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Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum

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A B S T R A C T

A mobile guide system that integrates art appreciation instruction with augmented reality (AR) was designed as an auxiliary tool for painting appreciation, and the learning performance of three groups of visiting participants was explored: AR-guided, audio-guided, and nonguided (i.e., without carrying auxiliary devices). The participants were 135 college students, and a quasi-experimental research design was employed. Several learning performance factors of the museum visitors aided with different guided modes were evaluated, including their learning effectiveness, flow experience, the amount of time spent focusing on the paintings, behavioral patterns, and attitude of using the guide systems. The results showed that compared to the audio- and nonguided participants, the AR guide effectively enhanced visitors' learning effectiveness, promoted their flow experience, and extended the amount of time the visitors spent focusing on the paintings. In addition, the visitors' behavioral patterns were dependent upon the guided mode that they used; the visitors who were the most engaged in the gallery experience were those who were using the AR guide. Most of the visitors using the mobile AR-guide system elicited positive responses and acceptance attitudes.

1. Introduction

Augmented reality (AR) technology has been gradually applied to various fields since 1990; it can be used as a method presenting additional information using physical operation as a medium, so that users can visually see the integration of the real world and virtual images. The applications of AR currently include language studies (Liu, 2009), social sciences (Hedley, Billinghurst, Postner, May, & Kato, 2002; Mathews, 2010; McCall, Wetzel, Löschner, & Braun, 2011), mathematical sciences (Wang, 2007; Yim & Seong, 2010), natural sciences (Klopfer & Squire, 2008; Liu, Tan, & Chu, 2009), biomedicine (Strickland, Fairhurst, Lauder, Hewett, & Maddern, 2011; Vilkoniene, 2009), arts and humanities (Portalés, Lerma, & Pérez, 2009; Shen, Ong, & Nee, 2010), leisure and recreation (Portales, Viñals, & Alonso-Monasterio, 2010), and advertising and marketing (Moltenbrey, 2011). Many studies have found that AR offers visitors interesting, fun, and challenging experiences, as well as immersive sensations. With respect to its educational applications, it has been reported that both

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teachers and students feel that AR not only promotes participation and motivation, but also creates a realistic and novel learning environment via the combination of the real and the virtual (Damala, Cubaud, Bationo, Houlier, & Marchal, 2008; Dunleavy, Dede, & Mitchell, 2008; Klopfer & Squire, 2008; Mulloni, Wagner, & Schmalstieg, 2008).

However, many studies have also found that while AR with the characteristic of virtual and real coexistence appealed to users viewing the additional information within a specific field of vision, it may cause them to pay too much attention to the content (i.e., the virtual information) of the guide system and ignore the surrounding physical environment (Billinghurst, Belcher, Gupta, & Kiyokawa, 2003; Dunleavy et al., 2008; Wang & Chen, 2009); some visitors even reported that the sense of presence that was shaped by the context of the AR had disappeared and only been transitory while leaving or moving between visit locations (McCall et al., 2011).

Sung, Chang, Hou, and Chen (2010) pointed out that the planning and application of an ideal mobile guide should contain the overall learning context in the guiding environment, such as the visitors, their companions, the exhibits and their cultural and social implications. The design of the mobile guide should fully support the interaction between the visitors and these aforementioned aspects, thus forming a "human–computer–context" interaction (HCCI). In light of this, the limitation underlying the planning for mobile AR-guide activities lies in the inability to balance a visitor's attention distribution between the virtual space and the physical scenes, causing them to focus their attention on the "human–computer (guide system)" excessively, and to ignore the importance of the "human–field/situation (exhibition and local context)" in the real environment. In other words, it cannot induce the desired HCCI.

The design of a mobile AR-guide for exhibitions should therefore emphasize the coupling between the virtual space and the physical scenes (Klopfer & Squire, 2008); that is, enhance the interaction between the additional, virtual information and the real exhibits. First of all, visitors should understand the profound meaning embedded in the exhibits through observation, interpretation, and evaluation of the material objects (i.e., artwork) during guided tours. In addition, the object of appreciation should also be stressed upon presenting the original appearance of works to fulfill the demands of the public with respect to sharing and discussing the artwork, which is called "art appreciation" (Feldman, 1972, 1973; Hamblen, 1984). For example, Feldman (1972) mentioned four steps in art appreciation, that is, a brief description of the artwork, analysis of its techniques, interpretation of its meaning, and value judgments. These four steps helped guide visitors in a series of painting learning processes. It is important during the course of art appreciation to focus on each exhibit itself, facilitating visitors to take the initiative to explore the significant values of the exhibits and stimulating connections between the visitors and the exhibits. This will hopefully serve to complement the aforementioned limitations of the current AR state (Damala, Marchal, & Houlier, 2007; Dunleavy et al., 2008) and promote the "human–field/situation (exhibits)" interaction. Diverse methods of art appreciation instruction have been developed. Whether through the utilization of digital archives (Jamil, Sembok, & Abu Bakar, 2011; Lin, Cheng, & Sun, 2007; Mei, 2004) or online interactive platforms (Arends & Goldfarb, 2010; Arends, Goldfarb, Merkl, & Weingartner, 2009; Pitt, Updike, & Guthrie, 2003), integrating information technology into teaching has become mainstream; however, there has been very little research on mobile AR-guide applications.

According to Sparacino (2002), although commentary posters and text instructions occupied a lot of space at general exhibitions, most people do not spend sufficient time to read or digest the informative content. Furthermore, interactive multimedia, audio commentary playback, and other devices can be attractive, but they are not always located next to the exhibits, and can create a barrier to those exhibits, denying visitors close observation, instant comparison, and confirmation of artwork, and may even deprive their visiting time at a museum. Improvements to these restrictions have been made through studies dedicated to the applications of digital guides—such as audio or audiovisual guides, interactive multimedia kiosks, and mobile devices with radio frequency identification or the quick response code (QR Code) system on exhibition tours. However, it has also been pointed out that the use of generic digital guides (Cosley et al., 2009; Hsi, 2003; Liu, Liu, Wang, & Wang, 2009; Liu, Tan, et al., 2009; Reynolds, Walker, & Speight, 2010; Sung, Chang, et al., 2010) may cause visitors to place too much emphasis on the information in the guide device, consequently resulting in them interacting only superficially with the exhibits and reducing their focus on them. This type of visiting behavior reduces the value of the original appeal of the actual objects of appreciation, which runs counter to the pursuit of the ideal of art appreciation.

Combining the function of the mobile AR-guide with art appreciation instruction is expected to help in solving the aforementioned problems (Barber et al., 2001; Damala et al., 2007, 2008; Portalés et al., 2009). AR not only retains the advantages of the digital guide, but also allows visitors to see the supplementary explication above a painting through a camera lens, bringing the guide information and the artwork together within the user's range of vision. This method enables visitors to interpret the description provided by the AR guide by observing and comparing it with the original painting, while simultaneously reading the formal analysis and interpretation based on art appreciation instruction. They are able to think about and reflect on the exhibit observed, thus fully appreciating the form, content, and creative ideas surrounding the artwork, as well as drawing out reasonable criticism and judgment during the guide system's instructions and art appreciation. This kind of human–computer interactive process not only makes it possible to simplify the explanation of details on the painting, but also maintains the continuity of the overall viewing experience (Barber et al., 2001; Pitt et al., 2003), which promotes an in-depth understanding and reflection of the artwork.

Webster, Trevino, and Ryan (1993) believed that an interesting and exploratory human–computer experience would promote a subjective psychological state of control, attention focus, curiosity, and intrinsic interest in users (defined as "flow"), which represents the smooth, enjoyable experience accompanied by a loss of self-consciousness and self-reinforcing conditions of the human–computer interactivity (Novak, Hoffman, & Yung, 1999). The AR guide service promotes visitors' concentration and visual focus on the exhibit, and deepens the level of art appreciation and esthetic comprehension by allowing them to become more closely connected to the display entities. This helps the achievement of a certain level of flow and the coupling of the HCCI within their interaction.

Based on the current applications of AR and art appreciation, the study developed a mobile AR-guide system and applied it practically to painting appreciation activities in an art museum, by implementing art appreciation instructions. The properties of both AR technology and art appreciation theory were thus integrated to produce flow states that would allow visitors to concentrate on observing and understanding the value and meaning of the artwork within a combined real–virtual environment, and promote the learning performance with respect to painting appreciation. Besides the evaluation of learning effectiveness, the researchers also need to observe visitors' behaviors of staring, examining, and interacting with the painting in the process of painting appreciation to ensure they are attracted by the exhibits. Through the observation and video analysis of learners' visiting behaviors of using AR guide devices, the researchers can understand the time the visitors spent focusing on the paintings and their visiting behavioral patterns, which help realize if the AR system can effectively promote the interaction between the visitors and the exhibits. Meanwhile, how easy the AR system can be used and how this system can assist in painting appreciation perceived by visitors may also affect their motivation and acceptance of painting appreciation via the AR-guide system (Davis, 1989; Kwahk & Ahn, 2010; Ward & Parr, 2010; Yaratan & Kural, 2010). Therefore, the evaluation of the AR-guide system should contain multi-dimensions of the users' flow states, attitudes toward the use, their focusing time, and their behavioral patterns. The aim of the study was to delve more deeply into the learning process of the mobile AR-guide, specifically with reference to art appreciation, as well as to further explore its effect on visitors' flow and the amount of time spent focusing on paintings relative to when using other modes of guidance for painting appreciation. In addition, the visiting behavioral patterns of the HCCI were analyzed, together with their features and the limitations of the sequential correlations (i.e., the initial or subsequent behaviors during the process of painting appreciation, including viewing the painting, operating the guide device, and discussing with peers). Finally, comments regarding the use of the mobile AR-guide system are discussed for future research. The specific objectives of the study were as follows:

(1) Design a mobile AR-guide system based on art appreciation instructions.
(2) Compare the learning effectiveness of AR-guided, audio-guided, and nonguided (i.e., without carrying auxiliary devices) modes of art appreciation instruction during a visit to an art museum.
(3) Explore the flow states achieved using the three modes of painting appreciation.
(4) Compare the applications of the three modes and their effect on the amount of time spent focusing on the paintings.
(5) Compare the differences in visitors' behavioral patterns with the three modes of guidance.
(6) Understand the attitude of the visitors toward the acceptance and use of the mobile AR-guide system.

2. System design

A mobile AR-guide system was developed according to the mobile guide design principle of the HCCI framework (Sung, Chang, et al., 2010) and the four-step instruction process of description, analysis, interpretation, and judgment in art appreciation, and this system was used to provide assistance to visitors in painting appreciation (Clark & Zimmerman, 1978; Feldman, 1972; Mittler, 1980).

The system adopted an image recognition technology based on the mobile AR-guide method designed by Zhang, Hou, and Chang (2012), using a 10-inch tablet PC (with the Android 3.2 operating system) as the mobile device. This differs from the QR Code identification method, since it employs a lens on the device to recognize the true appearance of a painting in a more direct and instinctive way, rather than a sensing system using an extra square matrix barcode that has no meaning about the artwork. The absence of a tag as a medium allows the visitors to focus more closely on viewing the painting. This not only saves the space normally occupied by the explanations of the paintings in an exhibition room, but also enhances the coupling and interactivity between the visitors, the exhibiting artwork, and the guide device to promote the intuitiveness of the guide with respect to art appreciation. Overall, there were two system functions:

(1) The painting guide: Visitors stand in front of the artwork and position the camera lens of a mobile device so that it can recognize the whole picture (Fig. 1). They can then view or listen to the corresponding commentary about the painting that would guide them in observing the original artwork and carry out the "description" step of the art appreciation instruction, such as the introduction, the background, and the impressions of the painting (Barber et al., 2001; Damala et al., 2008; Sparacino, 2002).
(2) The painting observation: This function advises visitors how to recognize localized scopes of the picture via the operating functions of zooming in and out on small areas of the picture on the device interface, which provides localized descriptions of the artwork for a more detailed explanation (Fukaya, Mitsumine, & Inoue, 2001; Pitt et al., 2003). It also assists visitors in analyzing the form of the artwork and obtaining the meaning of the image, and finally exploiting the first three steps of the art appreciation instruction toward gaining knowledge about the painting that will allow them to make value judgments: "analysis," "interpretation," and "judgment."

Fig. 2 shows how the image on the screen is divided into parts A and B, where part A is the guiding description that is appended above the image comprising part B (the authentic painting presented through the lens). This design can help visitors to cross-reference the descriptions of part A with the localized scales of the painting by viewing it carefully (the system shows different explanatory content about

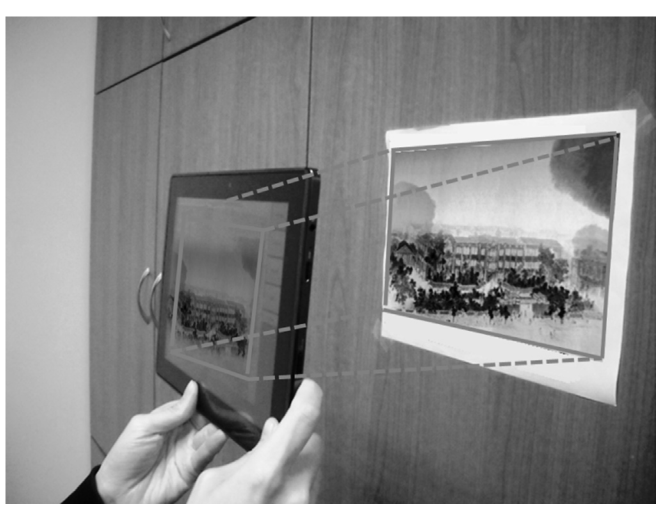

Fig. 1. Painting identification.

Fig. 2. Localized descriptions.

the artwork according to the identification of the whole or part of the picture; Fig. 2 shows a localized description). The guiding materials were combined with the four-step methodology of art appreciation as follows, we used a Taiwanese painter Chen Cheng-Po's artwork "Soochow" as an example to illustrate how this system guided learners in painting appreciation:

(1) The "description" step mainly used a simple statement to guide visitors to locate the subject matter of objective existences in the paintings. For example, when the users used the AR system to view "Soochow", the system would immediately present additional information that explained the basic elements and subject matter of the painting by indicating that it drew "a multicolored silk hanged down from the top, covering the bridge in the middle of the picture… (TFAM, 2012)". This information promoted learners' basic observation and understanding of the painting.
(2) The "analysis" assisted visitors to observe the artwork's lines, shapes, colors, space, balance, proportion, rhythm, and other design elements and principles (Feldman, 1972). For example, in the painting observation, as soon as the localized scopes of the painting were accurately identified, the system would immediately present addition information and provided the functions of zooming in and out for observations of the tiny techniques in painting, guiding learners to analyze "Soochow." The learners read the feedback, "…the silk in the painting divides the picture into two sides. The river in the right side disappears towards the right, and the road and the steps beside the river disappear towards the left, which shape two bilateral traffic flow" via the tablet PC; meanwhile, they analyzed the painting by comparing this information with the on-site painting.
(3) The "interpretation" step involved use of the above knowledge to further explore the significance and creative ideas of the painting. For example, as soon as the localized areas of the painting were identified, the system would immediately present additional information with the functions of zooming in and out for painting observation, guiding the learners to interpretate "Soochow." With additional information, the system guided learners to focus on the left bottom of the painting, in which the painter used characters strolling side by side intimately to add the atmosphere of warmness and happiness and to make the peculiar narrative style more obvious.
(4) The "judgment" step prompted the visitors' art criticism experience accumulated from the previous three steps to assess the value of the artwork through reference materials for exploration and comparison with other similar paintings provided during the guided tour. For example, when the users viewed "Soochow," the system immediately provided additional information and other pictures of related artworks for learners to compare and make value judgments after the localized areas of the painting were identified; for instance, the special composition of the artwork "Soochow" is like "Paris Street; Rainy Day" by an impressionistic painter Gustave Caillebotte in 1877 (At this time, the AR system would guide learners to use relevant functions to make a comparison between the on-site painting "Soochow" and "Paris Street; Rainy Day" with its additional information and appearance in the AR system).

3. Methodology

3.1. Participants

In total, 135 college students who attended related art appreciation courses at 2 universities in Taipei City, Taiwan, were divided into 2 experimental groups of 46 and 44 participants and a control group of 45 participants. Each group was provided with a different mode of guidance when visiting the "Journey through Jiangnan: a Pivotal Moment in Chen Cheng-po's Artistic Quest" exhibition at the Taipei Fine Arts Museum in 2012. The expression technique of the painter, Chen Cheng-po, fuses Chinese and Western painting styles, and his work includes paintings of figures, nudes, scenery, and other related documents. The exhibition explored the artistic profile of Chen Cheng-po and the course of the important changes in his style and characteristics (TFAM, 2012).

3.2. Research design

The study used a quasi-experimental design. The independent variables were the three modes of guidance: nonguided, audio-guided, and AR-guided. The dependent variables were learning effectiveness, flow experience, the amount of time spent focusing on paintings, visiting behavioral patterns, and visitors' attitude regarding the use and acceptance of guidance systems. The control group viewed the paintings directly without carrying any auxiliary devices in the nonguided mode, while experimental group A employed the AR guide system and experimental group B used the digital audio guide system that is currently the most commonly used in exhibitions, which was borrowed from Taipei Fine Arts Museum. These were applied to assist visitors with their art appreciation experience at the exhibition.

3.3. Research tools

3.3.1. Pretests and posttests for painting appreciation

The aim of the pen-and-paper pretests and posttests for painting appreciation was to determine whether there was an improvement in the visitors' art appreciation skills after using the different guide systems, and hence to ascertain their effectivenesses. All of the test topics were relevant to the artwork on display and validated by two art education experts. The pre- and posttests had identical content, and had been subject to a parallel forms test with 50 college students prior to the formal experiment. The coefficient of the reliability analysis was 0.802, with internal consistency. The contents of the items are as follows:

Q1. Which color was used most in the painting "Street Scene on a Summer Day"? (A picture of the painting was attached to the test.)
(A) Cool shades of blue and white
(B) Warm shades of red, yellow, and orange
(C) Dark shade of jasper
(D) Shades of orange and blue with a strong contrast
Q2. "Self-portrait" in 1930 covered elements of several painting styles, but which one below was not included? (A picture of the painting was attached to the test.)
(A) Munch's painting style (A picture of the painting was attached to the test.)
(B) Matisse's painting style (A picture of the painting was attached to the test.)
(C) van Gogh's painting style (A picture of the painting was attached to the test.)
(D) Gauguin's painting style (A picture of the painting was attached to the test.)

3.3.2. The flow experience scale

The flow experience scale was divided into three sections, namely antecedents of flow, structural properties of flow, and the experience of flow, according to the proposal of Chang, Wu, Weng, and Sung (2012). This scale was used to explore the differences in the visitors' intensity of flow experience, or to determine whether there was a flow experience at all in this process of art appreciation. The aim of the first section, antecedents of flow, was to determine whether a visitor, with his or her own conditions and the environmental characteristics, was able to enter a flow experience. The section on structural properties of flow was designed to discover whether a visitor had the flow of focus attention or pleasure during the event. The third section, the experience of flow, referred to whether a visitor emerged the flow experience as conducting the activity. This scale was piloted with 50 college students, and the obtained reliability coefficients were 0.735, 0.905, and 0.860 for the three sections, respectively.

3.3.3. Pocket video cameras

In order to observe the visitors' interactive behaviors with regard to painting appreciation, each of them wore a camera on his or her head to record the time of each behavior over the course of the visit. Then these data were analyzed to determine the amount of time spent focusing on the paintings and the behavioral patterns of the visitors.

3.3.4. The interview questionnaire

An interview could clarify the impact of their encounters during the activity. The interview questions referenced the questionnaire of the mobile guide application at the museum (Sung, Chang, et al., 2010), the aim of which was to explore the visitors' attitudes toward the use, acceptance, and advantages and disadvantages of the guide systems. The interviewers used neutral phraseology throughout the interviews so as not to interfere with the views and ideas of the interviewees.

3.4. Procedure

The experiment was conducted with the experimental groups (i.e., A and B) and the control group. Related exhibition data had already been built into the database of the system before the activity. All of the participants had to first complete the painting appreciation pretest; the experimental groups had to also undertake operation training and equipment adaptation for the guided modes to ensure that the impact of any technological obstacles was significantly reduced. In the process of the exhibition tour, experimental group A used the mobile AR-guide system, which provided the guidelines of art appreciation instruction to help visitors explore the implications and value of the paintings. Visitors in experimental group B were given the digital audio guide that is currently used in exhibitions to help visitors attain the exhibit information. The control group proceeded without any guidance devices. Each tour lasted 60 min.

The participants were required to appreciate 16 specified paintings. In order to observe the interactive behaviors during the course of the painting appreciation, each visitor wore a pocket video camera to record the time of each behavior for subsequent further analysis, and in particular to determine the amount of time that the visitors spent focusing on the paintings and their behavioral patterns. After the tour, all groups were required to take the painting appreciation posttest and complete the flow experience scale. Ten visitors from each group were randomly sampled for a follow-up interview.

3.5. Data collection and analysis

The collected data were classified into quantitative and qualitative aspects. For the quantitative data, the painting appreciation test results were analyzed with one-way ANCOVA, for which the pretest score was a covariate variable. The flow experience scale was analyzed with one-way ANOVA to explore the learning performance and flow experience using the two different guide systems. With respect to the sample size in this study, some visitors omitted certain items in the test or they didn't join in the whole process of the experiment. Therefore, the number of effective samples in the painting appreciation test results included 42 persons in the non-guided group, 43 persons in the audio-guided group, and 46 persons in the AR-guided group. Also, the effective sample sizes in the flow experience scale were 36, 40, and 43 for the three groups, respectively.

The qualitative data contained the recorded visiting behavior and interviews. With respect to the sample size collected via the videotapes, some visitors didn't follow the instructor' directions to wear the cameras or carelessly touched the buttons on the cameras resulting in the failure of videotaping or loss of signal in the process, so the effective sample sizes in visitors' focusing time were 26, 25, and 23 persons for the three groups. In terms of data analysis, a lag sequential analysis was conducted as behavioral analysis (Bakeman & Gottman, 1997; Hou, 2010, 2012; Sung, Hou, Liu, & Chang, 2010); that is, after encoding the recorded behaviors on a form, a behavioral–frequency transition table was formulated to visualize the behavioral patterns. This approach makes it possible to understand the sequential relationships between each participant's behaviors, which can in turn be used to compare and discuss the characteristics and limitations of the behavioral patterns of the three groups. The applied coding table given in Table 1 was revised from the coding scheme for transcribing the videos by Sung, Chang, et al. (2010), and added to the related AR function operations of the study. All video recordings were analyzed, and every visiting behavior was coded and arranged in chronological order to produce 74 sets of coded data, comprising a total of 4222 behavioral coded items for subsequent sequential analysis. To ensure that visitors were indeed attracted by the paintings, the minimum amount of time spent focusing on a painting for code A1 in Table 1 was set at 5 s, representing the participants' actions of examining, interacting, and watching another visitor interact with the painting (Sandifer, 1997, 2003). Codes B1 (operating the device) and B2 (reading or listening to the guide content) were suitable for the audio-guided and the AR-guided groups, and code B3 (operating the zoom-in/out function) referred to the special behaviors of the AR-guided group.

In addition, in order to improve the reliability of coding, two coders who had previously participated in the experimental activity for the study were asked to randomly select the same video recording and encode it into corresponding behavioral codes, with 5-s interval serving as a time unit. All of that encoded data were subjected to a reliability analysis; the interrater kappa coefficient was 0.825, demonstrating a remarkably high consistency. Moreover, the impact of the different guided modes was explored by compiling and discussing the participants' attitudes toward art appreciation and guide systems through qualitative content analysis of the interview transcripts.

4. Results

4.1. Analysis of visitors' learning effectiveness

The results of ANCOVA analysis of the painting appreciation tests revealed that the different guidance modes exerted significant effects on the visitors' learning effectiveness, with significant differences among the three groups ($F = 19.883$, $p = 0.000 < 0.001$; Table 2). Post-hoc comparisons using the least squares difference (LSD) test indicated that the posttest score did not differ significantly ($p = 0.159 > 0.001$) between the nonguided and audio-guided groups, while it was significantly better for the AR-guided group than for both the nonguided ($p = 0.000 < 0.001$) and audio-guided ($p = 0.000 < 0.001$) groups. The learning performance of the AR-guided group was thus superior to that of the other two groups.

4.2. Analysis of visitors' flow experience

The flow experience was subjected to ANOVA analysis. The results revealed significant differences in the three sections between the groups ($F = 6.776$, $p = 0.002 < 0.05$; $F = 8.485$, $p = 0.000 < 0.05$; $F = 4.499$, $p = 0.013 < 0.05$; Table 3). Multiple-comparisons analysis (LSD) revealed that the antecedents of flow did not differ significantly between the nonguided and audio-guided groups ($p = 0.297 > 0.05$), but was significantly higher for the AR-guided group than for both the nonguided ($p = 0.001 < 0.01$) and audio-guided ($p = 0.012 < 0.05$) groups.

Table 1
Coding table for visiting behaviors.

Code	Visiting behaviors		
A1	Look, observe, and focus on a painting (for more than 5 s)		*Human–situation (exhibits) interaction*
A2	Browse through the paintings (for less than 5 s)		
B1	Operate the device (painting identification for the AR guide; pressing buttons for the audio guide)		*Human–computer (device) interaction*
B2	Read/listen to the guide content (audio/visual commentary)		
B3	Operate the zoom-in/out function on a tablet PC		
C1	Discuss with peers (discussions on paintings or pretest, excluding chatting)		*Human–human interaction*
C2	Seek help from service staff		
D1	Walking/moving		
D2	Other behaviors		
	D21	View other exhibitions (for a nonisolated exhibition venue)	
	D22	View on-site introductions to the exhibition	

Table 2
ANCOVA analysis of the painting appreciation tests.

Variable	Mean score						F
	Nonguided group ($n = 42$)		Audio-guided group ($n = 43$)		AR-guided group ($n = 46$)		
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	
Learning effectiveness	59.0476	58.0952	59.8450	62.0155	57.6812	71.0145	19.883*

*$p < 0.001$.

However, the structural properties of flow did not differ significantly between the audio- and AR-guided groups ($p = 0.057 > 0.05$), but were significantly higher for the audio-guided and AR-guided groups than for the nonguided group ($p = 0.029 < 0.05$ and $p = 0.000$, respectively). Finally, analysis of the experience of flow revealed that only the AR-guided group was significantly superior to the nonguided group ($p = 0.003 < 0.01$; Table 4).

4.3. Analysis of visitors' focusing time

In line with how Sandifer (1997, 2003) defined the amount of time focused on an exhibit, the total time during which the visitors' attention was focused on the paintings (in minutes) included the time spent on viewing and interacting with the painting, as well as that spent reading and listening to the information on the guide device. ANOVA revealed that this parameter differed significantly between the three groups ($F = 149.022$, $p = 0.000$; Table 5). Post-hoc comparisons showed that the time spent focusing on paintings was significantly longer for both the AR-guided (mean = 17.3278 min) and audio-guided (mean = 16.114 min) groups than for the nonguided group (mean = 4.76 min). The focusing time did not differ significantly between the AR-guided and audio-guided groups.

4.4. Analysis of visitors' behavioral patterns

Lag sequential analysis of the visitors' behavioral patterns was conducted to explore the visitors' HCCI during their visits to the art museum (Bakeman & Gottman, 1997; Hou, 2010, 2012; Sung, Hou, et al., 2010). First, the encoded data for each group were tested by computing Z-score statistics to produce adjusted residuals tables for the visitors' behaviors (Tables 6–8). These tables show that when the Z-scores were greater than 1.96, their sequential relationships achieved significance ($p < 0.05$); these values were arranged to form the sequential patterns of behaviors shown in Figs. 3–5, wherein the arrows indicate the directions of the statistically significant behavioral sequences. The sequential analysis revealed 11, 13, and 14 behavioral sequences for the nonguided, audio-guided, and AR-guided groups, respectively.

Fig. 3 shows that the behavioral sequences D1 ↔ A1, D1 ↔ A2, D1 ↔ D21, D1 ↔ D22, A1 → C1, and C1 ↔ A2 from the nonguided group achieved significance, the most obvious patterns being D1 (walking, moving) ↔ A1 (focusing on a painting) and D1 ↔ A2 (browsing through the paintings). The bidirectional status of these sequences indicate that the visitors often focused on (A1) or browsed through (A2) a painting or a theme, then walked away (D1) to either leave or to continue viewing the other paintings. The absence of any auxiliary guide device thus produced a simple circular visiting pattern. In addition, the sequences A1 → C1 (discussing with peers) and C1 ↔ A2 indicate that the visitors also had interactive discussions about the paintings with their peers.

Fig. 4 shows that the significant behavioral sequences in the audio-guided group were B1 → B2, B2 → D1, D1 → A2, D1 ↔ A1, A2 → B1, D1 ↔ D21, A2 ↔ C1, D1 → B1, D22 → D1, and B2 → C1. The sequences B1 (operating on the device) → B2 (listening to the guide content), B2 → D1 (walking, moving), and A2 (browsing through paintings) → B1 clearly indicate that the visitors first browsed the painting (A2), then operated the device by pressing the numbered buttons (B1) after looking at the code assigned to the corresponding exhibit, and finally began to listen to the recorded spoken commentary (B2). They walked or moved (D1) aside in order to allow other visitors to also view the same painting in front of them, but continued appreciating the painting while doing this. In addition, sequences A2 ↔ C1 and B2 → C1 illustrate that while visitors were viewing the painting and listening to the audio commentary, they also discussed related subjects (C1) with their peers.

Fig. 5 shows that the behavioral sequences B1 → B2, A1 → B1, D1 → A1, B2 → D1, D1 → A2, A2 → B1, B3 ↔ B2, D21 → A1, D22 → D1, D1 → D21, C2 → A1, C1 → C2, and D1 → C2 from the AR-guided group achieved significance. The sequences B1 → B2 (listening to/reading the guide content), B2 → D1, and A2 → B1 did not differ significantly from the behaviors of the audio-guided group. With the assistance of the guide device, the AR-guided visitors focused on (A1) or browsed the painting (A2), then operated the device to implement painting identification (B1) and access descriptions and commentary regarding the corresponding painting (B2), and finally moved (D1) aside but continued to appreciate the painting. Visitors in the AR-guided group demonstrated a special behavioral sequence, B3 ↔ B2, that was not exhibited by those using other guide devices or no device. That sequence shows that while visitors who drag and drop items on the touch screen with their fingers are operating the zoom-in/out function (B3) to aid the process of listening to/reading the commentary (a

Table 3
ANOVA of the flow experience scale.

Variable	Mean score			F
	Nonguided group ($n = 36$)	Audio-guided group ($n = 40$)	AR-guided group ($n = 43$)	
Antecedents of flow	22.83	23.63	25.47	6.776**
Structural properties of flow	22.28	24.33	26.02	8.485***
Experience of flow	19.94	21.85	23.05	4.499*

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 4
Post-hoc comparisons of flow experience.

Dependent variable	(I) Group	(J) Group	Average difference (I–J)	Standard error	p
Antecedents of flow	Nonguided group	Audio-guided group	−0.792	0.756	0.297
		AR-guided group	−2.632**	0.743	0.001
	Audio-guided group	Nonguided group	0.792	0.756	0.297
		AR-guided group	−1.840*	0.723	0.012
	AR-guided group	Nonguided group	2.632**	0.743	0.001
		Audio-guided group	1.840*	0.723	0.012
Structural properties of flow	Nonguided group	Audio-guided group	−2.047*	0.925	0.029
		AR-guided group	−3.745***	0.909	0.000
	Audio-guided group	Nonguided group	2.047*	0.925	0.029
		AR-guided group	−1.698	0.884	0.057
	AR-guided group	Nonguided group	3.745***	0.909	0.000
		Audio-guided group	1.698	0.884	0.057
Experience of flow	Nonguided group	Audio-guided group	−1.906	1.055	0.074
		AR-guided group	−3.102**	1.038	0.003
	Audio-guided group	Nonguided group	1.906	1.055	0.074
		AR-guided group	−1.197	1.009	0.238
	AR-guided group	Nonguided group	3.102**	1.038	0.003
		Audio-guided group	1.197	1.009	0.238

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

combination of texts, images, and audio), they are benefitting from guidance provided by the device. They appear to be benefitting in particular from the localized observations and graphic-text descriptions, which accentuate material and organization of the artwork, hence assisting in the visitors' process of painting appreciation by exploring the formal analysis and interpretation of the works. Furthermore, the independent behavior of C1 in this group differs from the other two groups with respect to discussions with peers, such that the C1 → C2 sequence indicates that visitors in the AR-guided group only had problems seeking assistance (C2), but did not readily discuss the paintings with others. This represents one of the potential limitations of the AR guide in the study.

In general, the audio-guided and AR-guided groups shared similar behavioral patterns during the visiting process, as evidenced by the B1 → B2 behavior under the influence of the guide devices, whereas the behavioral patterns of those in the nonguided group, who carried no auxiliary guide devices, were relatively simple. Although every visitor still exhibited some degree of behaviors involving departing from viewing the paintings, the AR-guided group exhibited the most behavioral sequences demonstrating that they ultimately returned to focus on the painting (D1 → A1, D21 → A1, and C2 → A1). Thus, visitors using the AR guide system appeared to more easily revert to appreciating the painting following attention-diverting behaviors, which facilitated in-depth interactions between them and the exhibits in the study. The results also showed that all three groups shared the behavior of D1 ↔ D21 (viewing other exhibitions), indicating that all visitors may occasionally be influenced by external factors, resulting in behaviors unrelated to the art appreciation activity.

4.5. Analysis of the interviews

Regarding the attitude toward the use of different guide systems, most visitors in the audio-guided and AR-guided groups believed that the guide devices promoted a greater motivation to learn and a greater knowledge of the artwork during the art appreciation activity. By contrast, the nonguided group expressed a desire for guides or commentaries to help them to understand and appreciate the paintings, and indicated that art appreciation on their own was not very effective:

S001: "I have visited some exhibitions in the past, and whenever I had questions about a certain exhibit and there were no guides or docents around to explain, I would feel like giving up trying to understand the artwork. So, their presence would definitely provide some descriptions about the paintings, and I would then be more willing to want to understand it."

S002: "I think it's a pity that there was no guide in our group; we didn't learn anything, and the researchers also didn't gain anything useful. What a waste of time…"

In the acceptance of different guide systems, the nonguided group reported that they would be willing to use the audio guide and the AR guide systems in the future. Visitors in the audio-guided group noted that they would apply the AR-guided system or continue to select the audio guide; some even reported that they did not need to favor a single system, with the most appropriate depending upon the situations of the exhibition at the time. Finally, most visitors in the AR-guided group expressed the opinion that they would continue to use the AR guide system:

Table 5
Post-hoc comparisons of the focusing time.

Dependent variable	(I) Group	(J) Group	Average difference (I–J)	Standard error	p
Focusing time	Nonguided group ($n = 26$)	Audio-guided group	−11.35400***	0.79820	0.000
		AR-guided group	−12.56783***	0.81570	0.000
	Audio-guided group ($n = 25$)	Nonguided group	11.35400***	0.79820	0.000
		AR-guided group	−1.21383	0.82333	0.145
	AR-guided group ($n = 23$)	Nonguided group	12.56783***	0.81570	0.000
		Audio-guided group	1.21383	0.82333	0.145

***$p < 0.001$.

Table 6
Adjusted residuals table of the nonguided group.

Z	A1	A2	C1	D1	D21	D22
A1	−8.83	−8.68	4.49*	13.92*	−2.92	−3.12
A2	−7.67	−8.33	2.82*	12.87*	−2.99	−0.69
C1	−3.36	4.49*	−3.33	1.88	−1.64	−1.75
D1	17.5*	13.05*	−3.28	−27	6.47*	4.77*
D21	−2.84	−2.92	−1.64	6.22*	−0.81	−0.86
D22	−2.29	−0.75	−1.81	4.09*	−0.89	−0.95

*$p < 0.05$.

S003: "I preferred to read the content of the device when I was using the AR guide system. Previous guide devices usually only provided audio commentary, whereas this guide offers texts and images! The descriptions are visually more detailed, so I can remember them better…"

S004: "The AR guide seems to offer more autonomy than the regular docent-guided tours, so I can decide for myself how long I stay to view a painting."

S005: "It all depends on the crowd! If there are fewer visitors I would apply the docent service; otherwise, I would choose the audio guide or a mobile device."

Analysis of the interviews revealed that most participants credited the mobile AR-guide system with six advantages: high autonomy, frequent HCCIs, good visual effects, detailed observations toward specific parts of a picture, convenient content management, and long-term benefits. They also mentioned six ways in which the system design could be improved: identification sensitivity, adequate interface design, variety of content, high cost of hardware, volume and speed of audio recording, and number and length of commentaries. These comments and advice were offered by visitors on the painting appreciation activity for both present and future considerations. It was further mentioned that the activity arrangements could also be improved; they felt that the allocated visiting time was insufficient, there were too many visitors at one time, and the guide device was cumbersome to carry:

S006: "There is more freedom with the AR guide, which promotes a greater interaction between visitors and paintings. So when remembering information about the artwork, the AR guide makes it livelier and less boring."

S007: "The AR guide is more interesting because it is a combination of sounds and images."

S008: "The AR guide has the zoom-in/out function that allows me to see the texts and paintings more clearly, especially for observing parts of a painting."

S009: "The identification sensitivity of the AR guide for parts of a painting is poor, while it is too great to recognize some pictures, such as 'Shanghai Wharf'."

S010: "I think it should have more interactive content; for example, if interactive commentaries or explanations were added, it wouldn't have been playing subtitles. Sometimes, the large number of words on the guide device did not let us digest or understand the key points at once, even though we have listened to or read the commentary."

S011: "Because of too many participants and insufficient time for this activity, I wasn't able to carefully view the paintings. We should view the exhibits in batches, which will hopefully give plenty of time to appreciate them."

5. Discussion

All of the experimental results were discussed on the basis of the underlying research purposes, and the visitors' learning effectivenesses, flow experiences, focusing times, behavioral patterns, and attitudes toward the use and acceptance of the guide systems during their painting appreciation process were examined. Comparison of the three different guided modes revealed differences in learning performance that were confirmed by the empirical study. The AR-guided group had better learning effectiveness (as evidenced by their posttest scores), and it was found that most visitors believed the AR guide made it easier to digest information than the audio guide due to the extra visual commentary that is provided. This mode not only offers an audio commentary, but also displays visual information dominated by text and images. It facilitates the development of art appreciation by imprinting the knowledge of paintings on visitors' memories, supporting the coupling between the visitors, the guide system, and the artwork (Klopfer & Squire, 2008) by using AR technology, and helping visitors

Table 7
Adjusted residuals table of the audio-guided group.

Z	A1	A2	B1	B2	C1	D1	D21	D22
A1	−3.97	−3.53	1.04	−4.58	−1.59	8.93*	−1.26	1.65
A2	−4	−3.46	10.99*	−6.4	4.52*	0.69	−1.52	−1.46
B1	−4.17	−6.71	−7.2	28.74*	−2.81	−8.8	−1.65	−1.58
B2	−1.88	−4.47	−6.1	−7.75	2.34*	15.88*	−1.72	−0.12
C1	1.46	3.17*	−1.39	0.17	−1.07	−1.77	−0.63	−0.6
D1	11.17*	13.78*	3.1*	−8.61	−1.88	−14.23	5.43*	1.86
D21	−1.17	−1.51	−1.62	−1.71	1.02	4.51*	−0.37	−0.36
D22	−1.12	1.05	−1.55	−1.64	−0.6	2.96*	−0.36	−0.34

*$p < 0.05$.

Table 8
Adjusted residuals table of the AR-guided group.

Z	A1	A2	B1	B2	B3	C1	C2	D1	D21	D22
A1	−9.06	−3.83	17.26*	−7.75	−0.39	−0.16	−2.36	1.89	−0.96	1.23
A2	−3.26	0.29	7.82*	−4.9	−1.71	1.55	1.02	−0.37	−0.56	−0.62
B1	−8.35	−5.85	−11.3	25.77*	−1.63	−0.17	0.39	−1.63	−1.05	−1.18
B2	1.45	−3.2	−4.26	−10.43	5.17*	−0.8	−1.47	13.45*	−1.01	−1.13
B3	−1.6	−1.64	−3.21	6.41*	−0.91	−1.23	−0.73	0.58	−0.3	−0.33
C1	−0.05	0.27	1.11	−2.66	1.35	−1.68	2.21*	1.1	−0.4	−0.45
C2	2.48*	−1.32	0.43	−2.49	−0.73	0.08	−0.58	0.88	−0.24	−0.27
D1	16.41*	12.85*	−4.78	−5.04	−1.93	1.38	2*	−13.81	3.54*	1.87
D21	4.25*	−0.53	−1.05	−1.01	−0.3	−0.4	−0.24	−1.17	−0.1	−0.11
D22	−1.05	−0.6	−1.17	−1.13	−0.33	−0.45	−0.27	3.82*	−0.11	−0.12

*$p < 0.05$.

keep their memories of the artwork vivid. This also shows the necessity of the HCCI (Sung, Chang, et al., 2010). In contrast, after viewing the painting, visitors in the nonguided group were still confused about what the painter wanted to express, and they even said: "If there was no description about the artwork, I would probably walk directly past it."

Analysis of the flow experience revealed that the visitors in the AR-guided group were clearly more ready to enter the state of flow with respect to the antecedents of flow, and were more proactive in appreciating the artwork than were those in the other two groups. During the activity, those in the audio-guided and AR-guided groups expressed the flow states obviously. Visitors in the audio-guided group were required to input the number code of the artwork onto the device and start to listen to the commentary while viewing the work, with these behaviors depended on the length of the audio play (the audio commentary of each painting lasted about 2 min). However, in addition to the audio commentary, the AR guide also implemented visual effects using the lens to provide a screen display to guide visitors in careful observation, exploration, and description of the artwork. This process aided the formal analysis and meaning interpretation of the painting, such that visitors could construct subjective and objective esthetic reactions and comprehension regarding the artwork, and in turn extend their acquired skills, knowledge, and their own judgment or external criticism in assessing the value of each piece of art (Clark & Zimmerman, 1978; Mittler, 1980). Therefore, the AR guide not only prolongs the duration of the time spent visiting the artwork, but also eliminates the limitations of traditional interactive multimedia kiosks and video player equipment—which fail to offer instant comparisons with the authentic exhibits and reduce visitors' viewing time (Sparacino, 2002)—thus achieving and even elevating the flow experience in art appreciation.

Dunleavy et al. (2008) and McCall et al. (2011) found that AR system users placed too much emphasis on the content of the mobile device and consequently ignored the real environment. However, our analysis of the behavioral patterns revealed that during the activity of painting appreciation with the AR system, the visitors did not focus on the device excessively, did not largely ignore the paintings, and were not particularly attracted by the technology because of its novelty and thereby took no notice of the in-depth knowledge about the paintings that it provided. Furthermore, the behavioral patterns of the three groups, from the simple behaviors of viewing painting in the nonguided group, namely D1 (walking) ↔ A1 (focusing on the painting) and D1 ↔ A2 (browsing through the paintings), as well as the behaviors of the audio-guided group regarding viewing and listening to the commentary via the audio guide device (B1 → B2, B2 → D1, D1 → A2, D1 ↔ A1, A2 → B1, and D1 → B1), to finally the behaviors of focusing on and appreciating the painting via the AR guide system (B1 → B2, A1 → B1, D1 → A1, B2 → D1, D1 → A2, A2 → B1, and B3 ↔ B2), indicate that the AR-guided mode deepened the interaction between the viewing of the artwork and its explanation.

Nevertheless, from the perspective of visitor–peer interactions, visitors in the AR-guided group may have paid particular attention to the painting and its commentary, or the device may have offered useful and detailed observations in such a way that the visitors did not readily discuss the artwork with others, resulting in an isolated phenomenon. For example, some visitors (*S012,S013,S014*) indicated in the interviews that "*The AR guide can make us pay more attention, and we can understand the knowledge in the paintings more.*" Even someone (*S015*) felt that "*If we don't* really understand the paintings, the use of AR guide allows us to look up the content and related knowledge of the paintings instead of relying on others' *explanations.*" In contrast, there were evidently more discussions and a certain degree of peer–peer interactions in the nonguided and audio-guided groups (A1 → C1, A2 ↔ C1, and B2 → C1). For example, one visitor (*S016*) in audio-guided group indicated in the interview that "*Sometimes the audio guide is not very clear*…" Also, still one visitor (*S017*) pointed out "*Without any guidance devices, we can discuss with other people directly when we have some questions.*" In addition, all three groups exhibited the D1 ↔ D21 (viewing other exhibitions) behavior sequence; since the design and layout of the room meant that there was no spatial separation between this and other exhibitions, the visitors' behaviors were affected by external factors.

Overall the visitors using the mobile AR-guide system during painting appreciation activities felt that it was an interesting, innovative, creative, and entertaining guide device; some even stated that this guided mode made the experience livelier and more vivid than outdoor

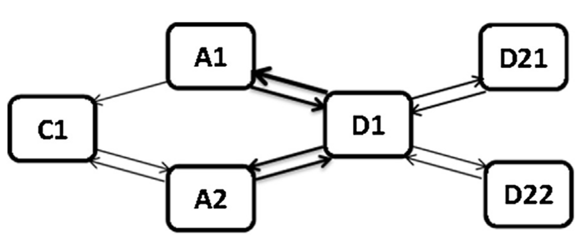

Fig. 3. Behavioral patterns of the nonguided group.

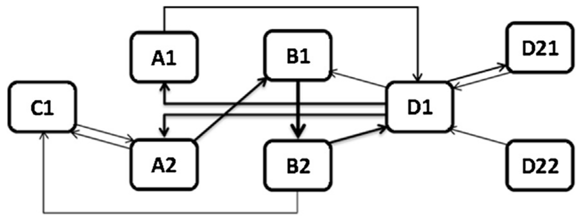

Fig. 4. Behavioral patterns of the audio-guided group.

teaching that they had experienced in the past. This system merges the exhibit and additional information into the same field of view, displays images and texts supplemented by the zoom-in/out function for clarity and detailed observation, and maintains the convenience of continuous viewing. Indeed, as Barber et al. (2001), Fukaya et al. (2001), and Pitt et al. (2003) point out, it encourages users to act on the localized descriptions and explanations through comparison with the original paintings.

However, some participants of the AR-guided group stated that certain aspects of this system need to be improved. For example, a few of the paintings could not be detected by the device, and so the visitor could not access the corresponding commentary. If situations in which the gesture angle of the recognition system was not appropriate or the user was not yet familiar with the device are excluded, this problem is probably attributable to similarities in the paintings' composition, colors, and other characteristics, or the reflection of light affecting the recognition of a painting positioned under a protective glass frame, so that the painting identification capability was variable—sometimes sensitive, sometimes poor. Moreover, the activity arrangements also affected the users' attitudes toward the use and acceptance of guide systems, such as the insufficient visiting time and a large crowd of visitors, which may have led to inefficient procedures; some also mentioned that the 10-inch tablet PC used in this activity was too heavy, bulky, and inconvenient for a mobile guide device, and suggested that a mobile-phone-sized guide device would be more suitable.

Based on the above discussions and the empirical analysis of integration of art appreciation instructional strategy and the mobile AR-guide system, this study demonstrates that the instructional process of art appreciation helped guide and enhance the interactivity between students and real exhibits via the system. With the functions of AR, the effect of the art appreciation instructional strategy can work better, and resolve the problems discovered in the past studies that the AR users excessively focused on human–computer interaction. The zoom-in/out function of the AR system that helps visitors observe the localized details in the artwork and the feedback provided according to the four steps in art appreciation instructional strategy enables the visitors to observe, compare, interpret, and analyze more thoroughly in terms of the depth of art appreciation. Also, the art appreciation instructional strategy makes the visitors have deeper knowledge learning of the paintings via the implementation of the AR system.

6. Conclusions

The aim of the study was to integrate art appreciation (Feldman, 1972; Hamblen, 1984; Mittler, 1980;) with AR (Billinghurst et al., 2003; Dunleavy et al., 2008; McCall et al., 2011; Wang & Chen, 2009), two complementary characteristics that can not only instruct visitors to focus on the observation of the exhibits, but also provide detailed guidance and information within the same field of view at the same time, thereby further promoting the HCCI. The data collected in the study showed that the applications of the AR-guided mode in the painting appreciation activity is beneficial for learning performance and could become a guide tool that should not be ignored in art museums in the future (Damala et al., 2008; Johnson, Smith, Willis, Levine, & Haywood, 2011).

In summary, the standardized characteristics of the mobile AR-guide system tested in the study included mobility, location-based service, real-time functionality, autonomy, intuition, integration of the real and the virtual, visual concentration, personalization, HCCI, multimedia information, and convenient content management (Damala et al., 2007, 2008; Klopfer & Squire, 2008; Johnson, Levine, Smith, & Stone, 2010; Mulloni et al., 2008; Papagiannakis, Singh, & Magnenat-Thalmann, 2008; Rose, Potter, & Newcombe, 2010). In addition, although good results were achieved using the AR guide system, there remains a need for the following improvements: (1) in the system design, the sensitivity of painting identification needs to be moderated, the interface design needs to be improved, and the numbers and lengths of the commentaries need to be increased; and (2) for the activity arrangements, the visiting time and the number of visitors need to be controlled, and the carrying instrument needs to be simplified and made more portable.

We hope that researchers, educators, art-museum administrators, and system designers will consider these recommendations as useful references for art appreciation and the application of mobile guides. The study made an important revelation regarding the behaviors of

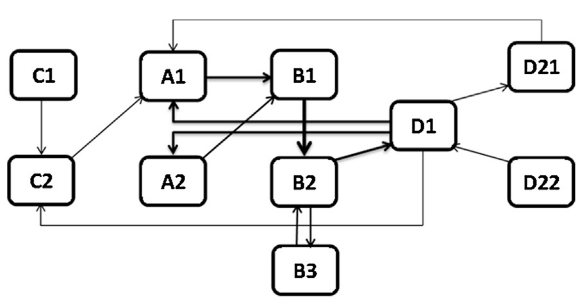

Fig. 5. Behavioral patterns of the AR-guided group.

visitors in an AR-guided group: these visitors rarely discuss the paintings with their peers, focusing too much on the painting and its commentary, and this limits their interpersonal interactions. Therefore, we further suggest that appropriate situational tasks be integrated into the AR guide system, such as a systematic art criticism questioning strategy (Hamblen, 1984). This would certainly promote the peer–computer–situation interaction and encourage closer interactions based on the content of the artwork between the visitors and their companions (Sung, Hou, et al., 2010).

In addition to continuing and expanding the 11 standardized characteristics of the mobile AR-guide system proposed by the study (Zhang et al., 2012), future research could also include an authoring tool design concept for conveniently allowing managers and instructors to use a cloud platform in the authoring tool to design a complete art appreciation teaching content. This will promote effective information management and the sharing and recycling of art appreciation resources, thus achieving the combination of guide and management in art appreciation. Furthermore, this system is not only limited to painting displays, but may also be applied to all kinds of exhibitions, such as other types of museums, art centers, education centers, and theme parks, with various relevant topics being initiated for each venue in accordance to the needs of the visitors, thereby creating a multifunctional integration system with AR.

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