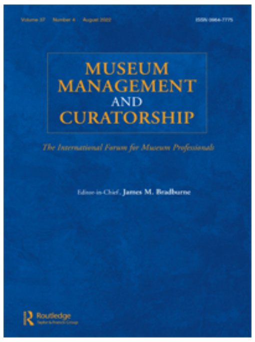

Museum Management and Curatorship

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rmmc20

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MUSEUM MANAGEMENT AND CURATORSHIP
https://doi.org/10.1080/09647775.2022.2086605

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The effects of salience and ordinal position of exhibit objects on visitor attention in digital exhibitions

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ABSTRACT
The aims of the present experiments were to investigate the impact of (a) ordinal position, (b) object salience (size and three-dimensionality), and (c) proximity to salient objects on visitor attention in digital exhibitions, and to make comparisons with trends observed in physical exhibitions. The results of two experiments involving 210 participants, conducted using a tablet computer, indicated that (a) the ordinal position and salience effects observed in physical exhibitions were also present in the digital medium; (b) however, the overshadowing effect by the salient objects on the adjacent ones observed in physical exhibitions did not seem to emerge when three-dimensionality was the salience parameter; and (c) the negative impact of the salient object's presence on the overall attention to the exhibition observed in physical exhibitions seemed to be eliminated in digital exhibition environments regardless of the salience parameter.

ARTICLE HISTORY
Received 28 January 2022
Accepted 1 May 2022

KEYWORDS
Exhibit object salience; ordinal position; virtual exhibitions; visitor attention; visitor behavior; digital museums

Introduction

Digital exhibitions seem to have a growing potential to have an impact on the way museums manage their collections and visitors (Desvallées and Mairesse 2010). COVID-19 pandemic has further augmented this tendency: According to a survey conducted by ICOM (2020, 10), approximately 27% of the museum institutions that have responded to the survey reported that their digital services have either begun or increased after the lockdown. Under the circumstances, further research is needed to explore to what extent can the research findings regarding physical exhibition environments apply to digital exhibition environments. Considering this necessity, in the present study we aimed to expand on the findings of a previous research (Turgay Zıraman and Imamoğlu 2020) – which investigated the impact of ordinal position, object salience, and proximity to salient objects on visitor attention in physical exhibitions – (a) by addressing the same variables in a digital environment to explore whether the impacts of these variables on visitor attention would change with the medium, and (b) by investigating the impact of two different salience parameters (size, as in previous studies, and three-dimensionality) separately in order to explore whether there would be a difference between their

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impacts on visitor attention. The following sections consider the *general value principle* and *perceived presence,* hence their strong influence on the way visitors allocate their attention in exhibitions.

Visitor attention and the general value principle

Regardless of the physical or digital quality of the exhibition environment, the way visitors allocate their attention in exhibitions may be forecasted with the help of the *general value principle*, which suggests, 'the value of an experience is calculated (usually without awareness) as a ratio between the benefits and the costs' (Bitgood 2006, 464). More specifically, throughout their visits, visitors intuitively make decisions about the way they will distribute their limited attention to the exhibits on display. While making these decisions, they instinctively compare the cost (e.g., money, time, effort) and benefit (e.g., entertainment, aesthetic enjoyment, learning, self-actualization) of viewing each exhibit object. Therefore, exhibit objects with higher benefit/cost ratios have an increased chance of receiving attention from visitors.

As the first independent variable addressed in the present study, ordinal position of exhibit objects was previously shown to influence attention distribution schemes. For example, the amount of visitor attention allocated to individual exhibit objects tends to decrease as the visitors proceed toward the end of exhibitions, due to factors such as fatigue or object satiation (Bitgood 2002, 2009, 2013; Bitgood and Patterson 1987; Johnston 1998; Melton 1935; Robinson 1928; Turgay Zıraman and Imamoğlu 2020). Turgay Zıraman and Imamoğlu (2020) also reported that the ordinal position effect seemed to be independent of the exhibit objects' salience levels involving size. Considering the value ratio of the visiting experience, it becomes gradually more difficult to attend to the exhibits as the visitors get physically and mentally tired due to fatigue, or satiated due to exposure to similar objects on display.

Physical properties of the exhibit objects may also influence the value ratio for the viewing experience of each object, and consequently the attention distribution schemes. Numerous studies have shown that the salience levels of exhibit objects tend to be influenced by parameters such as size (e.g., Bitgood, Patterson, and Benefield 1988), three-dimensionality (Peart 1984), sense-modality (e.g., Bitgood and Patterson 1987), and motion (e.g., Melton 1972). These studies have shown that the amount of attention allocated to objects displaying different levels of these parameters varied accordingly.

Moreover, when exhibit objects with different salience attributes are exhibited together in a single space, these attributes may interact with each other; e.g., a larger object might attract less visitor attention, if the others are in motion, despite their smaller size. In addition, the intensity of competition for visitor attention seems to increase when exhibit objects are positioned in adjacent locations (Bitgood 1992, 2010; Bitgood, Patterson, and Benefield 1988; Melton 1972). This effect parallels the *neighborhood inhibition hypothesis*, which asserts that, in the presence of a salient element in a multielement display, the elements presented closer to the salient element would attract less attention compared to those presented further away (Mounts 2000). Therefore, proximity relationships between exhibit objects should be considered in conjunction with their physical properties. For example, Turgay Zıraman and Imamoğlu (2020) revealed that small objects exhibited in an adjacent location to a larger object tend to attract significantly less attention than the small objects exhibited further away from the larger object. Increased competition could impede the efficiency of the visiting experience; therefore 'exhibits should be placed in locations that minimize competition with each other' (Bitgood, Patterson, and Benefield 1988, 490). Thus, the amount of attention received by individual exhibit objects can be increased in the absence of sensory distraction, when they are isolated from visual, auditory, or olfactory stimuli from other elements sharing the space (Bitgood 1992, 2009, 2010, 2013). Besides sensory distraction, competition may also occur due to selective choice, which results in visitors preferring to allocate their attention to objects that have larger value ratios (i.e., benefit/cost) over those with smaller value ratios (Bitgood 2009, 2013).

Perceived presence

As proposed via the notion of *perceived presence*, if the digital exhibition is planned as a three-dimensional representation of the physical museum, it should provide a strong sense of being in the cyberspace represented (Sylaiou et al. 2010). More specifically, when more attention is allocated to the mediated environment than to the environment in which an individual is physically located, the sense of being in the digital environment is strengthened, leading to a strong perceived presence (Kim and Biocca 1997).

Perceived presence is mainly influenced by variables categorized as *media characteristics* and *user characteristics* (Lessiter et al. 2001). While user characteristics are hardly modifiable, media characteristics can be adjusted according to different circumstances. Attention and involvement are user responses associated with perceived presence and there is a close relation between perceived presence and enjoyment (Sylaiou et al. 2010). So, a high level of attention and involvement are expected to result in a high level of perceived presence, which would consequently produce a satisfactory and enjoyable experience with a higher benefit/cost ratio.

Aims and hypotheses

As noted, in the present study we aimed to investigate the impact of ordinal position, object salience, and proximity to salient objects on visitor attention attracted by individual exhibit objects and overall exhibition in a digital environment. In accordance with this aim, we conducted two experiments, which were parallel in all respects, except for the type of salience parameter: In the first digital exhibition experiment (DE1), size was used as the salience parameter, whereas in the second one (DE2), the impact of three-dimensionality was investigated. Furthermore, to explore the degree to which the impact of the variables considered in the digital context differ from those in physical exhibitions, the design of DE1 was made parallel to that of a previous experiment conducted in a physical setting (i.e., Turgay Zıraman and Imamoğlu 2020), which will be referred to as the physical exhibition experiment (PE).

Four hypotheses regarding (1) ordinal position, (2) object salience, (3) proximity to salient objects, and (4) their impact on attention to the overall exhibition were formulated as follows:

Hypothesis 1: Considering the previous findings pointing to the attention decline toward the end of exhibitions due to object satiation and similar effects noted above, we hypothesized that, objects appearing at the beginning of a digital exhibition would receive more attention than those appearing near the end (Hypothesis 1a). However, we expected the decline in the amount of attention in the digital medium to be smaller than that in a physical exhibition, due to decreased effort (cost) required for viewing more objects (benefit) (Hypothesis 1b).

Hypothesis 2: In view of the previous research on the influence of object salience on visitor attention, we hypothesized that salient objects would attract more attention than non-salient ones in a digital exhibition – in a similar manner to physical exhibitions (Hypothesis 2a). Considering the impacts of different salience parameters on the salience levels of the exhibit objects might be different, and that the extra dimension added with three-dimensionality might increase the novelty of the exhibit objects, we expected that three-dimensionality would augment the amount of attention held by the exhibit objects at a higher rate than size would do, resulting in a greater increase in viewing durations at the three-dimensional objects in DE2 compared to the increase caused by the larger ones in DE1 (Hypothesis 2b).

Hypothesis 3: Considering the previous findings involving physical exhibitions on exhibit object salience and competition, we hypothesized that non-salient objects would be overshadowed by salient objects, and the overshadowing effect would be more intense for the non-salient objects that are displayed in an adjacent position to a salient object in digital settings as well (Hypothesis 3a). However, we expected the intensity of the overshadowing effect to diminish in the digital medium due to decreased presence perception (Hypothesis 3b). Since we expected three-dimensionality to be a stronger salience parameter than size, we also expected that the overshadowing effect exerted by the three-dimensional objects would be stronger compared to that of the larger objects (Hypothesis 3c).

Hypothesis 4: In a previous study involving physical exhibitions (Turgay Zıraman and Imamoğlu 2020), it was found that the presence of an object larger than other equal-sized objects in an exhibition could create a suppression effect on the overall attention attracted by the exhibition as a consequence of the intense overshadowing effect exerted by the larger objects on the small ones – especially those adjacent to the larger objects. In the present study, in view of Hypothesis 3b referring to a diminished overshadowing effect in the digital medium (relative to the physical setting), we expected that, rather than an overall suppression effect, the overall attention attracted by the exhibition would tend to increase when a salient object is introduced to the digital exhibition (Hypothesis 4a). Moreover, we expected the overall attention to the exhibitions in DE2 to be higher than that in DE1 owing to the difference between the salience parameters in terms of attention attracting capability (Hypothesis 4b).

Method

Participants

The participants of both experiments (DE1 & DE2) of the present study consisted of casual visitors to a contemporary arts center in a metropolitan city. All visitors who viewed the exhibition and completed the questionnaire were included, since they were all within the age range of 18 and 65, all of them had been using touch-screen devices in their daily lives, and none of them have seen the exhibit objects before. Ethical approval of the study was granted by the ethics committee of Bilkent University.

In the context of DE1, 30 participants visited the exhibition and completed the questionnaires in each condition (one control and three experimental; $N_{TOTAL} = 120$). For the case of DE2, again 30 participants visited the exhibition and completed the questionnaires in each of the three experimental conditions ($N_{TOTAL} = 90$). The control condition in DE1 was used as the control condition for DE2 as well, since the control objects were all non-salient with no distinctive attributes for the two experiments. Power analyses for the independent samples t-tests (power 85%, two-tailed, $\alpha = .05$) indicated that the sample sizes were sufficient to detect small effects.

According to separate analyses, gender, age, education, exhibition-visiting frequency, and previous experience with the exhibit venue did not differ between DE1 and DE2, or the study conditions within the two experiments. Independent samples t-tests for gender, age (below and above 45), and previous experiences with the venue; and one-way ANOVAs for educational levels and exhibition visiting habits were conducted separately for the experiments, in order to explore if the demographic information reported by the participants had an influence on the results. None of these tests revealed significant effects of these demographic variables on viewing durations at $p = .05$ level.

Digital exhibition

The exhibit objects used in the first experiment (DE1) consisted of sets of seven stimuli (each having a square form and containing six layers of irregular shapes), which were adapted to the digital medium from those used in a previous study involving physical exhibitions (Turgay Zıraman and Imamoğlu 2020). For the second experiment (DE2), exhibit objects that were intended to be the salient ones were further manipulated to achieve three-dimensionality (i.e., they were extruded in the z-axis to achieve depth) using AutoCAD software. Thus, two-and-a-half-dimensional (2.5D) exhibit objects were generated to be used as salient objects in DE2 (Figure 1). By doing so, all variables outside the scope of the study – such as display layout or surface, viewing direction, form, color scheme, texture, and scale – were kept constant by adapting three-dimensionality as depth, and using 2.5D objects as a substitute to 3D ones. Throughout the text, the first appearing object is referred to as Exhibit Object 1, the following is referred to as Exhibit Object 2, and so on.

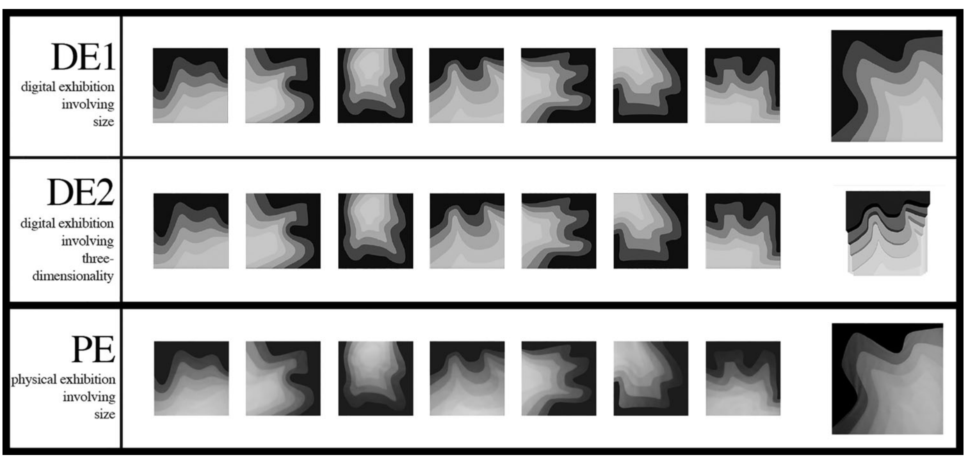

Figure 1. Digital exhibit objects (DE1 & DE2), which were produced from physical exhibit objects (PE) used in Turgay Zıraman and Imamoğlu (2020).

The digital exhibitions were prepared using Microsoft PowerPoint. A digital model of the venue used in the previous study by Turgay Zıraman and Imamoğlu (2020) was created (Figure 2). Arrow buttons were integrated in order to enable the visitors to navigate through the exhibition. Small icons of all seven exhibit objects were available on the bottom of each scene in the same order as they appeared in the exhibition, and the current exhibit object was highlighted among all seven. This provided a sense of orientation for the visitors. It also enabled visitors to skip certain exhibit objects. Moreover, the faded images of the exhibit objects adjacent to the object currently being viewed were also included in each frame, in an attempt to imitate the peripheral vision in the physical medium (Figure 3).

Considering the audience of the venue, a touch-screen tablet computer was used, to enable direct user input, and an intuitive input-display relationship (Taveira and Choi 2009). Last, a tutorial section was provided prior to entering the actual digital exhibition, to avoid problems of unfamiliarity or inexperience.

Measures and procedure

Four conditions (control condition and three experimental conditions of L1, L4, and L7, where L stood for *large*) of the previously mentioned physical experiment (PE) were recreated in the digital medium. Since there are two salience parameters (size and three-dimensionality) in the present study, the experimental conditions were labeled as S1, S4, and S7, where S stands for *salient*. Each condition consisted of seven objects exhibited on a single wall. The control condition consisted of seven equal-sized (35 cm by 35 cm) two-dimensional objects, whereas the experimental conditions consisted of six equal-sized (35 cm by 35 cm) 2D objects and one salient object, which was larger (50 cm by 50 cm) and 2D for DE1, but equal-sized (35 cm by 35 cm) and 2.5D for DE2. The first (initial), the fourth (mid) and the seventh (last) objects were the salient ones in S1, S4, and S7 conditions, respectively (Figure 4).

Figure 2. Two photos from the exhibition setup in the previous study by Turgay Zıraman and Imamoğlu (2020) on the left column, and two snapshots from the same spot in the digital model that imitated the physical space on the right column.

Figure 3. A snapshot from the digital exhibition, showing the faded images of the exhibit objects adjacent to the object currently being viewed to imitate peripheral vision.

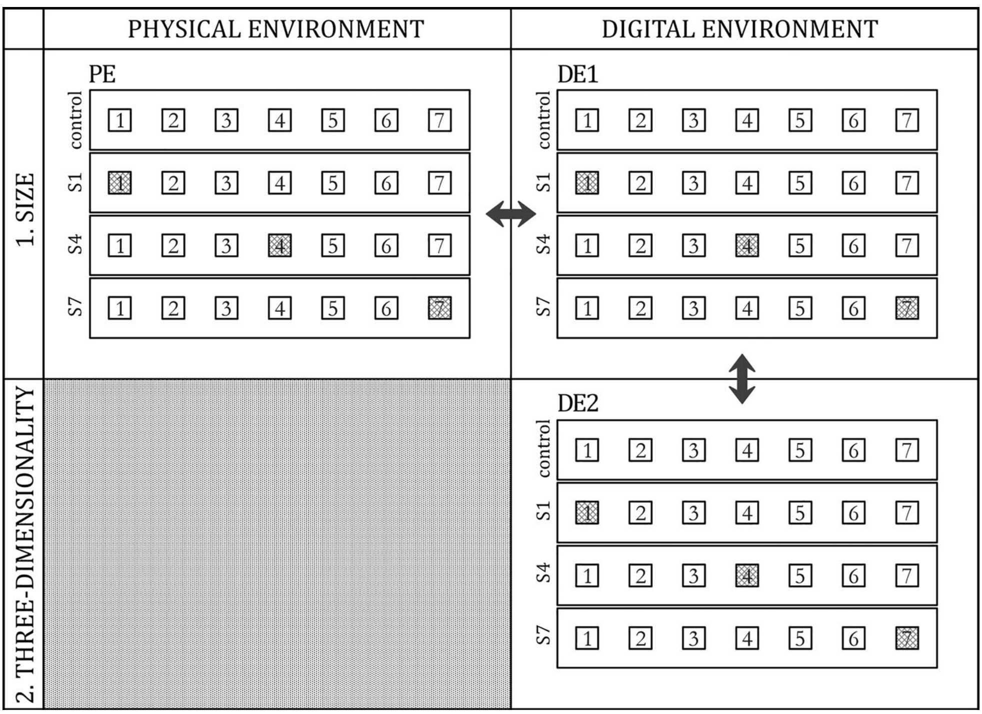

Figure 4. Chart showing the structure of the conditions in PE of Turgay Zıraman and Imamoğlu (2020), and DE1 and DE2 of the present study.

According to Bitgood (2013, 18), the behavioral indicators that occur as the exhibit object starts to capture attention are ‘looking at, approaching, and stopping’. Secondly, concentrating on a single exhibit object by excluding others indicates that the visitor has moved on to the focusing stage (Bitgood 2013). Last, the indicators of the engagement stage are ‘highly focused examination of the exhibit content, reading text passages, discussing the content with group members, and thinking about the implications of the exhibit material’ (Bitgood 2013, 18).

To address the earlier stages of attention – i.e., *capture* and *focus* (Bitgood 2010) – we collected the timing data by recording the screen of the tablet computer through which participants viewed the digital exhibition. We analyzed the recordings to obtain the viewing durations for each exhibit object in each condition. Then, we converted the timing data into average holding time (AHT) values, which refers to the mean time spent at a particular exhibit object (whenever a participant skipped an exhibit object, the viewing duration was counted as zero, and included in the calculation of AHTs). Prior to entering the digital exhibition, the visitors were informed through a note on the screen that their visits were going to be recorded for academic research purposes.

To provide the opportunity for a further level of attention, that is the *engage* stage, some behaviors that would occur in physical exhibitions (i.e., touching, stepping closer, returning, etc.) were translated to the digital medium. In this regard, an option of zooming into the exhibit objects was added to the digital exhibition. If a visitor chose to zoom into an exhibit object or chose to view an object for a second time, it was recorded in the observation sheets as *closer look* or *return* while processing the screen recordings. Namely, these behaviors indicate that the specific exhibit object attracted the attention of the visitors at a high level such that they were eager to explore the object further. An option of zooming out was also provided, to enable the visitors to view the entire exhibition from a distance.

We also included a questionnaire desk in the digital model of the exhibition environment, and participants were redirected to the online questionnaire by tapping the desk image. To avoid any familiarity biases, we checked whether the participants had visited the exhibition before to eliminate those who had already participated in any part of the studies. Last, a section consisting of presence questions adapted from the Slater-Usoh-Steed (SUS) presence questionnaire was integrated to explore if perceived presence levels influenced the timing results (Usoh et al. 2000). Nevertheless, an independent samples t-test to check whether the perceived presence levels (*1–5 = low; 6 and 7 = high*) influenced the viewing durations indicated that, the viewing durations of participants with low perceived presence scores ($M = 5.58$, $SD = 4.57$) did not differ from those with high perceived presence scores ($M = 4.43$, $SD = 2.31$), $t\ (118) = 1.30$, $p = .20$, $d = .32$. Each condition was terminated as soon as a sample of 30 participants was reached with a balanced gender distribution.

Results

In this section, first, we present the results of DE1 and DE2 separately, in line with the independent variables addressed in the hypotheses that are ordinal position (Hypothesis 1), exhibit object salience (Hypothesis 2), adjacency to salient objects (Hypothesis 3), and the impact of the presence and position of the salient object on visitor attention to the overall exhibition (Hypothesis 4). Second, we provide a comparison of the general results of DE1 and DE2. Last, we examine frequencies of the behaviors that indicate a further level of attention.

Average Holding Time (AHT) analyses for DE1

Ordinal position

Mean times spent at each exhibit object (AHTs) and their standard deviations for each condition of DE1 are presented in Figure 5. An independent samples t-test to explore the significance of the gradual decrease toward the end of the exhibitions showed that the participants spent significantly more time at the first objects ($M = 11.78$, $SD = 9.28$) than they did at the last objects ($M = 4.14$, $SD = 3.82$) across conditions, t (158) = 8.34, $p < .001$, $d = 1.08$, 95% CI [6.94, 8.98]. Since Levene's test indicated unequal variances, degrees of freedom were adjusted from 238 to 158 ($F = 39.03$, $p < .001$). Furthermore, an independent samples t-test conducted to compare the mean times spent at the first three objects ($M = 7.21$, $SD = 7.89$) with the last three objects ($M = 3.68$, $SD = 3.55$) across four conditions also revealed a significant difference, t (499) = 7.75, $p < .001$, $d = 0.58$, 95% CI [4.98, 5.91]. Degrees of freedom were adjusted from 718 to 499 since Levene's test indicated unequal variances ($F = 81.87$, $p < .001$).

Salience

An independent samples t-test indicated that the mean AHT of the three larger objects ($M = 8.34$, $SD = 7.85$) was significantly greater than the mean AHT of the 18 small objects ($M = 4.86$, $SD = 5.34$) in the three experimental conditions, t (103) = 4.06, $p < .001$, $d = .52$, 95% CI [4.89, 5.81]. Since Levene's test indicated unequal variances [$F = 13.6$, $p < .001$], degrees of freedom were adjusted from 628 to 103.

Adjacency

Separate independent samples t-tests showed that the mean time spent at the four small objects adjacent to the larger ones ($M = 3.79$, $SD = 4.39$) was significantly less than;

- the mean time spent at the larger objects ($M = 8.34$, $SD = 7.85$) across the experimental conditions, t (130) = 4.95, $p < .001$, $d = .72$, 95% CI [4.86, 6.62] (Note first, that Levene's test indicated unequal variances, $F = 16.01$, $p < .001$, so degrees of freedom were adjusted from 208 to 130; second, that a similar test conducted for the corresponding objects in the control condition yielded a nonsignificant result);
- the mean time spent at the other small objects that were not adjacent to any larger objects in all three experimental conditions ($M = 5.16$, $SD = 5.55$), t (239) = 2.83, $p = .005$, $d = .27$, 95% CI [4.41, 5.31] (Note that because Levene's test indicated unequal variances [$F = 4.40$, $p = .04$], degrees of freedom were adjusted from 538 to 239).

On the other hand, there was no significant difference between the mean time spent at the objects adjacent to the larger ones in the experimental conditions ($M = 3.79$, $SD =$

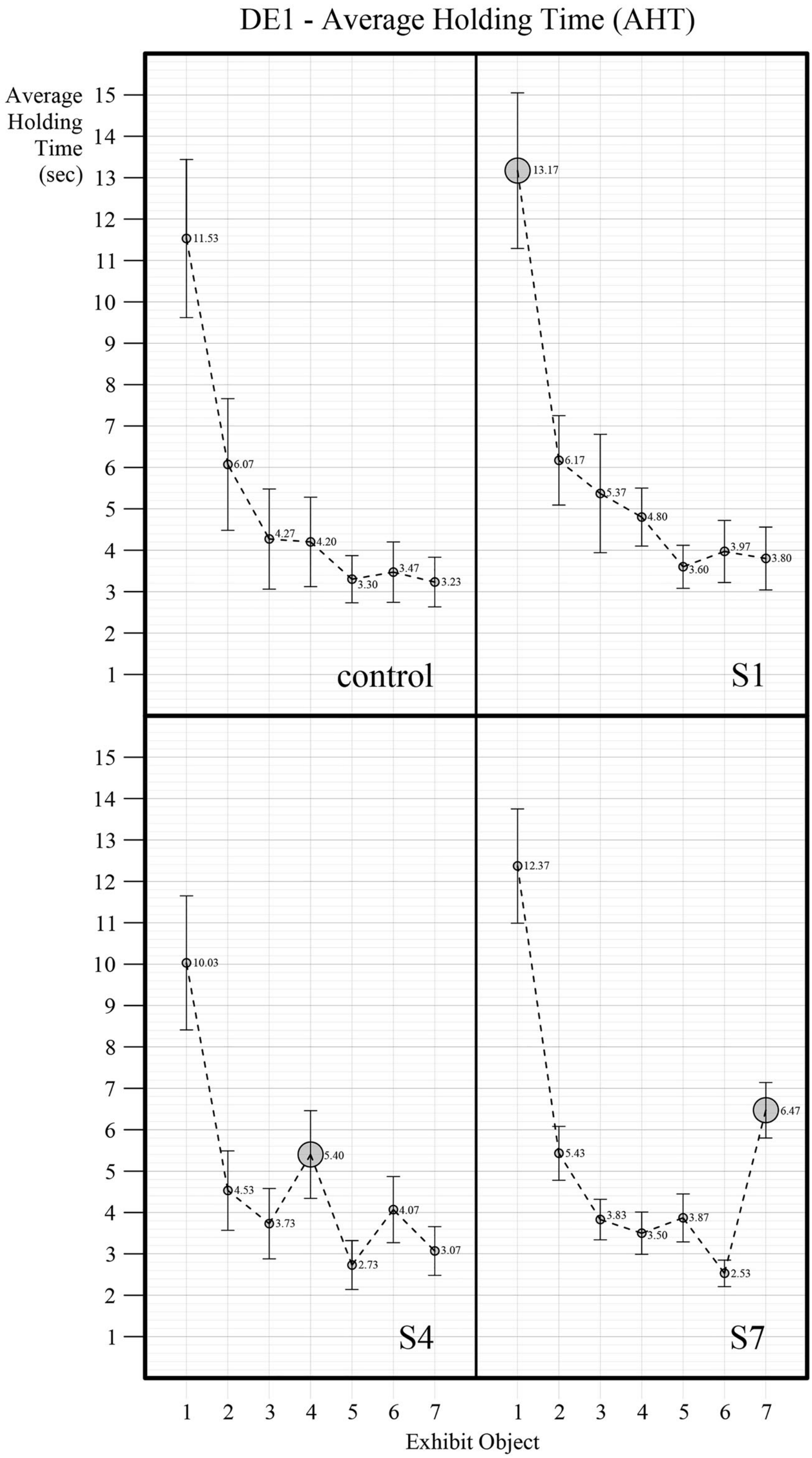

Figure 5. AHTs of the exhibit objects in the four conditions of DE1. Salient objects are indicated with larger markers.

4.39) and the mean time spent at the corresponding objects (#2, #3, #5, and #6) in the control condition ($M = 4.28$, $SD = 5.98$).

Overall attention to the exhibition

Several analyses were conducted to examine whether the presence and the ordinal position of the larger object made any difference in terms of the overall attention to the exhibitions. Based on the AHT values shown in Figure 5, the mean viewing times for each of the control and experimental conditions of the present study were calculated. An independent samples t-test showed that, in general, there was no significant difference between the mean time spent at the control condition ($M = 5.15$, $SD = 6.95$) and the mean time spent at the three experimental conditions altogether ($M = 5.35$, $SD = 5.89$). Similarly, no significant difference was found between the four conditions in terms of overall AHTs through a one-way ANOVA.

Average Holding Time (AHT) analyses for DE2

Ordinal position

Figure 6 shows the mean times spent at each exhibit object (AHTs) and their standard deviations for each condition of DE2. An independent samples t-test conducted across conditions indicated that the overall AHT of the first objects ($M = 11.21$, $SD = 8.32$) was significantly higher than that of the last objects ($M = 5.85$, $SD = 6.84$), t (229) = 5.45, $p < .001$, $d = 0.70$, 95% CI [7.51, 9.55], in a similar vein with DE1. Degrees of freedom were adjusted from 238 to 229 since Levene's test indicated unequal variances ($F = 7.76$, $p = .006$). Another independent samples t-test conducted to compare the mean times spent at the first three objects ($M = 6.97$, $SD = 7.20$) with the last three objects ($M = 4.26$, $SD = 5.14$) across four conditions also revealed a significant difference, t (649) = 5.81, $p < .001$, $d = 0.43$, 95% CI [5.15, 6.09]. Degrees of freedom were adjusted from 718 to 649 since Levene's test indicated unequal variances ($F = 36.25$, $p < .001$).

Salience

An independent samples t-test indicated that the mean AHT value of the three salient (2.5D) objects ($M = 13.11$, $SD = 11.58$) was significantly greater than the mean AHT value of the 18 non-salient (2D) objects ($M = 4.61$, $SD = 4.77$) in the three experimental conditions, t (94) = 6.87, $p < .001$, $d = 0.96$, 95% CI [5.29, 6.37]. Since Levene's test indicated unequal variances [$F = 73.33$, $p < .001$], degrees of freedom were adjusted from 628 to 94.

Adjacency

Addressing the effect of adjacency to a salient object, an independent samples t-test showed that the mean time spent at the 2D objects adjacent to 2.5D ones ($M = 4.13$, $SD = 4.85$) was significantly less than the mean time spent at the 2.5D objects ($M = 13.11$, $SD = 11.58$) across the experimental conditions, t (112) = 6.92, $p < .001$, $d = .17$, 95% CI [6.7, 9.26] (Note that Levene's test indicated unequal variances, $F = 27.81$, $p < .001$, so degrees of freedom were adjusted from 208 to 112). On the other hand, another independent samples t-test showed that there was no significant difference between the mean time spent at the 2D objects adjacent to the 2.5D ones, and the mean time spent at the other 2D objects that were not adjacent to 2.5D objects in all

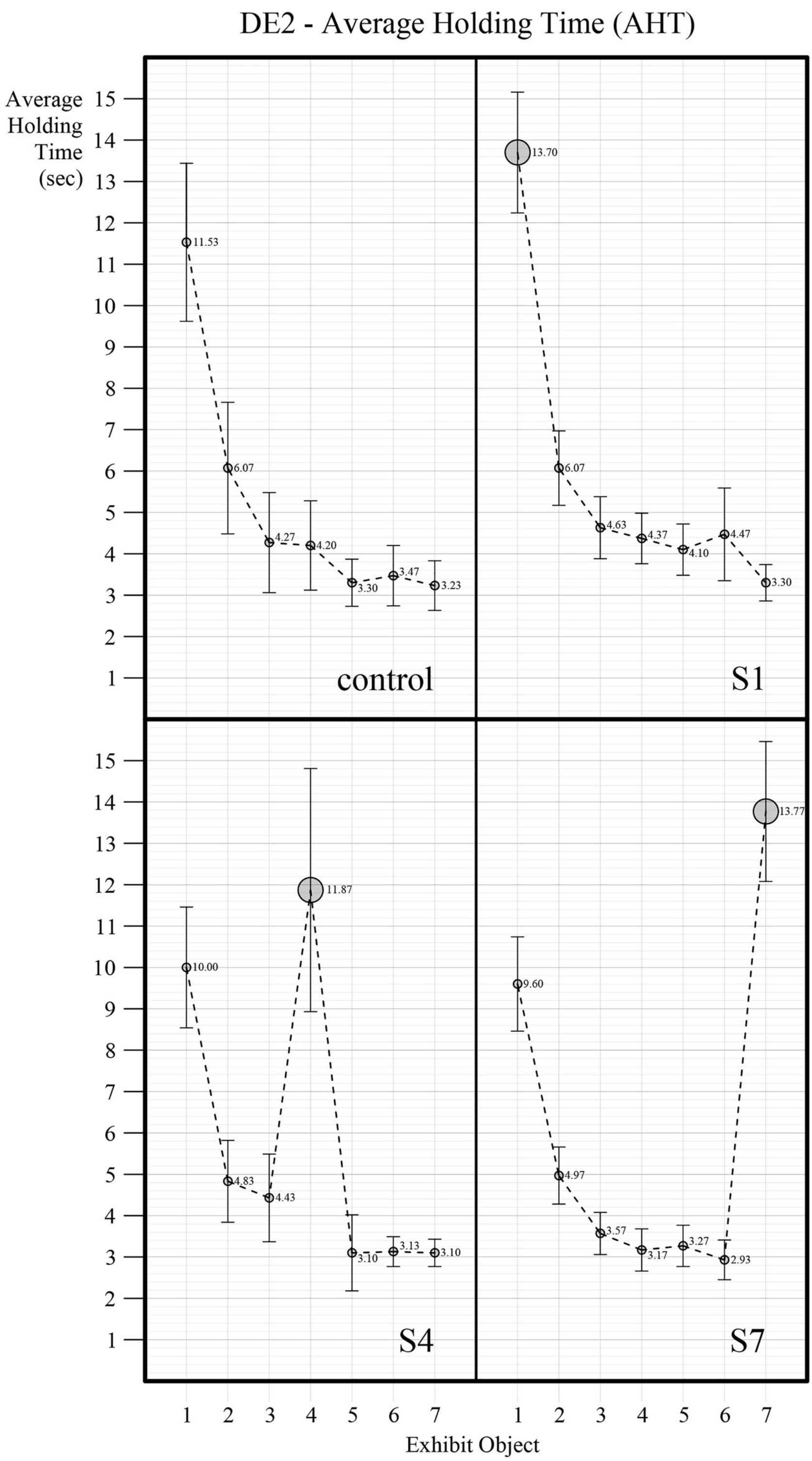

Figure 6. AHTs of the exhibit objects in the four conditions of DE2. Salient objects are indicated with larger markers.

three experimental conditions (*M* = 4.75, *SD* = 4.75). Although the mean time spent at the objects adjacent to the 2.5D ones in the experimental conditions was less than the mean time spent at the corresponding objects (#2, #3, #5, and #6) in the control condition (*M* = 4.28, *SD* = 5.98), the difference did not reach significance.

Overall attention to the exhibition

To check whether the presence and the ordinal position of the 2.5D object made any difference in terms of the overall attention to the exhibitions in DE2, another group of analyses were conducted based on the mean viewing times calculated for each of the experimental conditions from the AHT values shown in Figure 6. An independent samples t-test showed that, in general, there was no significant difference between the mean time spent at the control condition (*M* = 5.15, *SD* = 6.95) and the mean time spent at the three experimental conditions altogether (*M* = 5.83, *SD* = 6.88). Similarly, a one-way ANOVA indicated nonsignificant differences between the four conditions in terms of overall AHTs.

Comparison of the general results of experiments involving digital exhibitions (DE1 & DE2) and physical exhibitions (PE)

As shown in Table 1-A and 1-B, object satiation effect did not seem to vary as a function of physical or digital presentation. In a similar vein, as shown in Table 1-C, salient objects received more attention than non-salient objects in all three experiments. Digital medium did not seem to lead to a considerable difference in the impact of object salience,

Table 1. Results of the experiments involving Digital Exhibitions (DE1 and DE2) and Physical Exhibitions (PE), showing the average times spent at the first and second groups of the independent variables, and the results of separate independent samples t-tests for the difference between the two groups.

		DE1		DE2		PE*	
A.	(1) First Objects vs. (2) Last Objects	$M1 = 11.78$ $M2 = 4.14$	$SD1 = 9.28$ $SD2 = 3.82$	$M1 = 11.21$ $M2 = 5.85$	$SD1 = 8.32$ $SD2 = 6.84$	$M1 = 8.72$ $M2 = 3.02$	$SD1 = 7.94$ $SD2 = 3.37$
		$p < .001$, $t(158) = 8.34$		$p < .001$, $t(161) = 7.24$		$p < .001$, $t(229) = 5.45$	
B.	(1) First Three Objects vs. (2) Last Three Objects	$M1 = 7.21$ $M2 = 3.68$	$SD1 = 7.89$ $SD2 = 3.55$	$M1 = 6.97$ $M2 = 4.26$	$SD1 = 7.20$ $SD2 = 5.14$	$M1 = 5.82$ $M2 = 3.19$	$SD1 = 5.97$ $SD2 = 3.43$
		$p < .001$, $t(499) = 4.75$		$p < .001$, $t(573) = 7.25$		$p < .001$, $t(649) = 5.81$	
C.	(1) Salient Objects vs. (2) Non-salient Objects	$M1 = 8.34$ $M2 = 4.86$	$SD1 = 7.85$ $SD2 = 5.34$	$M1 = 13.11$ $M2 = 4.61$	$SD1 = 11.58$ $SD2 = 4.77$	$M1 = 7.30$ $M2 = 3.71$	$SD1 = 8.14$ $SD2 = 3.90$
		$p < .001$, $t(103) = 4.06$		$p < .001$, $t(96) = 4.10$		$p < .001$, $t(96) = 6.93$	
D.	(1) Adjacent Objects** vs. (2) Non-Adjacent Objects	$M1 = 3.79$ $M2 = 5.16$	$SD1 = 4.39$ $SD2 = 5.55$	$M1 = 4.13$ $M2 = 4.75$	$SD1 = 4.85$ $SD2 = 4.75$	$M1 = 2.60$ $M2 = 4.03$	$SD1 = 2.80$ $SD2 = 4.11$
		$p = .005$, $t(239) = -2.83$		$p < .001$, $t(281) = -4.40$		$\mathbf{p = .21}$, $t(538) = -1.25$	
E.	(1) Control Condition vs. (2) Experimental Conditions	$M1 = 5.15$ $M2 = 5.35$	$SD1 = 6.95$ $SD2 = 5.89$	$M1 = 5.15$ $M2 = 5.83$	$SD1 = 6.95$ $SD2 = 6.88$	$M1 = 5.54$ $M2 = 4.22$	$SD1 = 5.07$ $SD2 = 4.90$
		$\mathbf{p = .68}$, $t(838) = -.41$		$p = .001$, $t(348) = 3.28$		$\mathbf{p = .22}$, $t(838) = -1.23$	

* Data in the column labeled as *PE* are derived from a previous study by Turgay Zıraman and Imamoğlu, (2020).
** *Adjacent Objects* refers to the objects adjacent to salient ones.

since the difference between the AHT means of salient (i.e., larger) and non-salient (i.e., smaller) objects in DE1 (8.34–4.86 = 3.48) was almost equal to that in PE (7.30–3.71 = 3.59). However, three-dimensionality seemed to be superior to size as a salience parameter, since the difference between the AHT means of the salient (i.e., 2.5D) and non-salient (i.e., 2D) objects in DE2 (13.11–4.61 = 8.5) was considerably higher than those in both PE and DE1. To test the significance of this trend, we calculated the difference between the time spent at the salient object, and the average time spent at the non-salient six objects for each of the 90 visitors in the experimental conditions, and compared the difference scores of the three experiments using a one-way ANOVA, which yielded a significant result, F (2, 267) = 11.62, MSE = 63.53, $p < .001$, 95% CI [4.2, 6.18]. Follow-up Scheffé tests revealed that the difference between the times spent at the salient and non-salient objects were significantly higher in DE2 (M = 8.50, SD = 9.93), compared to those in PE (M = 3.59, SD = 7.02, $p < .001$) and DE1 (M = 3.49, SD = 6.54, $p < .001$).

We conducted another pair of one-way ANOVAs to test if there was a difference between the three experiments in terms of (1) the AHT means for the salient objects and (2) the AHT means for the non-salient objects in two separate analyses. The first one-way ANOVA indicated a significant difference between the mean AHTs of the salient objects in PE, DE1, and DE2, F (2, 267) = 9.89, MSE = 87.34, $p < .001$, 95% CI [8.44, 10.7]. Follow-up Scheffé tests indicated that the mean AHT of the salient objects in DE2 (M = 13.11, SD = 11.58) was significantly higher than the mean AHTs of the salient objects in PE (M = 7.30, SD = 8.14, $p < .001$) and DE1 (M = 8.34, SD = 7.85, p = .003). The second one-way ANOVA also revealed a significant difference between the mean AHTs of the non-salient objects in PE, DE1, and DE2, F (2, 1617) = 8.85, MSE = 22.19, $p < .001$, 95% CI [4.16, 4.62]. Follow-up Scheffé tests indicated that the mean AHT of the non-salient objects in PE (M = 3.71, SD = 3.90) was significantly less than the mean AHTs of the non-salient objects in DE1 (M = 4.86, SD = 5.34, $p < .001$) and DE2 (M = 4.61, SD = 4.77, p = .007).

As shown in Table 1-D, significant adjacency effects were observed in PE and DE1; however, in DE2, AHT of objects adjacent to salient ones did not seem to differ significantly from those of non-adjacent objects.

On the other hand, regarding the overall impact of salient objects on the exhibition, unlike the results of PE, an overall suppression effect was not observed in the digital presentations of DE1 and DE2, as shown in Table 1-E. In fact, in the digital medium, mean AHTs of the experimental conditions were higher than the mean AHT of the control condition. Further analyses indicated that although the mean AHT associated with the control conditions in the physical (M = 5.54, SD = 5.07) and digital (M = 5.15, SD = 6.95) presentations did not differ, those associated with the experimental conditions of the digital settings, namely DE1 and DE2 (M = 5.59, SD = 6.41) were significantly greater than those of PE (M = 4.22, SD = 4.9), t(1585) = 5.14, $p < .001$, d = 24, 95% CI [4.86, 5.4] (Note that Levene's test indicated unequal variances, F = 14.48, $p < .001$, so degrees of freedom were adjusted from 1888 to 1585).

Discussion

In general, the results of the present study indicated that parameters related to the ordinal position of viewing, exhibit object salience, and adjacency to a salient object seemed to influence visitor attention in digital exhibitions in a similar way to how they do in physical exhibitions as indicated by the results of PE (i.e., a preceding study that was conducted in a physical exhibition environment; Turgay Zıraman and Imamoğlu 2020). Alongside the similarities in the results detected by comparing the two salience parameters (i.e., size versus three-dimensionality) and the two types of exhibition media (i.e., physical versus digital), some differences were also revealed in terms of the parameters addressed in the hypotheses, as considered below.

Regarding our first hypothesis, the ordinal position effects were revealed through the comparisons of [1] the first and the last objects, and [2] the first three and the last three objects across conditions for both DE1 and DE2, which significantly showed that the objects appearing earlier held more attention from the visitors, as expected. As the visitors became more satiated with similar exhibit objects in the exhibition, they might have become less interested in them, which might have gradually lowered the benefit, and consequently, the value ratio of the viewing experience for the individual objects. However, considering the differences between the means of objects appearing earlier and later, the rate of the gradual decrease seemed to be lower in DE2 (relative to DE1). Considering that attractive and less monotonous exhibit content with high benefit/cost ratio would be perceived as worthy of more attention and viewing time, which would consequently result in a lower rate of attention decline throughout visits (Bitgood 2010), this result indicates that three-dimensionality might be a stronger salience parameter than size in compensating for the attention decline trend.

In line with our second hypothesis, both (digital) experiments indicated that object salience could be influencing the amount of attention held by the exhibits since the mean AHTs of the salient (i.e., larger and 2.5D) objects were significantly higher than those of all the non-salient objects across conditions. Furthermore, the mean AHT associated with DE2 (involving three-dimensionality) was found to be greater than that for DE1 (involving size), suggesting that three-dimensionality seems to be a stronger salience parameter than size. Thus, the results of the present digital exhibition study were congruent with previous reports involving the greater attention-holding capability of salient exhibit objects (associated with higher value ratio) in physical exhibitions (Bitgood and Patterson 1987; Bitgood et al. 1986; Bitgood, Patterson, and Benefield 1988; Marcellini and Jenssen 1988; Peart 1984; Turgay Zıraman and Imamoğlu 2020).

In this regard, we can also note that the AHT means of salient as well as non-salient objects in the digital experiments were higher than those of the experiment in the physical context. Thus, the digital medium seems to provide a general enhancement of attention holding times associated with ease of viewing relative to that in the physical context. However, our finding indicating that the difference scores between the AHT means of salient and non-salient objects in the physical context (PE) and its parallel in the digital medium (DE1) were almost equal, suggests that the digital medium does not seem to lead to a significant difference in the impact of object salience involving size. On the other hand, the difference between the AHT means of salient and non-salient objects in DE2 (involving three-dimensionality as a salience parameter), was found to be greater than those in PE and DE1; hence, again suggesting that three-dimensionality as a salience parameter appears to be superior to size.

In congruence with our third hypothesis, in both experiments, there seemed to be a trend for non-salient objects to be overshadowed by the salient objects at a higher rate when they were exhibited in an adjacent position to the salient ones, also supporting the *neighborhood inhibition hypothesis* (Mounts 2000). However, although the difference between the AHTs of the adjacent and non-adjacent objects was found to be significant in DE1, the comparison did not yield a significant result in DE2, which again points to a difference between the magnitudes of size and three-dimensionality as the two salience parameters investigated in these two experiments. Accordingly, relative to salience involving size (i.e., larger objects), salience involving three-dimensionality (i.e., 2.5D objects) seems to have a wider range of overshadowing effects influencing both the adjacent as well as other nearby similar non-salient objects.

It should also be noted that, in PE, there seems to be a larger attention decline at the objects adjacent to larger ones compared to the decline observed in DE1. This result may have originated from the decrease in both the perceived benefits and costs of the viewing experiences in the digital environment; e.g., encounters with objects in a digital environment might be less exciting than a physical encounter, but nevertheless, viewing more objects would require less physical effort in the digital medium. Therefore, the overshadowing effect created by the larger (more salient) objects on the smaller (less salient) ones may be diminished in the digital medium. In sum, although the significant negative impact of adjacency to salient objects was revealed in PE and DE1 that addressed size as a salience parameter in physical and digital exhibitions respectively, this effect did not reach significance in DE2 that addressed three-dimensionality in the digital environment (Table 1-D). In view of the enhanced attention holding power associated with 2.5D objects, non-salient objects (whether adjacent to a salient object or not) seem to recede to the background of salient objects (with the possible exception of the first objects).

In line with our fourth hypothesis, the presence of the salient objects in the experimental conditions seemed to contribute to the attention-holding capability of the overall exhibitions in the digital medium. That is, the present findings appear to be in contrast to the overall suppression effect findings of the preceding study involving physical exhibitions (Turgay Zıraman and Imamoğlu 2020), which indicated that the presence of a salient object is likely to create a general suppression effect on the amount of attention to the overall exhibition in the physical environment. Unlike those trends, in the experimental conditions of both digital experiments (DE1 and DE2), non-significant trends were observed for higher mean viewing durations compared to the control condition. Furthermore, while no difference was observed between the control conditions of the experiments conducted in the digital and physical contexts, the experimental conditions of both digital experiments seemed to attract significantly more attention than those in the physical context. Those results seem to point to the role of enhanced attention holding capability of salient objects in the digital context relative to that in the physical context, which seems to be even stronger for salience involving three-dimensionality rather than size.

The hypotheses were further supported by the behavioral indicators observed during visits that might indicate a further level of attention, which suggest that the visitors were more likely to engage with [1] the exhibit objects that appeared earlier in the exhibition than those that appeared later (the rate of this effect seemed to be higher in DE2 than in DE1), [2] the salient objects than the non-salient objects, [3] the objects in the digital exhibitions than the objects in the physical exhibitions, and [4] the objects in the exhibitions involving three-dimensionality (DE2), compared to those in the exhibitions involving size (DE1). On the other hand, competition between exhibit objects did not seem to deter the participants from engaging with the exhibit objects by viewing closely or having a second look, since no effects were observed concerning the suppression of the objects adjacent to salient ones, or the overall exhibitions by the salient objects. Moreover, the analyses showed that the participants performed these behaviors more frequently in DE1 compared to PE, which might be related with the minimized cost (physical effort) of these behaviors in the digital medium. Another set of analyses revealed that there were no significant differences between the two salience parameters in terms of their power of encouraging participants to engage with the objects, despite the higher number of behaviors observed in DE2 than in DE1.

Overall, the main findings of this study supported previous research in the field, as well as contributing to the newly growing research on digital exhibitions by providing support for the hypotheses addressing ordinal position, salience parameters, competition effects, and preliminary evidence for the difference between the way these parameters operate in physical and digital exhibition environments. It is expected that these research results will contribute to advancing the understanding of visitor attention in both physical and virtual museum settings.

Conclusions and suggestions for future research

A basic contribution of the present experiments was to explore the impact of ordinal position, two different parameters of object salience and proximity to salient objects on visitor attention in digital exhibitions (to our knowledge, for the first time). Our experimental designs also enabled us to make direct comparisons with trends observed in physical exhibitions. The specific results can be listed as below:

- Attention decline due to satiation toward the end of visits also occurs in digital exhibitions, regardless of the salience parameter.
- Salient objects hold more visitor attention in digital exhibitions as well, and three-dimensionality seems to be more powerful than size.
- There may also be a trend for exhibit objects in digital exhibitions to be overshadowed by salient objects when they are positioned in an adjacent position. However, the intensity of this overshadowing effect by the larger objects in digital exhibitions seems to be diminished compared to that in physical exhibitions, and it is non-significant when the salience parameter is three-dimensionality rather than size.
- The presence of a salient object did not seem to suppress the overall attention to the digital exhibitions, as it did in physical exhibitions. On the contrary, there was a trend for it to increase the overall attention held by both of the digital exhibitions involving size or three-dimensionality as salience parameters.

To be able to make direct comparisons between the trends observed in digital exhibitions and those in physical exhibitions, we tried to keep the design of the present experiments parallel to that of a recent experiment conducted in a physical context (Turgay Zıraman and Imamoğlu 2020), despite the extra opportunities provided by the digital medium to improve the design. Future research may employ more complex digital exhibition designs and more advanced measurement techniques such as eye-tracking in order to investigate the role of the related variables.

To explore if attention distribution schemes would be influenced by changing the salience parameters embodied by the exhibit objects in the digital context, we also investigated three-dimensionality in a separate experiment. Since we have found significant differences between these two salience parameters, future research may explore the impact of other parameters such as sense-modality (e.g., audio-visual artworks), motion, or interactivity in digital exhibitions. Moreover, only two levels of both size (small and large) and three-dimensionality (2D and 2.5D) were employed in the present study. Including additional levels of these salience parameters may provide a more elaborate view of their hierarchy. Furthermore, considering the well-established *Von Restorff effect,* which asserts that observers would memorize an item within a multielement display better when this item is different from the rest (Wallace 1965), future studies may benefit from involving reversed experimental setups: for example, by replacing smaller objects with larger ones and integrating only one smaller object among them. Such a manipulation in the design of the experiment might help distinguish whether larger or three-dimensional objects are indeed superior to smaller or two-dimensional objects in terms of salience, or visitor attention is in fact attracted to their distinctiveness of those objects.

By considering the interplay of the isolated impacts of all the parameters related with visitors (e.g., age, gender, ethnicity, interests), exhibition space (e.g., digital representation of space, architectural style, context, lighting, layout of doors and windows, layout of exhibits), and exhibits (e.g., physical parameters such as dimensions, symbolic meaning, novelty) on visitor attention, exhibition designers may be able to achieve attention distribution schemes approaching their intended outcomes. The results of the present study are expected to provide an input to this repository of variables.

In conclusion, in view of the concept of *digital exhibition*, the present study offers several inputs to the field of visitor studies by extending our knowledge of the role of some important variables to the digital context, and hence, providing a bridge between theoretical frameworks regarding exhibitions in physical and digital contexts. In addition, it suggests potential advantages over physical exhibitions such that the visitors can spend less energy, therefore they can spend more time in the exhibition, since the salient objects do not seem to take time away from the overall exhibition. Moreover, it responds to a rapidly growing necessity of research in the field: with the mobility restrictions due to COVID-19 pandemic, we have once again realized and faced the indispensability of digital media for our private and professional needs. This study is expected to induce further research to explore the relationships between physical and digital exhibitions, which may guide future digital exhibition designs.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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