Supporting Designers in Creating Cognition-centered Personalized Cultural Heritage Activities

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ABSTRACT

The heterogeneity of the audience of cultural heritage (CH) institutions introduces numerous challenges to the delivery of meaningful CH content. People with diverse cognitive characteristics are engaged with varying CH activities (e.g., games, guided visits) and considering that cognitive characteristics define the way we process information, our experience, behavior, and knowledge acquisition are influenced. Our recent studies provide evidence that human-cognition should be considered as an important personalization factor within CH contexts, and thus, we developed a framework that delivers cognition-centered personalized CH activities. The efficiency and the efficacy of the framework have been successfully assessed, but, non-technical users may face difficulties when attempting to use it and create personalized CH activities. In this paper, we present *DeCACHe* which supports CH designers in developing cognition-centered personalized CH activities throughout different aspects of the design lifecycle. We also report a case study with one CH designer, who used our tool to produce two versions of his CH game for people with different cognitive characteristics.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Interactive systems and tools**; *Interaction design*; • **Social and professional topics** → **User characteristics**; • **Software and its engineering** → **Designing software**; • **Information systems** → *Information systems applications*; • **Computing methodologies** → Cognitive science.

KEYWORDS

cultural heritage, cognition, cognitive characteristics, personalization, adaptation, design support, activity design, user modeling.

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1 INTRODUCTION

People differ in the way we think, sense, and experience, and we develop unique functions and processes to acquire, perceive, handle, and recall information. Among others, these differences result from our cognitive characteristics, such as cognitive styles and abilities. For example, a visualizer (i.e., an individual who processes and mentally represents information visually) tend to acquire information and build mental connections to process the acquired information through pictorial content (e.g., images), while a verbalizer (i.e., an individual who processes and mentally represents information verbally) tend to rely on textual content to perform the aforementioned processes [12].

In the cultural-heritage (CH) domain, there is evidence that cognitive characteristics influence the way individuals follow to visually explore CH scenes [17], develop their visiting style [1], interact with CH items [18], and gain information through interaction [16] in varying CH activities [19] and technological contexts [20]. Therefore, individuals with different cognitive characteristics develop different strategies to process CH information, which result in imbalances on their performance [18], experience [20], content comprehension [22], and knowledge acquisition [21].

The findings of the aforementioned studies necessitate the personalization of CH activities based on the cognitive characteristics of the users. Our recent works [23, 25] provide evidence that we can build adaptive interventions which leverage users' cognitive characteristics to enhance their experience and improve their knowledge acquisition. The cognition-centered personalization framework we proposed [23] aims to deliver CH activities tailored to the users' cognitive characteristics. The results of two user-studies verified the applicability, effectiveness, and efficiency of the framework and underpinned the added value of adopting cognition-centered personalization interventions within digitized CH interaction contexts.

However, non-technical stakeholders might face difficulties in understanding, learning, and applying the technical details of our framework. Hence, there is a need to support the designers when they create cognition-centered personalized CH activities through a standalone tool. Motivated by that need, in this paper, we present the design of such a tool. We also report a case study, in which a professional CH designer used our tool to create a personalized CH activity, tailored to the end-users' cognitive characteristics.

The remainder of the paper is structured as follows: firstly, we discuss the related work and present the motivation of this research endeavor. Next, we present the design of the tool, covering the aspects of the theoretical background, the architecture, and the implementation technologies. Finally, we present the case study, conclude the paper, and discuss our future steps.

2 RELATED WORK AND MOTIVATION

2.1 Related Work

In this section, we discuss our recent cognition-centered framework [23] for delivering personalized CH content, tools that have been used to create CH activities, and tools that focus on creating personalized CH activities.

Cognition-centered personalization framework for CH content. Our framework [23] enables CH stakeholders to provide personalized CH experiences to the visitors through adaptive interventions that leverage the visitors' cognitive characteristics. The framework consists of three stages: a) the design of personalized CH activities, b) the visitor modeling based on selected cognitive factors, and c) the configuration and delivery of the personalized CH activity to the visitor. The first stage is performed before the visit while the other two stages are performed during the visit. Hence, a CH designer creates different versions of a CH activity that build on the unique cognitive characteristics of the potential visitors, and then, the personalized CH activity is delivered to each visitor through rule-based techniques, which map each visitor's cognitive profile with the corresponding rules of content adaptation. The results of two user-studies provided evidence about the efficiency of the framework on enhancing visitors' experience and knowledge acquisition. However, the configuration of the framework was made through technical properties which can be a burden for non-technical CH stakeholders, such as educators, designers, and content providers. Hence, there is a need for providing an authoring tool for supporting such users in easily creating cognition-centered personalized CH activities.

Authoring tools for creating CH activities. Several tools have been proposed to support designers in creating interactive CH activities. Such tools can be used by CH stakeholders to create and manage CH content [30], create CH games [3], create interactive storytelling experiences [11], create multimedia applications [28], create navigational structures for virtual exhibitions [5], create chat-bots [27], etc. Moreover, the authoring tools can have different characteristics, such as leveraging open and structured data to create CH activities [26] and supporting co-designing [6] with varying types of CH stakeholders (e.g., curators, educators, content providers, visitors). Finally, the authoring tools can be used to produce CH activities in varying technological contexts such as mobile devices [7], location-aware contexts [8], and augmented reality [9].

Authoring tools for creating personalized CH activities. Focusing on research attempts that aim to create tools that support the design of personalized CH activities, Not and Petrelli [14] recently presented the *meSch* authoring tool that supports CH professionals – throughout the design cycle – in creating personalized and interactive CH experiences for visitors in diverse CH settings; Ardito et al. [2] presented a visual composition paradigm that allows non-technical CH stakeholders to manage ecosystems of interoperable smart objects and synchronize their behavior to create enhanced visit experiences; Katifori et al. [10] presented a tool that enables CH content providers and experts to create personalized and dynamically adaptive digital narratives, based on visitors' profile (e.g., interests, visiting behavior), in archaeological sites.

2.2 Motivation

From the discussion on the related work, it is evident that tools that support the design of digitized CH experiences (e.g., narratives, games) enable the non-technical CH stakeholders to create meaningful CH experiences, and thus, they benefit the end-users, as they receive enhanced visit experiences. Considering that our cognition-centered personalization framework provides enriched CH experiences, we need to provide a tool that could be used by non-technical CH stakeholders to create the appropriately adjusted activities. In this paper, we present the design of *DeCACHe*[1], which is a tool that supports the design of cognition-centered personalized CH activities. Moreover, we report a case study in which a professional CH designer used our tool to create new versions of his established CH game, tailored to the users' cognitive characteristics.

3 DESIGN OF *DeCACHe*

3.1 Theoretical Background

Design stages, functions, and principles. Following design research methodology [4], *DeCACHe* supports design decisions through the various stages (*DS*) of the design cycle, such as task clarification, conceptual design, embodiment design, and detailed design. The aforementioned stages reflect in specific design functions (*DF*), such as task definition, choice of representations, choice of methods, and definition of visualization, interaction, and distribution strategies. In turn, the aforementioned functions can be supported by providing well-defined design principles (*DP*), such as design guidelines, heuristics, and patterns. By adopting the derived principles in their design cycle, the CH designers can create personalized CH activities that build on and take advantage of the visitors' cognitive characteristics.

Design factors. As discussed in Raptis et al. [23], the cognition-centered personalization framework is based on three main factors: activity (*AF*), objective (*OF*), and cognition (*CF*), which are interrelated with each other. *AF* contains information about the activity characteristics, such as type (e.g., visual search, visual exploration), areas of interest (e.g., areas that contain critical CH information), and mechanics (e.g., interaction mechanisms that provide CH information); *OF* contains information about the objective (e.g., improve knowledge acquisition, enhance visit experience) of the CH activity; *CF* contains information about the cognitive characteristics (e.g., cognitive styles, cognitive abilities) that can be used as the basis of the creation of adaptive cognition-centered interventions. The derived design principles, discussed before, are dependent on this triple.

3.2 Tool Architecture

From the discussion on the theoretical background of the tool, it is evident that *DeCACHe* aims to deliver to the CH designers a collection of design principles (Eq. 1) to support them in designing cognition-centered personalized CH activities.

$$Set_{design-principles} = \{DP_1, DP_2, ..., DP_N\} \quad (1)$$

[1] ***DeCACHe*** is the acronym of "***De***sign of ***C***ognition-centered ***A***daptive ***C***ultural ***He***ritage activities".

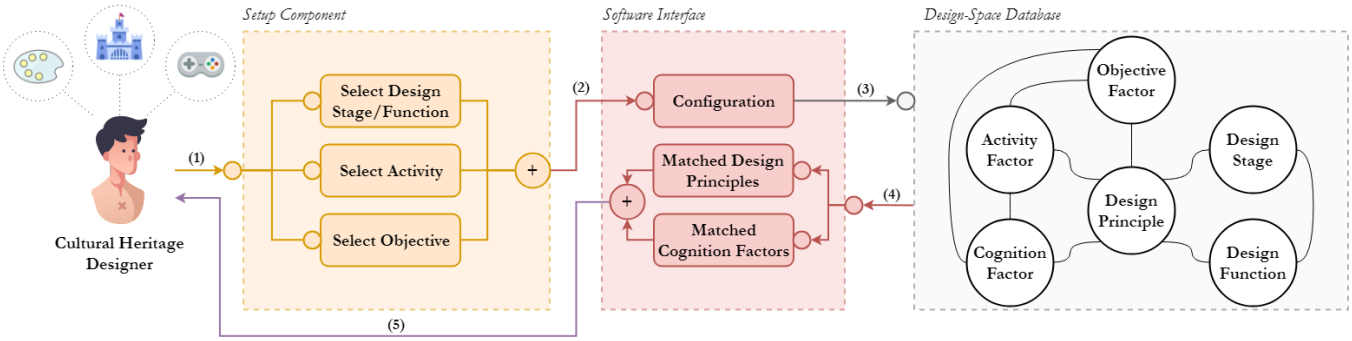

Figure 1: The architecture of the *DeCACHe* tool: (1) the CH designer selects the activity, the objective, and the design stages/functions to apply the design principles; (2) the selected features are sent to the configuration element of the software interface; (3) the configuration element requests the design principles from the database; (4) a software agent retrieves the matched design principles and cognition factors; (5) the matched features are sent to the CH designer.

Each design principle (*DP*) is characterized by the design stage (*DS*), the design function (*DF*), the activity characteristics (*AF*), the objective of the activity (*OF*), and the supported cognition factor (*CF*). These factors are interrelated with each other and when combining them, *DeCACHe* derives a design principle (Eq. 2).

$$f : \langle DS, DF, AF, OF, CF \rangle \rightarrow DP \in Set_{design-principles} \quad (2)$$

Therefore, the architectural model (Figure 1) of *DeCACHe* consists of three main components:

(1) the *setup component*, which is used by the CH designer to initialize the process and provide the selection criteria;
(2) the *software interface*, which provides the configuration element, which creates requests in the database, and the design principles and cognition factors, which meet the selection criteria;
(3) the *design-space database*, which consists of collections of interrelated data-sets, such as design principles and activity factors.

To better understand the process to support CH designers in creating cognition-centered personalized CH activities, we present its main steps (Figure 1):

(1) The CH designer initializes the tool by selecting the activity characteristics (e.g., visual search activity), the objective of the activity (e.g., enhance immersion), and the design stages or functions in which they will apply the derived principles (e.g., definition of interaction strategies);
(2) The selected features form a vector which is sent to the configuration element;
(3) The configuration element requests the design principles, which meet the selection criteria, from the design-space database;
(4) The database returns the matched design principles along with the corresponding cognitive factors;
(5) The CH designer receives the matched design principles (along with the cognition factors) and uses them to create new CH activities or adjust existing ones, tailored to the cognitive characteristics of the visitors.

3.3 Implementation Technologies

To implement our tool we were based on web technologies, aiming to build an accessible and interactive tool. We used various client-side tools, server-side tools, and client-server communication tools, which were built on top of each other and they collectively formed our solution stack. In particular, to develop the front-end part, we used the basic technologies of *HTML*, *CSS*, and *JavaScript*, along with various libraries, frameworks, and themes, such as *jQuery* and *Bootstrap*; to develop the server-side tools, we were based on *PHP* and *Apache* server technologies, along with *MySQL* to build the database for the relational representation of the design-space factors; we used *AJAX* to send and retrieve data from the server asynchronously in *JSON* format.

4 CASE STUDY

A professional CH designer, who has designed several digitized CH activities for many CH sites and institutions, agreed to use *DeCACHe* to adjust one of his popular CH games and create different versions that support visitors with different cognitive characteristics.

4.1 Setup

Activity. The CH designer decided to provide cognition-centered adaptations for *MuseumScrabble* [29], which is location-sensitive multiplayer mobile game for museums. It is played by competing players who use their mobile devices to scan museum exhibits and link them to CH themes.

Objective. The objective of *MuseumScrabble* is two-fold: a) to enhance the visitors' experience through immersive game-playing sessions and b) to help the visitors comprehend the CH content in depth and improve the knowledge-acquisition gains.

Design stage and/or function. The CH designer decided to adjust only the visualization of the CH content and the visualization of the game elements. He decided not to adjust the game rules, the game mechanics, or the game concept.

4.2 Design Decisions

Cognition factor. Considering the selection criteria, *DeCACHe* suggested the use of the *Visualizer-Verbalizer (V-V)* theory as the cognition factor. According to the V-V theory [15], information is processed and mentally represented in two ways: verbally and visually. Hence, the individuals are distinguished to those who think either more in pictures (visualizers) or in words (verbalizers).

Matched design principles. A sample of the design principles (e.g., design guidelines and patterns) that *DeCACHe* returned to the CH designer were:

- Consider displaying the content in textual format to verbalizers;
- Consider displaying the content in both pictorial and textual (ratio: 75-25) format to visualizers;
- In case that both content types (i.e., pictures and text) are required, consider using a ratio of 60-40 of textual-pictorial content for verbalizers (vice-versa for visualizers);
- Consider using salience filters in pictorial content (entropy level: .75+) to draw the attention of verbalizers into pictorial areas of interest;
- Consider using color in pictorial content to draw the attention of verbalizers into pictorial areas of interest;
- Consider emphasizing keywords of textual content (e.g., use of bold font) to draw the attention of visualizers into textual areas of interest;
- Avoid repetitions and redundant textual content when designing for visualizers.

4.3 Application of Design Principles

The CH designer followed the design principles that best describe *MuseumScrabble* and can be applied to adjust the visualization elements of the user interface. He developed sketches and wireframes for the main screens of *MuseumScrabble* both for visualizers and verbalizers. After creating the wireframes, we had a discussion with the CH designer on his reflections about the use of the tool to develop cognition-centered personalized CH activities. Overall, the CH designer found the design principles well-defined and very specific, which can have both positive and adverse impact, as, on the one hand, precise and easily-applicable design recommendations can help the CH designer to produce alternative versions rapidly and effortlessly, but, on the other hand, following "strict" and "limiting" principles can be a barrier for the designer's inspiration and creativity.

Moreover, the CH designer estimated that the extra development cost will not be high. However, it depends on the design stages where the adaptive interventions are made; for example, an intervention in game mechanics or game concept would probably have an increased cost compared to an intervention on the content visualization. A question raised by the CH designer was how he would know which cognition factor he should use. The suggestion of the V-V cognitive style was made on the match between the criteria selected by the CH designer and the requirements of the V-V cognitive style. However, it is a "black-box" functionality for the designers as they may not be aware of the suggested cognitive style. For example, a designer may wonder what the difference is between visualizers and verbalizers, field-dependents and field-independents (field dependence-independence theory), adaptors and innovators (adaption-innovation theory), etc. Moreover, the designers may be confused about which cognition factor they should select in the case where more than one of them are suggested by the system, which is a possible outcome when the selection criteria can be supported partially by various cognition factors. Therefore, to help CH designers to make better choices when the system suggests multiple cognition factors, *DeCACHe* should provide the designers with a) a brief description of the cognition factor and its varying dimensions, and b) a matching ratio between the selection criteria and the cognition factor criteria.

It is worth mentioning that the CH designer asked how the CH activity would be aware of the cognitive characteristics of the end-user. This can be achieved through implicit elicitation of the cognitive profile via various tools, such as classification techniques based on eye-tracking [24] and interaction data [13]. These tools are provided by the framework [23] and they are not part of the main design cycle of CH activities. Nonetheless, such tools should be integrable and easily adjusted to fit the context of the activity and be transparent to the user. Therefore, such tools can be provided as *services* (e.g., web-services) that can be utilized within the CH activity with little development/programming effort. Finally, the CH designer expressed his interest to fully develop the personalized versions of *MuseumScrabble* and deliver them to the visitors of a CH site, and hence, assess the impact of the cognition-centered personalization in real-visit settings by measuring the visitors' satisfaction and experience.

5 CONCLUSION AND FUTURE STEPS

In this paper, we presented *DeCACHe* which is a tool that complements our personalization framework [23] and supports designers in creating personalized CH activities that leverage the visitors' cognitive characteristics. Along with the design of the tool, we reported a small-scale case-study in which a professional CH designer used the tool to adjust the visualizations of his mobile location-based game to create two new versions and support visitors according to their ability to process and represent information either verbally or visually.

Our immediate future steps consist of a) refining the tool based on the comments of CH designer, b) further evaluating the tool by engaging more CH designers to create cognition-centered personalized CH activities of varying characteristics, c) integrating the tool in the personalization framework, and d) assessing the effect of cognition-centered personalization by performing a large-scale user-study in real-visit scenarios where the visitors of a CH site will use a cognition-centered personalized version of *MuseumScrabble*, which will be developed by the professional CH designer.

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