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CONCEPTUALIZATION AND DESIGN OF A WORKFLOW MANAGEMENT SYSTEM FRONT END FOR AUGMENTED REALITY HEADSETS

Research in Progress

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Abstract

A currently discussed approach to increase efficiency during task execution, inter alia to reduce error rates and execution times, is the utilization of headset-based augmented reality systems (HARS). Additional to direct task support, HARSes can offer workflow management and control functions. However, these are only covered very limitedly by existing design-oriented approaches. Thus, users have to resort to additional devices, decreasing efficiency, and usability. Based on a three-step systematic literature analysis and two focus groups, we present a novel tentative design theory for HARSes supporting the full range of workflow management and control functions. Our design theory consists of four design requirements and nine design principles and is the basis for a software artifact prototype. Both our tentative design theory and software artifact are formatively evaluated by a third focus group. Our contributions add to the prescriptive knowledge base of the community and may be adapted by researchers and practitioners.

Keywords: Augmented Reality, Workflow Management System, Workflow, Design Science Research, Design Theory.

1 Introduction

A well-known tool for the management and (partial) automation of workflows is the workflow management system (WFMS) (Reijers et al. 2016). A WFMS defines, interprets, instantiates, and manages the execution of workflows with software, integrates external applications, and interacts with human workflow participants (Workflow Management Coalition 1995). Many types of devices can be utilized to interact with WFMSes to archive workflow management and control, e.g., desktop PCs, tablets, and smartphones. However, we here focus on a currently discussed approach to increase efficiency during task execution, i.e., to reduce error rates, execution times, cognitive loads, or required training, which is the utilization of augmented reality (AR). AR combines and aligns real and virtual objects in real environments, runs interactively, and in real-time (Azuma et al. 2001). A frequent implementation is as headset-based AR systems (HARS), which offer versatile sensors and advanced modes of interaction like tracking hand gestures and eye movements (e.g., Microsoft HoloLens). During workflow task execution, HARSes support users in manifold ways, e.g., by providing task descriptions and instructions with text and images, visually highlighting important objects, marking spots for tool placement, or demonstrating handles (Berkemeier et al. 2019; Mourtzis et al. 2019; Makris et al. 2013). While clearly not all workflows are well suited for AR-based support, improved task efficiencies, i.e., reduction of error rates, execution times, cognitive loads, or required training, have been observed in the domains of, e.g., collaborative planning, assembly, service, maintenance, warehouse picking, process training and process modeling (Hanson et al. 2017; Lampen et al.; Seiger et al. 2021; Jetter et al. 2018; Sääski et al.; Hofmann et al. 2019; Wang et al. 2016).

Besides directly supporting the execution of workflow tasks, HARSes are also utilized to enable workflow control and management. However, the currently supported functions are very limited and are provided in isolation, e.g., advancing backward and forward through a workflow's tasks or switching to a task of a different workflow (Berkemeier et al. 2019; Mourtzis et al. 2019; Makris et al. 2013). In contrast, the well-known WFMS reference architecture (RA) by the Workflow Management Coalition (WFMC) describes a much greater variety of functions for workflow control and management, e.g., instantiating, pausing, canceling, and generating filtered lists of workflow instances (Workflow Management Coalition 1995). However, to the best of our knowledge, no conceptualized HARS in the literature enables or aims at such holistic workflow management and control. Therefore, users wishing to control and manage workflows during task execution have to resort to additional devices. This creates media breaks and decreases efficiency and usability. It also diminishes or neutralizes one of the primary strengths of HARSes: enabling hands-free modes of use. Also, the use of additional devices for workflow management and control is not even possible in many cases, e.g., when using tools. The challenge then is how to simultaneously provide HARS users with both AR-based workflow execution support and associated efficiency gains, as well as workflow management and control capabilities, while ensuring usability, i.e., enabling users to achieve their workflow goals effectively, efficiently, and satisfactorily (ISO 9241-11:2018). As this challenge is as of yet unaddressed within the research literature, there is no guiding design knowledge available for information system (IS) architects, developers, and researchers. To address this research gap, we define our research question (RQ) as:

RQ: What are the design requirements and design principles of a workflow management system front end for augmented reality headsets, providing the full range of workflow user interactions?

To answer the question, we apply a design science research (DSR) approach to generate a design theory (DT) for a workflow management system front end for augmented reality headsets (HoloWFM), whose methodical foundations are described in Section 2. In Section 3, we describe the process for deriving design requirements (DR), based on both a three-step structured literature review (SLR) (Cooper 1988; Vom Brocke et al. 2009) and two focus groups (Morgan 1997) with IS researchers specializing in workflow management, AR practitioners and users. In Section 4, we present corresponding design principles (DP) and a tentative DT as the main contribution of this paper, answering the RQ. Section 5 describes the first development stage of a HoloWFM prototype, and Section 6 evaluates both this prototype and underlying DT with two reconvened focus groups (Morgan et al. 2008) and the DT framework by Gregor and Jones (2007). Section 7 discusses related work, and Section 8 summarizes our findings and next steps in research.

2 Research Method

To structure our procedure and ensure scientific rigor while designing HoloWFM, we applied a DSR approach based on the well-known work of Vaishnavi and Kuechler (2015), which involves five steps: awareness of problem, suggestion, development, evaluation, and conclusion. Our multi-cyclical research design follows Meth et al. (2015) and at least one further cycle is currently planned (Figure 1). As of now, the first cycle has been completed, which was dedicated to an initial conceptualization of our DT and includes a set of tentative DRs and DPs. A complete DT has two necessary elements: requirements and components, which together embody a general design solution for a class of problems (Baskerville and Pries-Heje 2010). The DRs describe the general objectives of the DT and function as meta-requirements for the software artifact (Baskerville and Pries-Heje 2010; Walls et al. 1992). The DPs can be descriptive or–as in our case–prescriptive, stating how an artifact should be instantiated to fulfill the DRs (Fu et al. 2016). In the next sections, we present the results of each phase of the first DSR cycle.

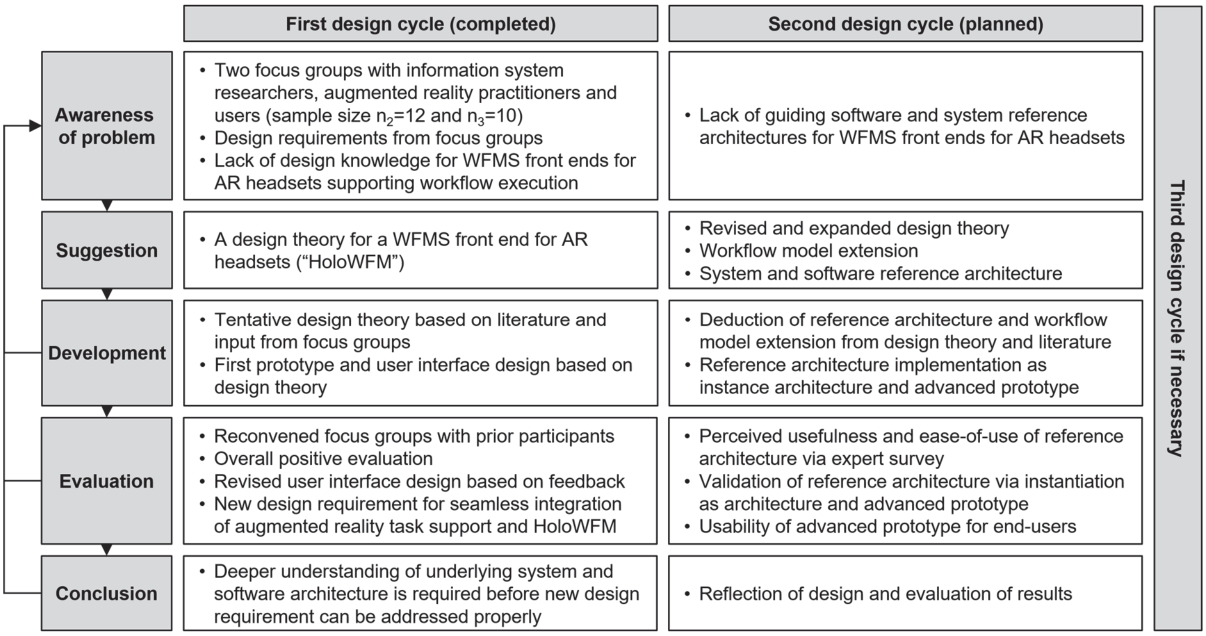


Figure 1. Design science research cycles for HoloWFM

3 Awareness of Problem

In the first phase of design cycle 1, we conducted a total of three SLRs, detailed in Table 1. In terms of the taxonomy by Cooper (1988) our SLRs can be characterized as focusing on research outcomes with SLR 3 additionally considering applications. The audience is specialized and general scholars. The coverage is representative for SLR 1-2 and exhaustive & selective for SLR 3. All SLRs have the goal to integrate the literature, organize it conceptually, and represent it in a neutral perspective.

	SLR 1	SLR 2	SLR 3
Search string	("workflow management" OR "process management") AND ("architect*" OR "ontology")	("augmented reality" OR "mixed reality") AND ("architect*" OR "ontology")	("augmented reality" OR "mixed reality") AND ("business process" OR "workflow")
Search fields	title	title	all search fields
Databases	ScienceDirect, ACM Digital Library, AIS electronic Library, SpringerLink, IEEE Xplore, Web of Science, EBSCOhost (Business Source Premier/Academic Search Premier)		
O/TA/F/BF	1.465 / 171 / 3 / 5	1.018 / 30 / 1 / 1	9.016 / 85 / 0 / 0

Note. O = original hits, TA = after title & abstract filter, F = after full text evaluation, BF = after backward & forward search.

Table 1. Details and characteristics of the structured literature reviews

From the respective hits, we first selected the literature by title and abstract, and second by analyzing the content, complementing the results with backward and forward searches. To ensure our state-of-the-art understanding of the involved technologies, we conducted SLRs on the RAs of AR and WFMSes. RAs are reference models for architectures that capture the essence of existing architectures and provide blueprints and guidance for the design of concrete architectures (Cloutier et al. 2009). In SLR 1, we searched for RAs of WFMSes and finally identified five relevant results: Lin et al. (2008), Rodriguez and Buyya (2017), Pourmirza et al. (2019), Workflow Management Coalition (1995), and Grefen and Vries (1998). With 23 mentions in 171 reviewed documents, the RA of the Workflow Management Coalition (1995) is currently the most representative RA for WFMS. In SLR 2, we searched for RAs of AR and first identified Reicher et al. (2003) and with a forward search MacWilliams et al. (2004), who fully include and extend the former, describing subsystems of AR systems and the relationships between the concepts and components involved. With our understanding thus grounded in the state-of-the-art, we conducted SLR 3, reviewing approaches to developing WFMS front ends providing the full range of a workflow client application (WCA) as defined by Workflow Management Coalition (1995). However, we could not identify any such approaches, but only some HARSes that complementarily offer very limited WCA functions, which we discuss in section 7.

To rigorously establish the DRs for HoloWFM, we conducted two moderated focus groups (MFG). An MFG is a qualitative research method where a moderator guides a group discussion and which relies on the interaction between participants to generate insights (Morgan 1997). As the number of MFGs necessary for reliable results is highly debated in the literature we follow the empirical findings of Guest et al. (2017), suggesting that two to three MFGs are sufficient. Therefore, we conducted two MFGs to identify DRs and two further MFGs as part of our evaluation (see Section 6). All groups consisted of a mix of workflow and AR researchers, AR practitioners, and AR users, all having several years of experience. The first group (n=12) included 6 IS researchers, 2 AR user interface (UI) and user experience (UX) designers, 1 AR engineer, and 3 HARS end-users. The second group (m=10) included 4 IS researchers, 3 AR engineers, and 3 HARS end-users. The MFG procedure consisted of four steps: 1) motivating the research topic, 2) discussing the problem context, 3) protocolling, and 4) evaluating the protocols through manual DR clustering. In both groups, the topic was approached by discussing the previously identified RAs of WFMSes and AR to establish a common understanding of the topic.

To systematize the statements by the participants, we took on the thoughts of Gioia et al. (2012) to distill first-order concepts and second-order themes from the verbalized statements of the subjects but adapted the method to our DSR approach. Thus, we clustered the statements of our subjects (concepts) and derived seven important themes for HoloWFM, shown in Table 2.

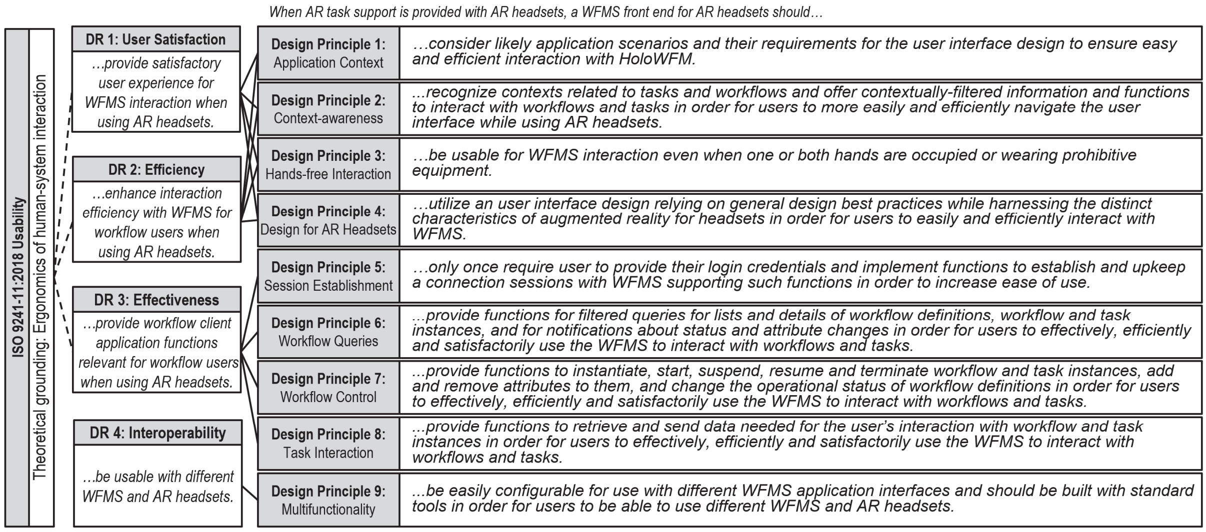
1st order concepts: clustered verbalized statements	2nd order themes
• AR can generally be utilized as an interaction format for all tools and human interfaces to the workflow engine, i.e., process definition tools (interface 1), administration & monitoring tools (interface 5), and especially workflow client applications (interface 2).	1) Applicability for workflow management system interfaces
• The user experience should be a focus of HoloWFM since adaption by employees is very important. • Many AR systems have poor usability and are thus hard to use. • HoloWFM should focus on use cases where conventional devices cannot be utilized well.	2) User Experience & Usability
• HoloWFM must be useful and offer the same functions as non-headset-based workflow client applications. • HoloWFM must be completely interoperable with existing workflow management systems as it were a "normal" workflow client application.	3) Effectiveness & Interoperability
• Scenarios and processes where users perform some manual labor are generally well suited. • Industrial processes are generally well suited for HoloWFM, including assembly, service, maintenance, and warehouse picking. • Utilizing real 3D experiences during, collaborative planning and design is a well-suited application scenario.	4) Application Scenarios
• HoloWFM should offer context-aware functions to fully utilize HARS sensors.	5) Context-awareness
• Application scenarios where only one or no hands can be utilized are well suited to fully realize the potential of HoloWFM.	6) Single-hand & hands-free interaction
• AR has great potential for user experience, but needs special user interface design. • Using web browsers in HARSes as workflow management system front ends is very user-unfriendly. • HoloWFM should be designed as an AR-native workflow client application. • Spatial AR (Bimber and Raskar 2005), is not well suited for many application scenarios, especially in the field.	7) Design for HARS

Note. AR = augmented reality, HARS = headset-based AR system

Table 2. Clustered statements of participants of the moderated focus groups.

4 Suggestion of a Tentative Design Theory for HoloWFM

To methodically underpin the development of the DPs and DT, we oriented ourselves on the supportive approach of Möller et al. (2020). Following this approach, DPs aim to provide design knowledge before the design process takes place. The DRs and DPs are derived in advance from the literature, case studies, focus groups, expert interviews, or other suitable sources of design knowledge (Möller et al. 2020).



Note. AR = augmented reality, WFMS = workflow management system.

Figure 2. Tentative design requirements and design principles for HoloWFM

After evaluating the distilled concepts and themes, we were able to cluster a total of 4 essential DRs for HoloWFM, which we addressed with 9 DPs as part of our DSR suggestion phase (Figure 2, cf. Figure 1). We divided the requirement "usability" into its components according to ISO 9241-11:2018: user satisfaction (**DR1**), efficiency (**DR2**), and effectiveness (**DR3**). To address interoperability, we defined **DR4**. DPs 1-4 address DR1 and DR2 respectively and must, therefore, be implemented considering both requirements. We define **DP1** to ensure that HoloWFM is designed for relevant scenarios, as suggested by the MFGs and discussed in the literature (e.g., Ganapathy 2013; Berkemeier et al. 2019). To increase the artifact's usability in relevant scenarios, we define **DP2** and **DP3**. Taking up the statements of the MFGs, the sensors of the HARS should be utilized to implement context-aware filtering of tasks and workflows and present appropriate interaction options to the user (**DP2**) (Dey 2001). To address scenarios where conventional devices are unusable or poorly suited, HoloWFM should be usable with one and without hands (**DP3**). While general design guidelines for UIs and UX apply, AR has distinct features that should be used to improve UI and UX (Dünser et al. 2007). Hence, HoloWFM should be natively designed for HARS (**DP4**). For DR3, we defined **DP5-DP8**, whose articulations are based on the functional requirements of a WCA as defined by the Workflow Management Coalition (1995), but were specified due to their relevance for HARSes. To address DR4, we define **DP9** to specify and constrain the software architecture and development toolset for HoloWFM.

5 Development of HoloWFM

In the first design cycle, we focus on a general design direction rather than on implementation details (Vaishnavi and Kuechler 2004). We understand our multi-cyclical DSR approach as an iterative-formative process in which design details of HoloWFM may change in later DSR cycles, although we are guided by the literature on UI design for AR (e.g., Dünser et al. 2007). We design HoloWFM as a software artifact consisting of four UI components: a heads-up display (HUD), a quick-access menu (QM), a main menu (MM), and a context-aware mode (CM). Figure 3 shows the UI design and the associated DPs. To illustrate the UI, we chose a fictional radio tower inspection workflow as an application scenario. In this, an engineer has already powered down the radio tower and climbed it, and now has to check a data logging unit before finally powering the tower back up.

Figure 3. The user interface design of HoloWFM

The HUD addresses DP4 and presents key information: the currently active task and subtask, the parent workflow, time remaining, and priority. The QM is associated with DP3-4 and DP8 and is anchored to the hand. It is minimized by default to minimize interference with the user's activities. The QM displays more detailed information about the currently active task than the HUD while minimizing the user's interaction with HoloWFM. In the example, subtasks are marked as completed with a slider. The MM corresponds to DP3 and DP6-8. It fills the entire field of view and displays tasks assigned to the user, additional information, and filters. The CM addresses DP2 as it visually highlights objects related to currently active tasks and workflows to guide the user. The visibility of the UI is toggled on the wrist.

6 Evaluation of HoloWFM

Our overall evaluation strategy follows Venable et al. (2016). Stemming from the DRs, the preeminent risk for HoloWFM is user-oriented, i.e., it must be ensured that the user's interactions are efficient, effective, and satisfactory. Furthermore, we place great emphasis on ensuring the benefit of the artifact for practice. Hence, we follow the *human risk & effectiveness* strategy of Venable et al. (2016) and consequently use formative evaluations early in our research process. As described in the awareness phase, we theoretically underpinned our research with a three-step SLR and empirically underpinned our DRs with two MFGs. Since we yet lack a complete operationalization of the DT, i.e., a fully executable prototype, we cannot yet empirically verify if the DPs effectively address the DRs. Thus, we continued our evaluation strategy with a formative evaluation of the tentative DT as part of two moderated reconvened focus groups (MRFG). MRFGs reunite the participants of previous sessions to discuss topics, concepts, theories, or issues in greater depth or to evaluate them under consideration of new information, or both (Morgan et al. 2008). Consequently, we reunited the groups from the problem awareness phase to check whether our tentative DT and prototype correspond to the groups' expectations.

The procedure of the MRFGs consisted of four steps: 1) reintroduction to the topic, 2) discussion of our DT and the HoloWFM prototype, 3) protocolling, and 4) the evaluation of protocols through manual issue clustering. Analogously to the MFGs (cf. Section 3), we based our systematization on Gioia et al. (2012) and distilled clustered verbalized statements, and derived three major themes, displayed in Table 3.

As theme 3 represents a significant expansion of the previously established DPs and requires system and software architecture-related design knowledge, we decided to address this in a second DSR cycle (cf. Section 8).

1st order concepts: clustered verbalized statements	2nd order themes
• Perceived usefulness and ease-of-use of the Technology Acceptance Model (Davis 1989) are established measures of the quality of an artifact. • Usability (ISO 9241-11:2018) not only includes subjective but objective measurements, i.e., efficiency and effectiveness. • Overall usability is the more holistic choice and should be kept.	1) Technology Acceptance Model or ISO 9241-11:2018
• In application scenarios, which restrict the use of hands, e.g., industrial maintenance, HARSes generally offer higher usability than handheld devices, especially because of novel single-hand and hands-free modes of interaction, e.g., eye tracking. • Group 1: HARSes have been evaluated positively in the literature, regarding task efficiency (cf. Section 1). • Group 2: HoloWFM's benefit must be discussed in a realistic context of already using a HARS for workflow task support. Then, using additional devices for workflow management and control is inefficient. • Context-aware selection of information and interaction options for tasks and workflows can be a major strength of HoloWFM .	2) Benefit of HoloWFM for real-world practice
• AR applications in the literature usually are usually hard-coded for a specific application and workflow. • How can AR support be integrated then for multiple workflows? • For HoloWFM, the AR support should be part of the workflow definition. • HoloWFM should enable a seamless integration of AR content from different workflows and workflow management functions into a unified AR user experience.	3) Integration of augmented reality support for various workflows

Note. AR = augmented reality, HARS = headset-based AR system

Table 3. Clustered statements of moderated reconvened focus groups.

In addition to the empirical evaluation via the MRFGs, we formally verified the quality of the DT with the framework by Gregor and Jones (2007), which defines six obligatory and two optional components a DT should include. We find our tentative DT in complete compliance with this framework (Table 4).

Component	Description
Purpose and scope	The goals of a WFMS front end for HARSes are providing a satisfactory user experience for interaction with WFMSes (DR1), improving efficiency for WFMS interaction (DR2), providing the full range of WCA functions for HARSes (DR3), and ensuring interoperability with other WFMSes and HARS (DR4).
Constructs	WFMS, Workflow, WCA, AR, HARS, front end, UI, IS architecture
Principles of form and function	DP1: application context, DP2: context-awareness, DP3: hands-free interaction, DP4: design for HARSes, DP5: session establishment, DP6: workflow queries, DP7: workflow control, DP8: task interaction, DP9: multifunctionality
Artifact mutability	HoloWFM can be used with different HARSes and WFMSes. The UI design and functionality can be adapted for different user tastes and can be enhanced based on specific practical and theoretical requirements.
Testable propositions	A WFMS front-end for augmented reality headsets offers higher user satisfaction, effectiveness, and efficiency than handheld-based approaches.
Justificatory knowledge	A three-step literature analysis and two moderated focus groups justify the derivation of DRs and DPs. Two reconvened moderated focus groups justified that a WFMS front-end for augmented reality headsets generally delivers higher user satisfaction, effectiveness, and efficiency than handheld-based approaches, especially since HARSes offer novel possibilities for UI design and one-hand and hands-free interaction modes.
Expository instantiation	Development of a first prototype, encompassing four UI components: a heads-up display, a quick-access menu, a main menu, and a context-aware mode.

Note. AR = augmented reality, HARS = headset-based AR system, IS = information system, WFMS = workflow management system, ‘ WCA = workflow client application, DT = design theory, DP = design principle, DR = design requirement, UI = user interface.

Table 4. Components of a tentative design theory for HoloWFM

7 Related Work

In SLR 3, we were unable to identify any articles explicitly mentioning WFMSes and no approaches that aim to conceptualize or develop a WCA. We were able to identify one approach (Berkemeier et al. 2019) that explicitly mentions BPMN and an "XML parsing service", which we interpret as a workflow engine in terms of the WFMS RA (Workflow Management Coalition 1995). Other approaches describe workflows and tasks with unspecified XML (e.g., Makris et al. 2013; Mourtzis et al. 2019). While no approach aims to conceptualize, design, or develop a WCA, some partial and basic WCA functions have been implemented by AR systems focusing on AR-based workflow (task) support. E.g., the AR system prototype by Berkemeier et al. (2019) enables the user to advance to the next or return to the previous task and the prototype by Mourtzis et al. (2019) allows the user to pause and switch tasks. However, the WCA functionalities in the analyzed articles are neither a major focus of the conceptualized or designed AR systems nor do they address workflow control and management holistically, i.e., in terms of the WFMS RA (Workflow Management Coalition 1995). Instead, the analyzed articles conceptualized and developed highly scenario-specific approaches to enable AR support for specific workflows and workflow tasks. Further, we noticed that nearly all AR systems described in the literature in general and all AR systems offering partial WCA functionality address only linear workflows, i.e., no branches or loops. In summary, our approach and DT distinguish themselves from the identified approaches by their purpose and scope (cf. Table 4): HoloWFM is designed explicitly for WFMSes, aims at full WCA functionality, supports complex workflows, and is scenario-agnostic.

8 Conclusion and Next Steps of Research

The goal of our ongoing research is to conceptualize and design a WFMS front end for HARSes, supporting the full range of user interactions. To address the initially raised research question, we consequently presented the results of a first design cycle. We introduced a tentative DT, consisting of four DRs and nine DPs, and implemented a first version of the software artifact HoloWFM. Finally, we evaluated HoloWFM and the tentative DT in two MRFGs with predominantly positive feedback. Practitioners and scientists can use and adapt our DT to develop new AR WFMS front ends for specific application scenarios. Furthermore, the DRs, DPs, and DT contribute to the prescriptive knowledge base of the IS community, according to Gregor and Hevner (2013).

For an adequate interpretation of our results, the following limitations should be considered. First, an inherent weakness to the conceptualization of DTs is the subjectivity of underlying design decisions, e.g., selection and naming of DRs and DPs. Other designers could make different decisions, thus reaching a different DT. However, not all design decisions must or can be grounded in theory and a degree of creativity is unavoidable and essential in the DSR process (Hevner and Chatterjee 2010; Baskerville et al. 2016). Nonetheless, we underpinned our DT methodologically via the consideration of the methods of Möller et al. (2020) for supportive design approaches and of Fu et al. (2016) for the prescriptive articulation of DP. Second, our DT conceptualization and evaluation results depend on our sample, i.e., the choice of other participants for the focus groups could lead to different results. However, consideration must be given to the fact that this was only a first formative evaluation in the first DSR cycle of HoloWFM. Our tentative DT will be refined in further design cycles and our evaluation strategy will consequently be continued with many further evaluations, especially involving end-users. Still, we believe that by selecting subject-specific experts and users for the focus groups in the first design cycle, and considering the comments by Guest et al. (2017) on the required number of groups, we have gained first well-founded insights, based on which we can trigger advancements of HoloWFM.

In the next DSR cycle, we will expand our initial problem definition to enhance the benefit of HoloWFM in practice. Based on the combined statements of the MFGs and MRFGs, as well as the existing body of literature (cf. Section 1) well-suited application scenarios for HoloWFM include industrial settings, e.g. assembly, service, maintenance, and warehouse picking. We consequently plan to conduct formative evaluations with practitioners from these domains to inter alia refine our initial UI design. Taking up theme 3 of the MRFGs, we will suggest an adapted DT, and based thereon, a software and system RA and workflow model extension, which we'll instantiate in a solution architecture and advanced prototype. The successful instantiation of the latter thus validates the former. Further, we will summatively evaluate the RA's perceived usefulness and perceived ease-of-use with experts and all three components of the advanced prototype's usability, i.e., user satisfaction, efficiency, and effectiveness with end-users (Venable et al. 2017; Davis 1989; ISO 9241-11:2018). For the aspect of user satisfaction, we'll also consider hedonistic aspects. If evaluation results are not satisfactory, we will continue our research efforts in additional DSR cycles.

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