] Another benefit of semi-automatically generated D-Tours is that the narrative can be dynamically adapted to the user's domain and visualization expertise.

To demonstrate the applicability of our concept, we implemented D-TOUR PROTOTYPE, an in-situ toolkit for authoring, disseminating, and viewing D-Tours within the Microsoft Power BI [35] software suite. Using D-Tour Prototype, a dashboard author can generate a D-Tour in three steps: (i) extract the content (semi)-automatically from the dashboard; (ii) arrange the content; and (iii) share the D-Tour with the end users. End users navigate through the D-Tour while interacting with the dashboard; tailoring the content as they go, with the option of switching to a free exploration at any time.

We make the following contributions: (*i*) a concept for crafting and using (semi-)automated interactive dashboard tours (D-Tours) inspired by ideas from open-world games; (*ii*) a prototype implementation of the concept in a web application that augments an embedded Microsoft Power BI dashboard; and (*iii*) results of evaluating the D-Tour Prototype in usage scenarios. Two qualitative user studies were done (one with five dashboard authors and one with six end users).

2 RELATED WORK

We discuss existing research on onboarding for both single visualizations and dashboards. We also explore how data storytelling techniques can be used to create clear and engaging onboarding experiences. We finally examine authoring tools in data storytelling, as their design significantly informed our approach to author D-Tours.

2.1 Visualization and Dashboard Onboarding

Onboarding solutions, although common in user applications and video games, are less prevalent for visualization dashboards. Stoiber et al. [51] characterized the onboarding space for *single* visualizations, listing online guides [40] and cheat sheets [60] as well as more recent approaches, such as step-by-step guides and scrollytelling [52].

The need for dedicated *dashboard* onboarding was emphasized by Walchshofer et al. [58], Brehmer et al. [5], Tory et al. [55] and Sarikaya et al. [43]. While the need for onboarding might in theory be reduced by adhering to professional design guidelines for dashboards [19, 61], our observations from both the literature and our industrial collaborations highlight a significant demand for effective dashboard onboarding strategies in real-world scenarios. Tory et al. [55] mention the use of simplicity and training to onboard dashboard users with low data literacy. Previous work on dashboard onboarding includes annotating dashboards [17] and assisting users in learning public-access interactive tools [25]. Recent work by Chundury et al. [10] added data-driven, contextual, in-situ help features for visual data interfaces.

Help systems [14] and guidance [7] serve different purposes than onboarding; in this paper, we focus on the latter. While approaches to interactive onboarding for a single chart exist, most approaches in the literature are static, such as tooltips and annotations [50]. This is surprising given the interactive nature of dashboards.

In real-life user-onboarding scenarios, presentations [58] and static documentation of interactive dashboards are utilized for onboarding users. Our D-Tour concept allows an author to create and present onboarding experiences that are integrated into the dashboard to enhance user engagement and understanding.

2.2 Data-driven Storytelling

Visualization dashboards, much like their constituent visualizations, often convey data facts through storytelling. We propose extending storytelling concepts to dashboard onboarding to enhance user engagement [29, 37, 48, 53]. Segel and Heer's narrative visualization framework [45] identified seven narrative genres in storytelling that we adapted to create various onboarding styles. Zhao and Elmqvist [65] extended this narrative framework to include additional media types.

[1] Compare this to an open-world game where the player can pick and choose from various encounters across a map, which makes side quests and other mandatory main plotline encounters.

Our work drew inspiration not only from data-driven storytelling but also from other narrative-rich domains, such as movies and open-world video games [26]. Recent research into visualizing non-linear storytelling in movies has identified various categories of relationships between story order and narrative order [38, 41]. While dashboards lack the inherent temporal order of movies, non-linear narratives from open-world video games offer valuable insights [31]. In fact, such non-linear narratives have been found to increase user engagement [3] and have also been studied in the context of multi-user analyses [63]. We adopt various narrative styles, such as branching, parallel, and free-form narration. Our goal is to provide authors with control over the narrative structure of the interactive dashboard tour and users with a flexible level of agency.

Finally, we also adopted assistive methods for narrative and data-driven story creation. Chen [8] surveyed authoring tools in data-driven storytelling, focusing on automation in narrative visualizations. While semi-automation is an aspect of our work, we prioritized keeping the author involved in the creation of the onboarding experience. For clarity, we also made use of visualization sequencing from the work of Hullman et al. [24] and Kim et al. [27], to ensure an effective delivery of the intended message during the onboarding process.

2.3 Authoring Tools for Storytelling

Our review summarizes authoring tools that support narrative creation across various domains. Green et al. [21] introduced a design pipeline that focuses on user experience for interactive narrative authoring tools. Meixner et al. [32] presented an authoring tool for non-linear videos utilizing a tree structure, with annotations attached to scenes. Novella [20] facilitates interactive story creation in games. Metamorphers [49] provide storytelling templates which can be used to generate animated transitions for multiple data sets in molecular visualizations.

Several authoring tools have been proposed specifically for data-driven storytelling. ScrollyVis [37] is an interactive authoring tool for guided dynamic narrations that uses storytelling and integrates diverse resources, such as images, text, videos, and maps. Molecumentary [29] enables the creation of narrated documentaries about molecules and supports various media types, such as text, audio, and video. Roslingifier [48] offers a semi-automated approach to constructing data presentations using animated scatterplots, and ChartStory [64] provides a unique comic-style data narrative crafting method. Finally, InsideInsights [30] allow authors to organize facts into a hierarchy that can be dynamically navigated by the viewer. We implemented the interactive dashboard tours within the D-Tour Prototype by building upon insights gained from these authoring tools. AutoClips [47] offers a fully automated video generation approach to storytelling from data facts. Notable solutions also include Narvis [59] for narrative visualization, Temporal Summary Figures [6] for annotated temporal visualizations, and Erato [53] for data fact sheets. Unlike these works, our approach focuses on creating non-linear narratives derived from dashboard content to onboard new users effectively.

2.4 Tours in HCI and Visualization

Interface tours have long been a popular approach to onboarding users to an interface or tool in HCI practice, especially for the web [42, 56]. This practice has also been applied to both commercial and academic visualization systems [28]. Tours provide guided walkthroughs that allow users to explore an interface systematically, thereby reducing cognitive load. Commercial tools such as Tango [54] and Scribe [12] allow for the creation of annotations and guided tours for websites, which can also be used for dashboards. Their approach is mainly static and based on screenshots. Chundury et al. [10] present guided tours as one of several help mechanisms. Elmqvist et al. [18] study guided 3D tours for introducing users to information-rich 3D visualization environments. In general, allowing users to retain agency over navigation facilitates memory and recall. Similarly, the D-Tour concept proposed in this paper seeks to strike a balance between a fixed presentation sequence and user control to improve the onboarding experience.

3 Design Rationale

Recent studies on the use of visualizations [5, 43] and dashboards [58] in larger organizations have shown that onboarding is currently done primarily through oral presentations at the time of a visualization's or dashboard's launch. This process requires the user to go through a prepared, narrated script. There is little or no agency involved on the user's behalf. Additionally, there is a considerable time and effort involved in creating elaborate onboarding material, such as a video or a guided tour [5]. This means that most organizations opt for a single onboarding experience that must work for all users, regardless of their expertise. In most cases, documentation in the form of slides or a standard document may be provided as a supplementary aid to the dashboard to avoid repetitive onboarding scenarios. The apparent lack of interactivity and user agency in such fixed, "one-size-fits-all" onboarding can be particularly problematic for two different user groups:

- **Novices:** Low visualization literacy [4] and lack of experience with a dashboard tool and workplace practices means that novice users easily become *confused* or even *overwhelmed* by onboarding material that does not match their level of knowledge.
- **Experts:** High visualization literacy and extensive experience with similar dashboards means that an expert may become *disengaged* or even *bored* by material that does not recognize their level of expertise.

Design Sources. We derive the following *sources* for the design:

S1 *Dashboard Onboarding Space*—In prior work [16], we characterized the onboarding space and addressed *what* dashboard components must be explained while onboarding a user (*who*). We also reflected on other questions, such as when, where, why, and how to onboard.

S2 *Industrial Collaborators*—Our work is inspired by a long-term, ongoing collaboration with a large industrial manufacturing company. We found that dashboard onboarding can help users transition to a new visual analytics tool. Customized onboarding experiences can tackle specific challenges, such as end user fear of interacting with the dashboards and making sense of myriad charts and complex data [58].

S3 *Existing Storytelling Tools*—We also draw on prior findings from authoring tools based on data-driven storytelling (Section 2.3).

Design Goals. Because author and user needs and interactions with a dashboard and corresponding onboarding are inherently different, we list their design goals separately (following from **S1**, **S2**, and **S3**).

G1 Access Dashboard (Authors + Users)

To create a dashboard onboarding experience, the author must have access to the dashboard's visualizations and their relationships. This requires understanding how interactions with one visualization affect others, a key factor in determining *what* needs to be part of the onboarding [16] (**S1**).

It is equally important, although not at the same level as for the authors, that the onboarding *users* have access to the dashboard. With this, they can easily relate onboarding material to the visualizations in the dashboard.

G2 Retain Agency (Authors + Users)

The onboarding material is the subset of a dashboard's content functionality that must be explained to the user. The author initially selects the material and then decides how much agency the user should have. The onboarding tool should support the author by equipping them with ways of selecting this subset and providing or modifying the information shown during the onboarding.

For users, the tool should offer flexibility in selecting the level of detail at which they wish to engage with the material (**S2**). They should be able to (i) choose which aspects of the dashboard to explore in more detail, (ii) customize the amount of information they receive, and (iii) potentially alter the path they take through the onboarding based on their interactions.

G3 Craft Interactive Tours (Authors)

Tours are common onboarding mechanisms [10], and interactive ones preserve agency and engage the user. Employing data-driven storytelling (**S3**) in our context suggests using multiple tour structures [38] to enhance onboarding comprehension and potentially cover more than one way of using the dashboard. The responsibility of crafting these tours lies with the author, who must understand *why* the onboarding is needed and *how* it can best be explained (**S1**). The tool should provide ways of creating these tour structures (**S2**).

G4 Choose Presentation Mechanism (Authors + Users)

Onboarding can be delivered in several ways, ranging from interactive guides to annotated walkthroughs, video tutorials, and more dynamic exploratory modes. The tool should allow the author to choose a delivery mechanism (**S1**, **S2**).

The users should also be able to choose the presentation mechanism configured and provided by the authors.

G5 Explore the Tour (Authors + Users)

The author can use the tour to evaluate its effectiveness in conveying the intended message and make necessary modifications.

For the users, navigating through this tour is essential to understand the dashboard. Based on the tour structure produced, the tool should offer the user varying levels of autonomy (**S3**).

4 Interactive Dashboard Tours (D-Tours)

We propose an approach to semi-automatically generate *interactive dashboard tours* (*D-Tours*). This helps onboarding authors to create engaging onboarding experiences that can be navigated dynamically by the user (Figure 1). The design of D-Tours is inspired by concepts from storytelling, interactive narratives, and open-world games (Figure 2). Here, we explain how the concept can be applied to support both authors and users. We also describe how it addresses our design rationale.

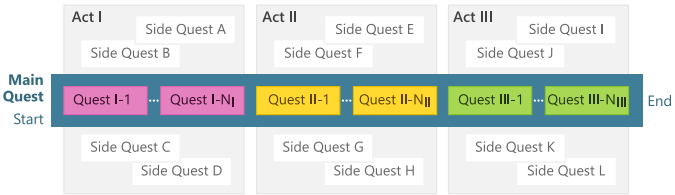

Fig. 2: **Open-world video-game narrative graph.** Video games based on an open world rather than a linear narrative grant the user maximum freedom in picking their actions. The main quest steps help players to progress towards completing the game. In contrast, side quests support but do not advance the story.

4.1 Design: Interactive Dashboard Tours

We define an *interface tour* as an annotated linear traversal of the components in a user interface intended to onboard a user [10, 42, 56]. In the context of a visualization dashboard, we refer more specifically to a *dashboard tour*. Most interface tours are fixed sequences—sometimes called *wizards*—where the user can move only forward and backwards. An *interactive tour*, in contrast, is a dashboard tour that preserves user agency by allowing them to navigate within components of the tour to a lesser or greater extent. The linear sequence thus becomes a narrative graph. Accordingly, interactive tours draw inspiration from dynamic storytelling and open-world non-linear narratives (Figure 2).

An interactive guided tour is a directed graph of story elements, where each element is either a visualization or a group element:

- **Optional:** The user can choose whether or not to visit the child elements in the container before proceeding. *Example:* a set of detailed charts not essential to understand a dashboard.
- **Visit at least one:** The user must visit at least one of the child elements before proceeding. *Example:* several line-series charts in a dashboard; understanding one is enough.
- **Visit one:** The user must visit exactly one of the child elements before proceeding. *Example:* visiting one of several related KPIs.
- **Visit all:** The user must visit all child elements before proceeding. The visiting order can be flexible or fixed. *Example:* key charts in a visualization dashboard that all must be explained.

A tour is a **Visit all** group consisting of one or more story elements. The approach can be used to emulate a fixed linear sequence.

4.2 D-Tour for Authors

In many organizations, creating a new dashboard typically means that the author must also create a dashboard onboarding experience for their end users. Whether manual or automated, this process can be structured into three steps: *extraction of the content* (Figure 1(a)) required for onboarding, *arranging the content* (Figure 1(b)) into an understandable sequence, and previewing the content to ensure that it aligns with the intended mental model before *sharing* (Figure 1(c)) it with the end user. We detail each of these steps below.

Content Extraction (**G1**, **G4**): The first step in authoring an onboarding experience is to list the content to be explained. For a dashboard, this includes identifying purpose, data, visualizations, and their interactions. We structure this content into a *component graph*, as outlined in our previous work [16]. Nodes represent the visual components (including data and insights) and edges represent their interactions. An edge from a filter node to a bar chart node indicates that the filter interacts with the bar chart through cross-filtering. To make the graph useful for onboarding, each component must be enriched with explanations, such as its description (type, mark, and encoding of visual components) and the insights it provides [52]. The edges representing the interactions must also be explained. We indicate all these types of explanations in Figure 1(a). Automating the content extraction and graph creation requires access to the components' low-level characteristics and the dashboard's data and interactions. In the next section, we describe how we accomplish this in the D-Tour Prototype. Creating an explicit component graph helps to automate and manage components and their relationships, especially when dashboard interactions occur and an update is required. In simple cases, the author can also use the component graph as a mental model.

Content Arrangement (**G2**, **G3**): The next step for the author is to arrange the content in a sequence, creating a path through the onboarding tour with directed edges (Figure 1(b)). If the content is structured as a component graph, the author can either employ traversal algorithms or manually create paths to arrange the components. In the latter case, the underlying component graph still remains valid and assists in managing the relationships between the components, while new paths determine an explicit order of the tour. Drawing on concepts from storytelling and open-world games, the content can be arranged in various ways, ranging from linear sequences to branched narratives and open-ended explorations. Such flexibility enables the author to tailor multiple tours to various types of users. This increases user agency by allowing them to choose the path that works best for them. The adaptability is crucial when introducing a single dashboard to a diverse audience with varying levels of domain and visualization expertise, such as managers, engineers, and sales personnel.

Dissemination (**G4**, **G5**): As with any created content, previewing the final version before delivery to the end user is crucial for testing (Figure 1(c)). An automated approach can show the tour to the author at any stage of its development. This can support the author in testing their onboarding tour throughout the creation process, allowing iterative improvements and refinements. The manual approach, however, might lack these iterative improvements and might involve only a cognitive walkthrough of the prepared onboarding tour.

4.3 D-Tour for End-Users

Our previous work [16] described different scenarios in which a user can be onboarded to a dashboard, including in-person meetings, textual documentation or video tutorials, guided tours, and an AI-based chat assistant. In each scenario, we highlighted user agency in relation to the onboarding content and how adaptable the onboarding could be. To maximize user agency and adaptivity, an onboarding experience should allow users to *choose an onboarding style* (predefined tour or self-guided exploration), *tailor the content* based on the style, and enable *interacting with the dashboard* and adapt accordingly.

Choose an onboarding style (**G2**, **G4**, **G5**): A user should have agency in choosing the style of their onboarding experience. For instance, novice users new to the domain of the dashboard and its visualizations might find it useful to go through an onboarding experience prepared by the author to help them understand the concepts. Experts, in contrast, might find it easier to explore the onboarding themselves, essentially creating their own onboarding experience (self-guided exploration). Additionally, if the author has configured multiple presentation mechanisms beyond text, users should be able to choose their preferred method of presentation. We explain how we incorporate these guided and self-guided modes in our implementation (Section 5).

Tailoring the content (**G2**): In addition to choosing the onboarding style and thus a path through the tour, the user should also be able to tailor the content to match their needs. For instance, a user might request more information on a specific visualization in a dashboard and less on others. Such dynamically adjusting content for each visualization level can be beneficial to all types of users.

Interacting with the dashboard (**G1**): Providing in-situ onboarding directly on the dashboard can be helpful, especially to users who prefer learning by doing or are afraid of "breaking the data" [58]. An onboarding tour should use the inherent interactive nature of dashboards to create an interactive onboarding tour for the end users.

5 The D-Tour Prototype Application

We propose the D-Tour Prototype as an implementation of our interactive dashboard tours. Similar to the description of D-Tours for authors and users, the D-Tour Prototype also has two modes: the *authoring* mode for onboarding authors and the *onboarding* mode for its users. We describe both modes in detail using a guiding example (Figure 3).

5.1 Authoring Mode

The authoring mode lets authors craft and preview interactive dashboard tours using extracted dashboard components. Based on the concept in Section 4, we divided the mode into *Content Extraction View*, *Content Arrangement View*, and *Dissemination View* (Figure 3). We describe the views in the following based on an exemplary use case which is described in more detail in Section 7. In the use case, an onboarding tour is created for a dashboard (Figure 3) that shows a company's market share and consists of two KPIs, a filter, a line chart, two-column charts, one combo chart (combination of line and column chart), and a table. This dashboard is available in Microsoft Power BI [35]. The D-Tour Prototype embeds the dashboard in a custom web application using Power BI REST API [46].

5.1.1 Content Extraction View

The Content Extraction View is an author's entry point into creating an onboarding experience. The dashboard content is presented in a simplified manner to the author, with the aim of providing an overview of the dashboard's purpose and a brief introduction to the visualizations and data. This is achieved through the use of two categories: *Introduction* and *Dashboard*. The Content Extraction View mirrors a real-world onboarding scenario that starts with the dashboard's goal and data.

The rest of the dashboard content, which is extracted and structured as a component graph in the background, is categorized first by type and then by the subcategory of the onboarding stage—reading, interacting

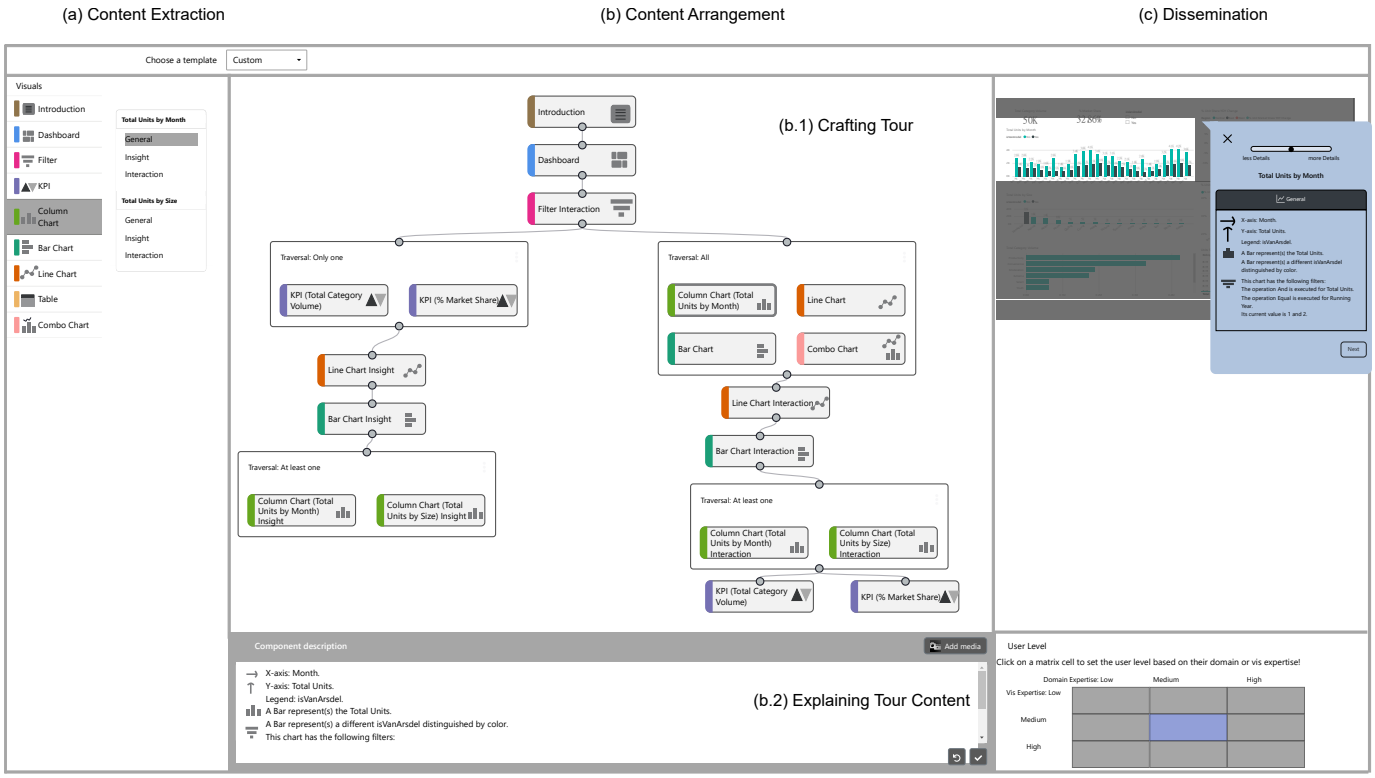

Fig. 3: **D-Tour Prototype's Authoring Mode**. Authors pick (a) automatically extracted visualization categories, *General*, *Insight*, or *Interaction*, from the Content Extraction View and drag them to the Content Arrangement View, where they (b) arrange them, (b.1) thus crafting a tour and (b.2) adding explanations to the tour content. In the Dissemination View they (c) test changes before disseminating them. A selection of the Column Chart *General* in the Content Extraction View is shown which is highlighted in the Content Arrangement View and in the Dissemination View. Its associated content can be seen in (b.2)

with, and using a visualization—as proposed by Stoiber et al. [51]. We call these subcategories *General*, *Interaction*, and *Insight*, respectively.

Figure 3(a) shows the extracted visualizations and their subcategories. For example, the highlighted category of Column Chart displays two column charts present in the dashboard that are identified by their titles and listed with corresponding subcategories. These subcategories are simplified representations of the low-level characteristics of a visual component in the component graph (Section 4).

The component graph is derived using (i) the meta-model by Ingelmo et al. [57], (ii) the Vega-Lite visualization grammar [44], and (iii) Krist's visualization component grammar [62]. It is then populated with information extracted from the Power BI REST APIs [46] and the data visualization catalogue [40], combined with text templates to ensure meaningful sentences. The graph is created automatically and updated whenever the dashboard changes, which in turn updates the *General*, *Interaction*, and *Insight* subcategories.

For crafting an interactive dashboard tour, the subcategories can be *picked* by dragging and dropping them onto the Content Arrangement View. Additionally, selecting a subcategory triggers two simultaneous actions: (*i*) highlighting the corresponding visualization in the Dissemination View and (*ii*) displaying the default description for the subcategory in the Content Arrangement View. This dual-display functionality helps authors to easily correlate all types of information about a visualization with its location in the dashboard. Figure 3 shows the subcategory of a column chart highlighted in the Dissemination View, which can be dragged and dropped into the Content Arrangement View.

Note that not every visualization will include all three subcategories. For instance, Key Performance Indicators (KPIs) typically lack interactivity and have overlapping general and insight information, so they are represented only by the subcategory *General*. Visualizations that are only filters, such as drop-down lists, do not provide insights and thus do not have the corresponding subcategory *Insight*.

5.1.2 Content Arrangement View

The interface of the Content Arrangement View enables the author to craft interactive dashboard tours with the subcategories picked from the Content Extraction View. Authors can either utilize predefined tours or create entirely new ones from scratch. Figure 3 shows an example tour created from scratch. In the following we explain the process of crafting a tour and then the means used for explaining the tour.

Crafting Interactive Tours. Our approach to interactive dashboard tours is inspired by non-linear storytelling and open-world game narratives (Section 4.1). This supports authors in crafting tours with linear, branching, or completely free narrative structures. We use a directed graph to represent D-Tours. The author can use the subcategories from the Content Extraction View (Subsection 5.1.1) as *story elements* for the *narrative structure* of the tour. To provide a sequence in this structure, the author can draw explicit edges between the elements. The branching structure can be specified by having multiple incoming and outgoing connections. These explicit edges indicate only the next element in the narrative of the tour. The implicit edges from the component graph obtained in Subsection 5.1.1 still remain valid and maintain the interaction relationships between the visualizations but are not shown to the author.

Figure 3 gives an example of an onboarding journey. It was crafted by dragging and dropping subcategories, such as a *General* component, from the column chart into the Content Arrangement View. The edges are created explicitly by connecting the elements, providing also a direction in the tour. Since this visual and interactive tour crafting is easy to use and requires no coding expertise, it is accessible to a broad audience.

Authors can group elements to improve the readability of the crafted journey. A *group* is a collection of elements bundled together by logical operations. They govern how users can navigate the tour (**G2**): ⊕ visit at least one, ❗ visit one, and ★ visit all elements of a group. Authors

can thus specify the conditions for a user to proceed to the next step.

The choice of grouping depends on the author's objectives. For instance, in scenarios with multiple visualizations of the same type, an author might prefer the ? optional or + visit one choice to streamline the process. In this manner, the author can ensure that users grasp the key concepts without having to explore all similar visualizations.

In addition to giving authors the option to craft the sequence themselves (Figure 4 (Custom)), we also provide a few predefined tours based on traversing the component graph (**G3**). These predefined tours can be easily customized by adding more nodes from the Content Extraction View or by deleting existing ones. Currently, we support the following narrative templates (Figure 4):

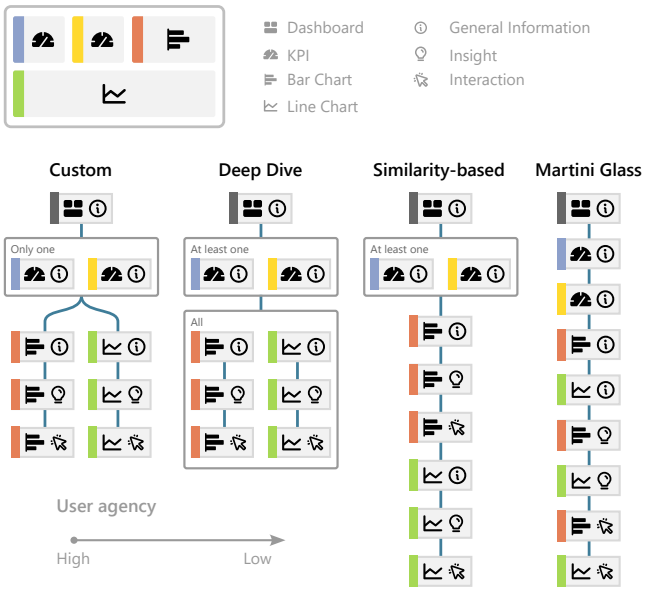

Fig. 4: **Predefined Narrative Templates in the D-Tour Prototype.** The templates allow authors to quickly create tours based on established narrative structures. Here, the simple example dashboard consists of two KPIs, a bar chart, and a line chart. At all times, authors can move to a completely customized narrative.

- **Deep-Dive:** A detailed, sequential walkthrough of all visualizations in a dashboard, starting from the top. It covers all the subcategories of a visualization—*General*, *Insight*, and *Interaction*—before moving to the next visualization.
- **Similarity-based:** A traversal of visualizations from top to bottom grouped by visualization type. The categorization criteria can extend beyond just the type of visualization. They may include aspects such as data characteristics and insights. This approach is based on the work of Hullman et al. [23] and on GraphScape [27].
- **Martini Glass:** A traversal based on the Martini glass storytelling metaphor [45]. It starts with a broad overview of the dashboard and gradually focuses on specific elements, mimicking the narrow shape of a Martini glass.

The supplementary material details various design considerations for the nodes and the narrative structures.[2]

Explaining Tour Content. Individual elements in an interactive tour can also be explained to the end user in various ways using, for instance, text, audio, or video depending on user needs (**G4**). With the D-Tour Prototype the author can also *adjust the displayed content detail* by specifying the perceived or assumed expertise of the end user through a *user-level matrix*. Our prototype supports text, audio, video, and screen recording and provides text as a default. The explanations are displayed at the bottom of the Content Arrangement View (Figure 3). They appear when the author selects a subcategory, such as *General* in this example from the Content Extraction View or an element (essentially a subcategory) in the Content Arrangement View.

Textual explanations are automatically generated from the component graph that is created and populated in the Content Extraction View.

In the Content Arrangement View, the explanations are attached to individual nodes. Herewith, authors can edit node-specific explanations even if they belong to the same subcategory of the same visualization in the Content Extraction View. This is helpful in cases where a node must be explained multiple times in different tour segments. In addition to text the author may also attach other means, such as a video, audio, or screen recording. The intention is to explain specific nodes, such as a filter interaction [58], that may be difficult for a new user to understand.

Beyond the node-specific explanations, the user-level matrix at the bottom right of the Content Arrangement View (Figure 3) can be used to set the expertise of the target user. This matrix displays two dimensions—domain and visualization expertise—on a scale from low to high. If the author sets the level of visualization expertise to high, only little *General* information will be shown, as the user is expected to be familiar with the visualization. Likewise, if the author sets the level of domain expertise to high, the default *Insight* description becomes concise. This supports **G2** by enabling authors to adjust the depicted details to the user group.

The Content Arrangement View is directly connected to the Dissemination View. All changes in the narrative structure of the tour or the content explanation immediately influence the Dissemination View.

5.1.3 Dissemination View

The Dissemination View is a miniature, real-time representation of the dashboard and incorporates interactions from the Content Extraction View and Content Arrangement View. As explained in Section 5.1.1, selections made in the Content Extraction View are concurrently highlighted in the Dissemination View (**G1**). Similarly, the nodes in the Content Arrangement View are also reflected in real time in the Dissemination View, which allows the authors to test both individual nodes and the entire narrative structure of the D-Tour as it is developed. This facilitates seamless exploration (**G5**), testing, and refinement of the tour, and eliminates the need to switch between modes.

If a subcategory is selected in the Content Extraction View or an element is selected in the Content Arrangement View, the corresponding visualization is highlighted in the Dissemination View with a pop-up showing the associated resources. Buttons facilitate navigation.

Once authors are satisfied with the onboarding narrative, they may optionally publish it, making the onboarding accessible to users. The authors can also edit and republish the onboarding story if necessary.

5.2 Onboarding mode

In the Onboarding mode, both authors and users can explore the onboarding story, which allows authors to experience the tour from a user's perspective (**G5**). Based on the concepts in Subsection 4.3, we explain how D-Tour incorporates user agency in this mode.

- **Choosing an onboarding style:** Users can navigate through the onboarding story in a guided manner. They either follow the predefined onboarding tour crafted by the author or choose a self-guided exploration mode. In the guided mode, the tour appears as a sequence of pop-up boxes with *next* and *previous* buttons. If a branch is encountered in the tour, users are prompted to select one of the paths indicated by green frames around specific visualizations. Their choice determines the course of the onboarding journey. Users can also backtrack and alter choices, to follow a different onboarding path.

  In the self-guided exploration mode, the onboarding journey is driven solely by user choice. The onboarding content for each visualization is accessible upon clicking it. There is no *next* and *previous* navigation, as the user is in charge of the narrative. Additionally, the users can access multiple presentation resources (such as video, audio or text) provided by the author (**G4**).

[2] https://osf.io/uf8ew

- **Adjusting the level of detail:** Users can adjust on the fly the detail level of the content they see during the onboarding.
- **Interacting with the dashboard:** As the onboarding is integrated into the dashboard, users can access the dashboard content at all times (**G1**). They can interact with the visualizations, and the onboarding content will update to reflect the changes. For interactive elements in the D-Tour, a *Try it out* option appears, encouraging active engagement with the dashboard.

The maximum level of control over the content and narrative gives users agency in their onboarding (**G2**). The onboarding finishes with a *close* button, but it can also be restarted.

6 Implementation

We implemented the D-Tour Prototype using the Microsoft Power BI Embedded report [36], which provides a practical dashboard solution and eliminates the need to build one from scratch. Using Power BI's REST API [46], we access comprehensive information about all the visualizations in any Power BI dashboard, making the D-Tour Prototype generalizable for dashboards with default Power BI visualizations. The source code of the D-Tour Prototype is available online [15].

We used the React framework [33] for the D-Tour Prototype front-end [33]. We employed Bootstrap [2] to structure the Content Extraction View, utilizing User Interface (UI) elements such as navigation bars, tabs, and accordions. Finally, we ensure that the component graph we construct and update via the Power BI REST APIs is in sync with the dashboard's current state.

The Content Arrangement View uses React-Flow [9], which offers support for building node-based editors. The Dissemination View integrates the Power BI dashboard and uses CSS and TypeScript for dynamic elements. We use FastAPI [39] and Python for the backend. These tools support multimedia content, such as audio and video.

7 Use Case: Sales and Marketing Dashboard

Here, we present the onboarding example of Section 5 and authored with the D-Tour Prototype in more detail. Marie is a mid-level executive working for a retail and manufacturing company. She has been asked to prepare an onboarding experience around the dashboard in Figure 3 for managers and employees to help them to monitor and analyze the company's industry standing. Managers are interested to see an overview of their sales and the most important insights while the employees need a more thorough onboarding on all the visualizations.

Authoring Mode. Marie starts the authoring process for the onboarding using the D-Tour Prototype. An overview of all the visualization types in the Content Extraction View helps her pick the elements required for the D-Tour. Instead of creating two different onboarding tours, Marie decides to create a single adaptable tour that accommodates both user groups. To create this tour, she starts from scratch and adds common categories from the Content Extraction View that are relevant to both user groups, such as *Introduction*, *Dashboard*, and filter *Interaction*. She also adds a supporting video to enhance the textual description of the filter.

The narrative then branches as depicted in Figure 3. The left branch is targeted towards the managers. It features grouped KPIs with an *Only one* option (❗), which allows managers to focus on KPIs of their particular interest. To explain the most important insights from each visualization type, the author creates a linear sequence of *Insight* elements for each unique visualization type. Since there are two column charts, Marie simply groups them with an *At least one* option (➕).

The right branch, specifically designed for employees, provides a detailed explanation of the visualizations. Therefore, Marie uses *All* option (★) to group all the visualizations' *General* elements. She wants to ensure that employees are familiarized with all visualizations before moving on to interactions. To explain the interactions, Marie creates a linear sequence of *Interaction* elements for each unique visualization type. This mirrors the left branch, but it is designed for the *Interaction* elements. The story concludes with a branch on each KPI, giving users a choice in their onboarding journey.

Onboarding Mode. Both user groups are given access to the onboarding and follow the prepared onboarding paths. The managers gravitate towards the KPI-focused branch, while employees' choices are influenced by their expertise. They can adjust the level of detail and interact with the dashboard while going through the prepared tour. After the onboarding has been completed, they can choose to close it or go back and follow the same or a different path. That both paths are accessible to both user groups makes onboarding flexible and adaptive.

Conclusion. Integrating different onboarding experiences into one dashboard decreases the effort required from the authors and allows them to create a single tour to onboard a variety of end users. A video demonstrating the scenario is available in the supplementary material.[3]

8 Evaluation

We validated the D-Tour Prototype in a user study with five onboarding authors and six users from our industrial collaborators.

8.1 User Study: Authoring Mode

The goal of the user study was to understand the challenges of current onboarding practices and how the D-Tour Prototype can address them and support authors in creating onboarding experiences for end users.

8.1.1 Study Method

We interviewed five authors from various departments and divisions of our industrial collaborators, who are active in the production of steel and steel-based technologies worldwide. The authors are experts in their domains, knowledgeable about visualization, and regularly onboard users. For each interview, we used a dashboard they had recently created and had planned to onboard end users. Each interview was conducted in person and individually. We chose the authors for three main reasons, i.e., their: (i) experience with real-world onboarding scenarios, (ii) role as actual onboarding authors, and (iii) usage of the same technology stack as our D-Tour Prototype.

The interviews began with preliminary questions,[4] including a self-assessment of the authors' data and domain knowledge, and their experiences and challenges with onboarding. We then provided an introduction to the D-Tour Prototype and explained its features. This took 15-20 minutes, depending on the questions posed by the participants. They were subsequently requested to perform basic actions, such as clicking on the categories in the Content Extraction View and dragging and dropping them to the Content Arrangement View. This was done in order to facilitate familiarity with the system.

The main task of the study was for the authors to create an onboarding experience for one of their own dashboards. They were asked to incorporate as many details as necessary to onboard their end users. All authors had different onboarding goals in mind that were based on their dashboards and domains. For instance, an author from process engineering wanted to onboard a new colleague on the workings of a manufacturing plant by explaining indicators, thresholds, and system failures, if any. In contrast, an author who creates dashboards for the finance team wanted to convey the finance KPIs and the estimated cost-to-profit ratio of certain products to their users. They each were given 1.5 hours to create an onboarding experience. After completing the onboarding authoring, we invited the end users to onboard themselves with the resulting material. The authors of the onboarding material observed the onboarding sessions.

We ended sessions by asking authors to fill out a post-experiment questionnaire on ease of learning, ease of use, efficiency, and satisfaction with and intuitiveness of the D-Tour Prototype. Questions used a 7-point Likert scale (1: weakest agreement and 7: strongest agreement). We also asked open-ended questions about their experience with and opinions of the prototype. We recorded all sessions and interviews.

8.1.2 Session and Results

The average age of the authors was 38.8 years (σ = 8.38) and their experience in the company ranged from 5 to 25 years.

[3] https://osf.io/q492g
[4] https://osf.io/cedzu

Challenges with current practices. All authors reported that they typically onboarded end users via documentation, videos, or online presentations, explaining each use case and the associated visualizations in the dashboard. Author A1 said that exposure to a new visualization type typically triggered questions that prompts them to *"explain every detail about it."* Author A2 mentioned being *"asked to create a video"* to provide reusable onboarding material. However, they felt that they are *"not a media person"*, so they instead *"ended up doing personal meetings"* for the onboarding. Author A3 observed that users had a *"fear of ruining the dashboard"* and *"do not know the [interactions] they can use within the dashboard."* If not properly onboarded, the users would *"just take the easiest way or go with the first guess"* without learning interactive ways to explore the material, which would *"hinder the analysis of the data."* Author A5 reported that, despite the dashboards having a consistent overall design due to *"corporate identity"*, they varied significantly, and without proper onboarding *"users could spend hours"* attempting to understand their functionality.

Using the D-Tour Prototype to create new onboarding experiences. Most authors opted to build their D-Tours from scratch, except A3, who switched from a predefined template to a custom tour due to an unanticipated technical issue. A1 started with sketching the intended onboarding experience on paper, where they picked the most important points that should be made clear. For example, they picked one parameter for which a value of zero indicates a production failure. After noting more of these points based on their domain knowledge, they switched to the D-Tour Prototype to directly craft their narrative. As the main language used in the company was German, almost all the authors, except A2, translated the default content, either partially or completely, to German. A1 found that *"you can guess 90 % of the questions in advance because of the automation and the flexibility of the message."* A3 attached a small video to explain the bar chart's drill-down functionality. Almost all authors combined elements with the *group* feature. After creating the narrative, all the authors thoroughly tested their D-Tours in the Dissemination View and Onboarding mode.

Experience with the D-Tour Prototype. A1 mentioned that using the D-Tour Prototype might *"reduce the training time of the colleagues"* and save them time as they *"did not need to be there all the time."* For authors A2, A3, and A5 the support of video content was valuable, especially for new users who are afraid of breaking the dashboard. A3 and A4 liked the self-guided option of onboarding but suggested that *"a small help button above the visualizations might be helpful."* All the authors found the D-Tour Prototype useful, time-saving, and easily adaptable to their dashboards. Nearly all authors highlighted the need for additional language support and adjustable font sizes, emphasizing the importance of accessibility in the onboarding experiences.

Almost all authors rated the experience metrics post-experiment as 6 or 7 on a 1–7 Likert scale. The exception was A1, who gave a score of 5 for intuitiveness, as they felt that the implementation could be improved, especially for creating groups. To create a group, an author must first select the components by clicking on them while pressing the Shift key. This was not obvious to A1, even though it was briefly explained before the study. To address this issue, we plan to add a group icon that can be dragged on existing components to form a group.

8.2 User Study: Onboarding Mode

We conducted another study to assess how users perceive the onboarding experience crafted with the D-Tour Prototype.

8.2.1 Study Method

The authors released the finished onboarding material to their end users. With the exception of author A4, who had two end users U4 and U5, all authors had one end user each. Nearly all the interviews were conducted in person. Only end user U6 was online, but they were given control of the application using an online remote conferencing tool. The interviews began with asking end users preliminary questions[5], for instance, about self-assessing the data, domain knowledge, and visualization knowledge, how they are currently onboarded, and what difficulties they experience.

8.2.2 Sessions and Results

The average user was 34 years old (σ= 5.09) and spent an average of about 10 minutes on the onboarding sessions.

Challenges with current practices. End users U1 and U5 had joined the company three months before the interview. They reported being onboarded routinely via in-person meetings or *WebEx* calls. According to U1, this *"was an overwhelming experience as it was too much information in a short time."* The other experienced users preferred to be onboarded on the data and the domain, as they were typically familiar with the visualizations. End user U3 reported that they sometimes are onboarded via the bookmarks feature of Microsoft Power BI [22], which can be used to share insights into the data. However, they found that it affected the dashboard's performance and the rearrangement of the bookmarked elements consumed considerable time.

Using the D-Tour Prototype to explore onboarding experiences. All users intuitively used the D-Tour Prototype to view the created onboarding experience by the author. U6 also tried the free exploration to learn more about the visualizations that were not part of the prepared D-Tour. Almost all the users found the translated text by the authors helpful in understanding the dashboard. U3 faced technical difficulties with video resizing. U2 mentioned that *"more description on how to* try out *the dashboard interactions would have been helpful"*.

Experience with the D-Tour Prototype. All users responded positively to the onboarding experience. U1 mentioned that *"the interaction with the dashboard"* alongside the onboarding was very convenient. Similar thoughts were expressed by U2 and U3. U1 pointed out *"missing contextual knowledge"*, which author A1 had forgotten to add. This also provided hints to A1 for their next onboarding session. Similar to U1, U2 also mentioned that they would have wished for *"more descriptive text"* concerning some visualizations. Nearly all the users mentioned that with the D-Tour Prototype, they could onboard at their own pace, potentially reducing calls or meetings with the authors. U2 liked the choice of less or more details in the content. The other users found the translated content helpful. U3 suggested that an animation might be more effective than a video, although they commended the overall presentation style. U2 and U5 liked the simple design. Almost all users found the onboarding easy to use and self-explanatory.

9 Discussion

We have presented interactive dashboard tours (D-Tours) as an effective approach to creating a dashboard *onboarding experiences* that preserves user agency. We implemented the concept in a D-Tour Prototype and evaluated it to assess usability in real-life onboarding scenarios. The D-Tour Prototype significantly decreases the authoring effort necessary to create reusable onboarding experiences. The effectiveness of the onboarding ultimately depends on the decisions made by the authors. We discuss the limitations and future research directions based on the evaluation of the D-Tour Prototype, existing research, and an interview with an expert who holds a PhD in visualization. With this expert, we also discussed the challenges and the opportunities in onboarding from both an author's and a user's perspective[6]. The topics are discussed in Subsections 9.1 Design, 9.2 Development, and 9.3 Evaluation to highlight the challenges and opportunities in each area. While all mentioned points are relevant, we use ✨ to indicate those particularly interesting from a research perspective.

9.1 Design

Difference from open-world game design: While our design of interactive dashboard tours is inspired by open-world games, there the next level unlocks only after completing the previous one successfully. In our component onboarding, we have no such verification in place to check successful completion. Currently, Microsoft Power BI Rest APIs [46] fetch visualization data to help the authoring process. Future

[5] https://osf.io/cedzu

[6] https://osf.io/vqz76

APIs could also help in verifying the onboarding success, for example by checking if a filter was correctly applied before moving on to the next component in the onboarding.

Multi-component onboarding: Currently, multiple components can be onboarded by grouping them together. However, the author has to check and update the description of each chart separately. An efficient approach could be to automatically update similar charts if one description changes.

Progress of the onboarding story: We received feedback during one of our pilot interviews to add a progress bar for conveying where the user is in the onboarding story. However, progress bars are directly applicable only to completely linear stories and may be misleading if users navigate through branched or free-form narratives.

9.2 Development

Optimizing onboarding narratives: Even with the D-Tour Prototype, choosing the onboarding material and narrative style for a given use case remains challenging. Additionally, currently, there is no support for automatically updating the narrative if the dashboard changes, requiring manual adjustments by the authors. Another limitation is the lack of functionality to export and import onboarding templates to other dashboards. Similar dashboards could benefit from using onboarding templates developed for a previous one. This would save authors time and potentially help create a standardized onboarding process.

Supporting more interactions and visualization types: One of the technical limitations of the D-Tour Prototype—but not of the general D-Tour concept behind it—stems from the constraints of the Microsoft Power BI APIs. While the Microsoft Power BI REST API [46] provides extensive details about the visualizations, it lacks specific interaction information, such as whether a visualization is highlighted. We infer missing information by analyzing changes in the displayed data and opacity to determine if parts are highlighted or filtered. Another limitation arises with non-standard visualizations from Microsoft AppSource [34], as the REST APIs do not provide information about their components. This makes it challenging to support custom visualizations. Multi-modal generative models could analyze dashboard screenshots to enhance support for non-standard visualizations.

Generalizability beyond Microsoft Power BI: Although the D-Tour Prototype uses Microsoft technology, the concept could be applied to other dashboard systems as well. The essential requirement is the ability to extract information about the visualizations within a dashboard. Once extracted, this information can be provided to the component graph, which can support additional visualization types and is applicable to non-Power BI dashboards as well. **Accessibility**: The automatically generated descriptions for the components in the D-Tour Prototype are currently in English. User feedback sessions revealed that authors frequently translate the descriptions to German to align them to their users' preferences. Adding support for multiple languages or translations would enhance accessibility. Additionally, improving font colors, background contrast, and font sizes could increase usability.

Conversational onboarding interface: Microsoft Power BI has recently launched an AI interface (co-pilot), which can help the authors create a dashboard from the given data and create a narrative about the dashboard. The main focus of this and similar AI interfaces for other BI platforms is on visualization creation and presentation. The approaches currently do not help authors create onboarding strategies or enhance onboarding material like text. A combination of onboarding created through the D-Tour Prototype and conversational interfaces to ask further questions could prove to be effective in this regard.

Collaborative onboarding process: Similar to a collaborative dashboard design process, onboarding could also be designed collaboratively by teaming up expert users before rolling out the onboarding material to a larger audience. This might enhance the *effectiveness of the created onboarding* and help with its wider adoption.

Adapting to different dashboard design patterns: Bach et al. [1] introduced design patterns for dashboards. The D-Tour Prototype already supports onboarding for dashboards that use many of these patterns. We plan to provide additional assistance for patterns like multi-page dashboards, parallel structures, and a wider range of interactions. A tabular summary of design patterns supported by the D-Tour Prototype can be found in our supplementary material [7].

9.3 Evaluation

Number of participants and dashboards: Due to the small number of participants and consequently dashboards, some of the advanced features of the D-Tour Prototype have not been utilized, such as multiple branchings. We may have missed edge cases that are not properly supported by the D-Tour Prototype. As the goal of the user study was to collect rich qualitative feedback to improve future versions of the D-Tour Prototype, we focused on the insights gained from interviews. In the absence of established guidelines for dashboard onboarding, it also becomes difficult to create a baseline for comparison.

Effectiveness of the created onboarding: A primary challenge in measuring the effectiveness of an onboarding experience is the subjectivity of learning, as it is a personal process. A longitudinal study might provide quantitative numbers by deploying the D-Tour Prototype at the collaborator's site over an extended period of time. Through tracking user interaction logs, we could assess whether the onboarding helped users get started with the dashboards, accomplish their tasks, discover new insights, and reduce communication time with the author.

Role-based usage analytics: We plan to deploy the D-Tour Prototype to study the *effectiveness of onboarding* and how much time authors might save as compared to their current onboarding practices. Based on the expert interview and participants' feedback from the user study in Subsection 8.1, it takes authors up to 30 minutes to onboard a single user in an in-person meeting. This depends on the size of the dashboard, the pages, the complexity of the visualizations, and other factors. While some authors prefer documenting the dashboard and insights, others spend more time on user questions. We plan to also save user interaction logs, which we already started by integrating the Trrack library [13][8]. This can help us identify the level of expertise so that the author does not have to manually specify it for each onboarding.

10 Conclusion

We propose *interactive dashboard tours* (*D-Tours*) as semi-automated onboarding experiences that support users with various levels of expertise. The interactive tours concept draws from open-world game design to give the user freedom in choosing their path in the onboarding. To demonstrate the applicability of our work, we implemented the concept in a tool called D-Tour Prototype, which allows authors to craft custom and interactive dashboard tours from scratch or use automatic templates. We validated the prototype with user studies for the authoring and onboarding modes. The authors' feedback was positive, as they successfully created reusable onboarding experiences with little effort. End-users also found the onboarding narrative engaging and expressed a desire to continue using such tours for their future onboarding needs.

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