Technological Novelty and Open-Endedness: Two Characteristics of Interactive Exhibits That Contribute to the Holding of Visitor Attention in a Science Museum

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Abstract: This study was undertaken to isolate characteristics of interactive exhibits that are particularly effective in attracting and holding the attention of visitors in a science museum. Forty-seven visitors were tracked through two adjacent exhibitions, comprising a total of 61 interactive exhibits. Four exhibit characteristics were identified and examined: technological novelty, user-centeredness, sensory stimulation, and open-endedness. Regression analyses show that two of these characteristics, technological novelty and open-endedness, help to account for the variance in average visitor holding time; these characteristics have positive correlations with the amount of time spent by visitors at exhibits. Nonsignificant results are explained in terms of mitigating environmental and exhibit-related factors. In addition, topics for future study are suggested. © 2003 Wiley Periodicals, Inc. J Res Sci Teach 40: 121–137, 2003

The factors that affect visitor behavior in a museum can be placed into three broad categories (Falk, Koran, Dierking, & Dreblow, 1985): visitor factors, setting or environmental factors, and exhibit factors. Visitor factors have previously been investigated in Sandifer (1997), a study that explored how visitor characteristics help explain visitor behavior. The study found differences in behavior between family and nonfamily visitors and weekday and weekend visitors; the differences were explained by an interaction between visitor goals (learning agendas) and aspects of the setting (crowdedness). The present study furthers our understanding of the museum visit by turning to the second category, exhibit factors, and focusing on the ways in which visitor behavior is affected by the exhibits. In particular, this study explores the relationship between visitor attention and characteristics of interactive science exhibits.

Research has already established that interactive exhibits attract and hold visitor attention for longer periods of time than noninteractive exhibits (Koran, Koran, & Longino, 1986; Koran, Morrison, Lehman, Koran, & Gandara, 1984; Melton, 1972). For example, the average time per exhibit spent by visitors at the Reuben Fleet Science Center (RFSC; the site for this study) was found (Sandifer, 1997) to be nearly three times the 30-second average reported by museums with noninteractive dioramas (Cone & Kendall, 1978; Naqvy, Venugopal, Falk, & Dierking, 1991). In the present study, however, the purpose was to go beyond the interactive versus noninteractive distinction to fine-tune our understanding of the type of exhibits that we already

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DOI 10.1002/tea.10068
Published online in Wiley InterScience (www.interscience.wiley.com).

know to be more successful in attracting and holding visitor attention—that is, interactive exhibits. More specifically, the purpose of this study was to answer the following research question: How do different characteristics of interactive exhibits account for the variance in visitor attention at these exhibits?

Prior Research on the Attraction and Holding of Visitor Attention

Measures of Visitor Attention

Since the 1920s and 1930s (cf. Melton, 1936; Robinson, 1928), researchers have used time-based statistics to describe visitor behavior at museums, in exhibitions, and at individual exhibits (Hein, 1998). More specifically, time has been used as a powerful, unobtrusive measure of visitor attention (Falk, 1982; Serrell, 1995).

Measures of attention at the institution include the total time spent in the museum and the amount of time centered on exhibits versus the amount of time spent eating and resting. Diamond (1986) found that the average total time for family groups at the Lawrence Hall of Science and the Exploratorium was a little over 2 hours; in these institutions, visitors spent an average of 80% and 92% of their total time, respectively, in exhibit areas. In an earlier analysis of the data used in the present study, Sandifer (1997) determined that visitors spent an average of 47 minutes in the RFSC; the shortest visit lasted 12 minutes, whereas the longest lasted 2 hours 23 minutes. However, not included in these times are the more than 60 minutes that many visitors spent in attendance at an OMNIMAX movie presentation.

Measures of visitor attention per exhibition include total time in the exhibition, fraction of the total number of exhibits at which the visitor stops or spends a minimum amount of time, fraction of the total time in the exhibition spent at the exhibits, and amount of time spent at each exhibit. Other exhibition-level indices of visitor attention include the number of square feet per minute covered by visitors and the percentage of visitors who interact with more than half of the exhibits in an exhibition (Serrell, 1998). In a summary of visitor tracking data from 34 different exhibitions, Serrell (1998, p. 29) calculated that on average, visitors spent 13 minutes in these exhibitions, during which time they stopped at 29% of the exhibits; overall, 20% of visitors interacted with at least half of the exhibits in these exhibitions. At the RFSC, it was found that visitors spent an average of 19 minutes in each of the two exhibitions and became engaged with 39% of each exhibition's individual exhibits (Sandifer, 1997).

Research into visitor attention at the exhibit level has primarily focused on three statistical measures: attracting power, holding power, and average holding time. Attracting power is typically defined as the percentage (or fraction) of visitors who stop at a given exhibit for a minimum amount of time (e.g., 5 seconds). Holding power is defined as the ratio (averaged over visitors) of the actual time spent at an exhibit to the minimum viewing time necessary to examine key objects, read labels, and so forth. An exhibit's average holding time is defined simply as the average time that visitors spend at the exhibit.

In some studies (e.g., Boisvert & Slez, 1995), the term *holding power* has been used synonymously with *average holding time*. However, Shettel (1997) made a careful distinction between holding power and holding time—where holding time is defined as the time that a visitor spends at an exhibit and holding power is reserved for the dimensionless ratio described above.

All of the measures of attention listed above are per visitor or per exhibit; overall trends in the data can be established by examining the mean, median, or distribution of measures over all visitors or all exhibits, respectively.

In the present study, attracting power and average holding time are used as measures of visitor attention at an individual exhibit. Holding power is not used because it is not clear how this measure, which typically has been applied to static exhibits, would be applied to the interactive exhibits in this study.

Characteristics Affecting the Attraction and Holding of Visitor Attention

The ways in which exhibits attract and hold visitor attention have seemingly always been on the mind of exhibit developers, museum directors, and museum researchers. A number of exhibit characteristics relating to attracting power and holding time have been addressed by prior research.

Large (Patterson & Bitgood, 1988), sound-emitting (Peart, 1984), or moving (Melton, 1972) exhibits have been shown to attract and hold visitor attention to a greater degree than small, soundless, or static exhibits. Drawing from their own observational data and a review of the literature, Borun and Dritsas (1997) identified seven exhibit characteristics that attract and hold the attention of family groups:

- multisided: the family can cluster around the exhibit
- multiuser: interaction allows for several sets of hands (or bodies)
- accessible: comfortably used by children and adults
- multioutcome: observations and outcomes are sufficiently complex to foster group discussion
- multimodal: appeals to different learning styles and levels of knowledge
- readable: text is arranged in easily understood segments
- relevant: provides cognitive links to visitors' existing knowledge and experience.

Peart (1984) determined that concrete exhibits (three-dimensional objects) had greater attracting and holding power than abstract exhibits (words or pictures only). In an analysis of five different exhibit styles, Boisvert and Slez (1995) found that exhibit Styles 1 (large, novel, and concrete exhibits), 2 (small, concrete, and interactive exhibits), and 3 (staffed demonstrations) attracted more visitors than exhibit Styles 4 (abstract, instruction-driven interactive exhibits) and 5 (abstract, computer bank or books). Holding time was largest for exhibit Styles 2 and 3. Overall, the superiority of concrete interactive exhibits in terms of attracting power and holding time has been verified by a number of researchers (Koran et al., 1984, 1986; Melton, 1972).

In a different kind of analysis, Alt and Shaw (1984) found that a statistically defined difference between individual exhibits and an ideal exhibit correlated negatively with attraction power ($r = -0.70$), although the difference did not correlate with holding time. Through a statistical analysis of visitor responses, Alt and Shaw determined that exhibits which approach ideal status do the following: make the subject come to life, allow visitors to understand the point(s) of the exhibit quickly, have something for all ages, and are memorable. In the same manner, it was determined that exhibits are far from ideal if they are confusing, do not give enough information, are placed badly, or lose attention to nearby displays.

Theories Underlying the Attraction and Holding of Visitor Attention

Although it is useful and necessary for museum educators to recognize exhibit characteristics that are successful at attracting and holding visitor attention, it is perhaps even more useful for educators to have a model for why particular exhibit characteristics have positive or negative effects on visitor attention.

As open-ended centers of informal learning, science museums allow visitors great freedom in how, when, and to what extent they direct their attention to the exhibits by which they are constantly surrounded. Csikszentmihalyi and Hermanson (1995) explained that in this type of environment, the initial attraction of visitor attention to an exhibit is primarily based on curiosity, which is defined as the degree to which an individual will devote cognitive resources to new information or stimuli. Csikszentmihalyi and Hermanson stated that, generally speaking, this devotion of cognitive resources results from the satisfaction that people receive from processing information that is novel, interesting, or personally relevant, which explains why novel or relevant exhibits (as shown above) are successful at attracting visitor attention. A second, more automatic reason for the devotion of cognitive resources to new information is that, from birth, people are innately attracted to loud noises or motion (Cole & Cole, 1996)—hence the reason why exhibits with these characteristics are generally more successful than others at attracting visitor attention.

Accepting that visitors initially attend to exhibits because of sensory stimuli (noises and sounds) or other curiosity attractors (novelty, interest, and relevance), there is still nothing to guarantee that visitors will be willing to dedicate additional attention to the exhibit, whether in the form of reading the exhibit text, examining the exhibit object, manipulating the exhibit's interactive components, or reflecting on the exhibit content. For this to occur, visitors must, through their engagement with the exhibit, reach an immersive experiential state of intellectual and emotional arousal (Csikszentmihalyi & Hermanson, 1995); at this point, the exhibit task has become intrinsically motivating, meaning that the task itself has become an interesting, enjoyable, or otherwise satisfying endeavor (Deci & Ryan, 1985; Schiefele & Rheinberg, 1997).

Psychologists have identified some general characteristics of intrinsically motivating tasks (Csikszentmihalyi & Hermanson, 1995; Deci & Ryan, 1985; Schiefele & Rheinberg, 1997), including clear task goals, the degree to which a person has control over the task, personal relevance (which is also found in the list of attracting characteristics because it affects both the initial attraction to the task and subsequent intrinsic motivation of the task), and the proper match of the task to the person's abilities (i.e., the task is neither too difficult nor too easy). Clearly, these general characteristics are represented in the characteristics of exhibits (above) that have been found to affect the holding of visitor attention: exhibit interactivity (Koran et al., 1984, 1986; Melton, 1972) partially represents the visitor's control over the exhibit task; concreteness (Boisvert & Slez, 1995; Peart, 1984), relevance (Borun & Dritsas, 1997), and the ability to make the subject come to life (Alt & Shaw, 1984) contribute to an exhibit's personal relevance; and an exhibit's accessibility and multimodality (Borun & Dritsas, 1997) address the issue of the appropriateness of the task to the visitors' varied abilities.

Setting

The site of this study, the RFSC, is a small- to medium-size (12,000 ft^2) facility that receives about 600,000 visitors annually. This study was carried out during a 4-month period when two exhibitions occupied the major portion of the museum floor space: Symmetry, consisting of 26 exhibits (these are the individual modules or units that make up the exhibition), and Signals, consisting of 35 exhibits.

Both exhibitions are highly interactive. The exhibits go beyond being hands-on, requiring physical manipulation; they are minds-on exhibits that allow visitors to explore and exercise control over one or more of the exhibits' variable parameters (Eratuuli & Sneider, 1990; Feher, 1990; Feher & Rice, 1985) and provoke the user to further interaction by providing feedback

(Rennie & McClafferty, 1996). Exhibits in these exhibitions are mostly ordinary-size tabletops or consoles that are open to more than one person at a time. In terms of content, the exhibits within each exhibition complement and reinforce each other; they are conceptually dovetailed so that the visitor finds several modes of expression for each idea that is exhibited.

Symmetry emphasizes the fundamental operations that are used in creating and analyzing symmetries. Subtitled "A Universe by Design," this exhibition aims to convey the universality and power of the concept of symmetry. The exhibits provide examples from the arts (Escher drawings, musical compositions, and dance choreographies), crafts (designs in baskets, quilts, and ribbons), physics (crystal structure), chemistry (molecular structure), biology (helical structure of life molecules), and geometry (tilings and mirror puzzles).

Signals deals with the transmission and storage of information. Subtitled "Of Semaphores and Cyberspace," it endeavors to demystify the modern world of the internet, e-mail, faxes, and telephones. To do this, Signals uses low- and high-tech signal generators (pneumatic devices, light semaphores, and long metal springs) to help visitors develop an understanding of the principles of signaling (wave motion, analog and digital systems, interference, and switching).

Methods

Participants

Forty-seven visitors were tracked through 61 exhibits in two thematic exhibitions (Symmetry and Signals) at the RFSC. School groups were excluded from the study because school visits are potentially teacher directed and often limited to a preallotted time duration. Visitors who did not spend time in both exhibitions were also excluded. In addition, because visitorship to the RFSC is distributed across all ages and evenly distributed between both sexes, tracked visitors were chosen such that both sexes and four age groups were equally represented. (One woman >61 years of age was inadvertently omitted from the study.) This stratified sampling reflected the age and gender distribution of the visiting public. The four age classifications in this study were: youth (8–18 years), young adult (19–35 years), adult (36–60 years), and senior (>61 years). Age classifications were assessed visually. For visitors in groups, the first group member to enter the exhibit area with the appropriate age and sex characteristics was the visitor who was chosen for tracking.

Procedure

For each visitor, the following data were recorded: path taken through the exhibition; time spent at each exhibit; and time spent on nonexhibit social and resting activities. Visitors were not aware that they were under observation. Visitor paths were recorded on sheets depicting the exhibition floorplans; a stopwatch was used to measure time. All data were collected by the author.

As visitors moved about the exhibition, their involvement with exhibits ranged from a cursory glance to rich interaction. For the purposes of analysis, only those exhibit interactions in which visitors became engaged were recorded. A visitor was considered to be engaged with an exhibit when she or he spent at least 5 seconds (a) examining the exhibit (which included reading), (b) interacting with the exhibit (i.e., manipulating, touching), or (c) watching another visitor interact with the exhibit. The use of a 5-second cutoff is fairly common in time-based behavioral studies (e.g., Boisvert & Slez, 1994; Naqvy et al., 1991).

Besides the 61 exhibits contained within the two exhibitions, the Science Center housed an additional 17 nonthematic exhibits. These exhibits were located in a room separate from the other display areas. The amount of time visitors spent in this separate room was recorded, although individual exhibit times were not recorded.

Analysis of Exhibit Characteristics

One key aspect of this investigation is that the exhibits in the Symmetry and Signals exhibitions shared a number of common characteristics that kept visitor attention at a relatively high baseline value. These characteristics included a high degree of interactivity, clarity of instructions, an intuitive user interface, and appropriate feedback in the form of immediate effects that result from visitors' interactions. To achieve these characteristics, the exhibits were prototyped, evaluated, and modified as needed before being finalized.

These shared characteristics cannot account for variations in visitor attention to the various exhibits, which is the problem addressed in this report. However, they undoubtedly contribute in an important way to the average (mean) value of visitor attention measures. In another set of exhibits, when feedback or instructions or interface design had not received equal care throughout the exhibit development process, these characteristics might show up as important in explaining differences in visitor attention to different exhibits.

In addition, other characteristics that researchers have found to be significant contributors to visitor attention, such as large size (Patterson & Bitgood, 1988) and accessibility to children and adults alike (Borun & Dritsas, 1997), are not relevant in the present study because none of the exhibits in the sample differs greatly in size from the others, and all of them are deliberately constructed to be as accessible as possible.

Therefore, in this investigation, the first step was to identify the relevant ways in which the 61 exhibits in our sample differed from one another. This was necessary to determine to what extent these differences helped to account for variations in visitor attention at these exhibits. The second step was to use these differences to develop exhibit categories. The third step was to classify the exhibits within these categories.

Developing the Exhibit Categories

This portion of the analysis was done by the author in collaboration with the director of the RFSC, an expert in the field of museum education, to ensure a high degree of validity for the exhibit categories developed in this article.

Identifying Differences Between Exhibits. The author and director each made a list of the ways in which the exhibits differed from one another. These differences represented many different dimensions of the exhibits, including accessibility to multiple users, type of object in the exhibit, degree to which the exhibit is confined to a particular use, relevance to the user, and sensory stimulation.

For example, some but not all exhibits require cooperation, such as one visitor sending a signal that is received by another visitor. In some exhibits the effect is experienced only by one person at a time; in others, one person does the interaction but a group can hear or see the results. Several exhibits require visitors to use technological devices such as lasers and computers, whereas others are low tech and use simple mirrors or tiles. Some exhibits encourage visitors to carry out their own personal explorations; others limit visitor usage to those actions prescribed by the designers. Many exhibits bring the visitor's person into the actual activity: visitors' voices are the signals studied, or visitors' bodies are the objects of symmetry operations. Many exhibits give sensory rewards to the users, such as noises or flashing lights.

The separate lists of exhibit differences were combined to form a single list of differences for the 61 exhibits in the sample. Once the many differences between exhibits had been identified, the next step was to narrow down and more precisely define the exhibit characteristics (categories) that would be used in the analysis of the variance of visitor behavior at these exhibits.

Defining the Exhibit Categories. Based on prior research on the characteristics of novelty (Boisvert & Slez, 1995), the ability to generate multiple outcomes (Borun & Dritsas, 1997), relevance (Borun & Dritsas, 1997), and the ability to move (Melton, 1972) or emit sound (Peart, 1984), four of our exhibit categories looked promising in terms of their possible relationship to visitor attention: exhibits that are technologically novel, open-ended exhibits, user-centered exhibits, and exhibits that provide sensory stimulation. Equally as important, these characteristics were present in enough exhibits that a valid statistical analysis was possible.

Once the number of categories had been reduced to four, the next task was to classify the 61 exhibits in the sample according to these categories. The process of classifying the exhibits was both lengthy and animated; each analyzer did an independent classification; then, when opinions differed, the criteria that defined the category were refined until consensus was reached. The procedure of defining and refining the four exhibit categories was analogous to the commonly used constant comparison method in qualitative research, in which emergent data categories undergo continuous refinement throughout the analysis process, which in turns feeds back into the process of category coding (Glaser & Strauss, 1967, as cited in LeCompte & Preissle, 1993).

For example, there was initial disagreement as to whether Thermal Images, an exhibit that uses an infrared camera, could be considered technologically novel. At the time, the only criterion for novelty was that the exhibit contains visible state-of-the-art devices, and infrared technology has been around for years. Yet, for visitors who have never used such a camera, it is certainly novel technology. The difficulty was resolved by introducing another criterion to define the category: The exhibit, through the use of technology, illustrates phenomena that would otherwise be impossible or laborious for visitors to explore on their own. Thus, the final characterization of the categories emerged from the very process of analysis.

At the conclusion of the collaborative process of exhibit classification, the four exhibit categories were operationally defined as follows.

Technologically Novel. An exhibit was considered to be technologically novel if it met at least one of the following criteria:

1. The exhibit contained visible state-of-the-art devices.
2. The exhibit, through the use of technology, illustrated phenomena that would otherwise be impossible or laborious for visitors to explore on their own.

Examples include exhibits that contain lasers, or sophisticated software (such as the Internet), or an infrared camera.

Open-ended. An exhibit was considered to be open-ended if it met at least one of the following criteria:

1. The exhibit allowed for the achievement of multiple visitor-set goals.
2. The exhibit allowed for one goal to be achieved in multiple ways.

For this category it is easier to give a counterexample: Exhibits that incorporate questions that have a definite answer, where the visitors lift a flap or press a button to find out if they are right or wrong, are not classified as open-ended.

User-Centered. An exhibit was considered to be user-centered if the outcome of the exhibit manipulation involved a representation of or an effect on the user's body or voice. Examples include exhibits with mirrors or microphones, where visitors see themselves or hear their own voice.

Stimulates the Senses. An exhibit was considered to be a member of this category if it met at least one of the following criteria:

1. The exhibit emitted sounds on its own or when in use.
2. The exhibit had one or more visible parts, objects, or images that moved on their own or when the exhibit was in use.
3. The exhibit had lights that blinked or flashed on their own or when the exhibit was in use.

Classifying the Exhibits

The Signals and Symmetry exhibits were classified as technologically novel, open-ended, user-centered, and/or stimulates the senses according to the criteria outlined above. Table 1 shows the list of classified exhibits. It can be seen that some exhibits fit one category or no categories; however, most exhibits fit multiple categories. Here are four examples.

Fragments of Jericho allows visitors to use a laser to retrieve the sounds that are stored as wiggles in the grooves of a clay cylinder. The exhibit is classified as technologically novel (because visitors use a laser) and stimulating the senses (because it produces sounds). It is not open-ended because it can be used only as prescribed by the design; nor is it user-centered because its manipulation does not result in a representation of, or effect on, the users' body.

In Do–Undo a videocamera records the user's movements and immediately plays them backward (in time reversal) on a monitor screen. This exhibits fits all four categories because there is no limit to the different movements the user can execute, the effect is dynamic (it involves movement), it involves a representation of the visitor's body, and it uses technology not readily available to visitors in everyday life.

Pattern Blocks provides the user with colorful geometric tiles for making repetitive, symmetric, two-dimensional patterns. This exhibit is classified as open-ended because users can produce as many patterns as they can create. It uses simple plastic blocks to produce static designs that do not involve representations of the user's body; therefore, the exhibit does not fit any of the other three categories.

Quartz Crystals provides the visitor with modified protractors to measure the angles on the surface of large crystals. Because the task is clearly prescribed, does not generate sound or motion,

Table 1
Exhibit characteristics, attracting power, and average holding time for each exhibit

Exhibits	Attracting Power	Avg. Holding Time (min)	Open-Ended	Technologically Novel	Stimulates the Senses	User-Centered	None of These
AM Messages	0.33	1.0	x		x	x	
Backwords	0.26	2.1	x	x	x	x	
Binary numbers	0.19	1.5					x
Blind spot	0.36	1.7				x	
Buckyball	0.47	1.2					x
Cafe wall	0.30	1.3				x	
Calcite	0.30	1.0					x
Carrier beam	0.51	1.2	x	x	x		
Dance patterns	0.47	0.5					x
Design-a-quilt	0.21	5.0	x	x			
Dial-a-wave	0.26	1.3	x	x	x		
Digital storage	0.40	1.8	x	x			
Digitize it	0.30	1.1		x	x		
Do–undo	0.51	1.6	x	x	x	x	
Fax it	0.34	1.6	x		x		
Flips, turns, slides	0.70	0.9	x				
FM messages	0.32	2.7	x		x	x	
Foot fun	0.28	0.8			x	x	
Fractals	0.26	3.9	x	x	x		
Fragments of jericho	0.43	1.1		x	x		
Frustums	0.45	1.1					x
Groovy records	0.49	0.6					x
Kaleidoscope	0.64	0.8			x		
Light sounds	0.48	1.1	x	x	x	x	
Lightning bugs	0.57	1.0			x		
Modulation	0.34	0.6				x	
Morse code	0.28	4.0	x				
Movers and shakers	0.38	1.0		x	x		
Moving melodies	0.28	1.8	x	x	x		
Mirror images	0.28	0.6	x				
Mirror puzzles	0.38	0.9					x
Noisy signals	0.25	0.5			x		
Pattern blocks	0.23	2.5	x				

Table 1
(Continued)

Exhibits	Attracting Power	Avg. Holding Time (min)	Open-Ended	Technologically Novel	Stimulates the Senses	User-Centered	None of These
Phone your image	0.30	5.6	x	x	x	x	
Polage	0.38	0.7		x			
Polight	0.15	0.5		x			
Quartz crystals	0.36	0.5					x
Resolutions	0.45	1.8	x			x	
Sand sines	0.25	1.5			x		
Self-reflections	0.32	0.5	x		x	x	
Shadow chase	0.60	0.5			x		
Shuftiscope	0.38	0.8		x			
Sikus	0.66	0.8	x		x		
Silicon retina	0.45	0.9	x	x	x	x	
Speech delay	0.27	1.0	x	x	x	x	
Spiraling tones	0.36	0.9			x	x	
Surf the net	0.19	4.2	x	x			
Sym-u-lations	0.40	3.4	x	x		x	
Tacoma narrows	0.38	3.9		x	x		
Thermal images	0.47	1.9	x	x	x	x	
Tilings	0.30	1.8	x				
Time of travel	0.45	0.6			x	x	
Timeshare	0.42	1.6		x	x		
Tones	0.38	1.8	x		x	x	
Tri-a-doodle	0.26	1.9	x	x	x		
Turnstable	0.51	1.2			x		
UV shades	0.36	3.0		x		x	
Visual feedback	0.39	2.6	x	x		x	
Vocal vowels	0.72	0.9	x		x		
Waveforms	0.45	0.8	x	x	x		
Word play	0.34	1.0	x				

and does not involve technologically novel objects or a representation of the visitor's body, this exhibit fits none of the four categories.

Statistical Analysis and Results

Analysis of the effect of the four exhibit characteristics on visitor attention focused specifically on two quantitative measures: attracting power and average holding time. The definitions of an exhibit's attracting power and average holding time are as follows.

Attracting Power = (Number of visitors who become engaged with the exhibit)
÷ (Total number of visitors who enter the exhibition).
Average Holding Time = (Total time spent at the exhibit by engaged visitors)
÷ (Total number of engaged visitors).

Range of Values for Attracting Power and Average Holding Time

Values for the attracting power ranged from high values of .72 (Vocal Vowels), .70 (Flips, Turns, and Slides), and .66 (Sikus) to low values of .19 (Binary Numbers and Surf the Net) and .15 (Polight). This means that the former three exhibits attracted over 65% of visitors, whereas the latter three exhibits attracted fewer than 20% of visitors. The overall mean for attracting power was .38. Values for average holding time ranged from high values of 5.6 minutes (Phone Your Image), 5.0 minutes (Design-a-Quilt), and 4.2 minutes (Surf the Net) to a low value of 0.5 minutes, or 30 seconds (Dance Patterns, Polight, Quartz Crystals, Noisy Signals, Self-reflections, and Shadow Chase). The overall mean for average holding time was 1.6 minutes.

Accounting for the Variance in Attracting Power and Average Holding Time

The relationships among the two dependent variables (attracting power and average holding time) and the exhibit characteristics were determined in the following manner. As a first step, a point biserial correlation between each exhibit characteristic (the dichotomous variable) and the dependent variable of interest (the continuous variable) was calculated. Next, if any of the exhibit characteristics were found to have a significant correlation with the dependent variable, a regression analysis was performed on the entire set of characteristics. The correlations were calculated to see if a significant relation existed between the exhibit characteristics and attracting power or average holding time. The purpose of the regression was to determine the amount of variance in attracting power and average holding time that each exhibit characteristic explained over and above the others.

Attracting Power. To explain the variance in attracting power among the exhibits, three characteristics were considered: technologically novel, stimulates the senses, and user-centered. Open-endedness was not included because it is a characteristic that cannot be appreciated unless the visitor spends considerable time at the exhibit. Because none of the zero-order correlations among these three exhibit characteristics and attracting power was significant, regression proved to be unnecessary.

The attracting power for each exhibit can be found in Table 1. The distribution of attracting power is shown in Figure 1. The zero-order correlations are shown in Table 2.

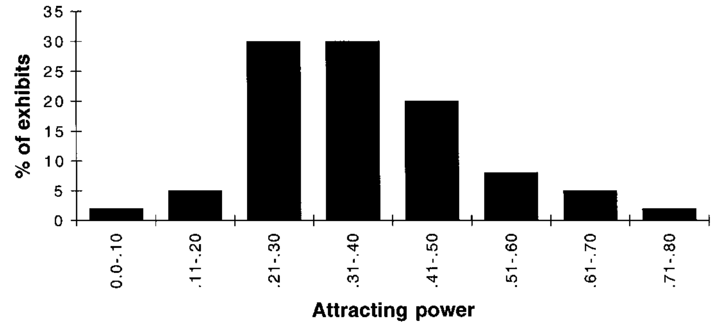

Figure 1. Distribution of attracting power. $N = 61$ exhibits.

Average Holding Time. Once it was determined that at least one of the zero-order correlations was significant, the characteristics of technological novelty, user-centeredness, sensory stimulation, and open-endedness were regressed on average holding time. Because there was no theoretical justification for entering the variables in a particular order, they were entered into the regression equation in a stepwise fashion (i.e., the statistical analysis program determined the order of entry based on the relative importance of the remaining variables' partial correlations with average holding time).

Only those exhibits that attracted at least five visitors were included in the analysis. Because one Symmetry exhibit (Sym-u-lations) and two Signals exhibits (Noisy Signals and Surf the Net) did not meet this criterion, the number of exhibits used for analysis was 58. The average holding time for each exhibit can be found in Table 1. The distribution of average holding time is shown in Figure 2. The zero-order correlations between variables are shown in Table 3. The results of the regression are shown in Table 4.

Discussion

Table 1 clearly illustrates that there was a wide variation in both attracting power and average holding time among the 61 exhibits. Three important results related to these variances. (a) Open-endedness and technological novelty helped account for a significant portion of the variance in average holding time, whereas user-centeredness and sensory stimulation did not. (b) None of the relevant exhibit characteristics (technological novelty, open-endedness, and sensory stimulation) accounted for a significant portion of the variance in attracting power. (c) A large portion of the variance in both attracting power and average holding time remains unexplained.

Table 2
Correlations between attracting power and exhibit characteristics

	Attracting Power	Technological Novelty	Sensory Stimulation	User-Centeredness
Attracting power				
Technological novelty	−.24			
Sensory stimulation	.23	.16		
User-centeredness	−.12	.09	.16	

Note. $N = 61$ exhibits. All correlations are nonsignificant.

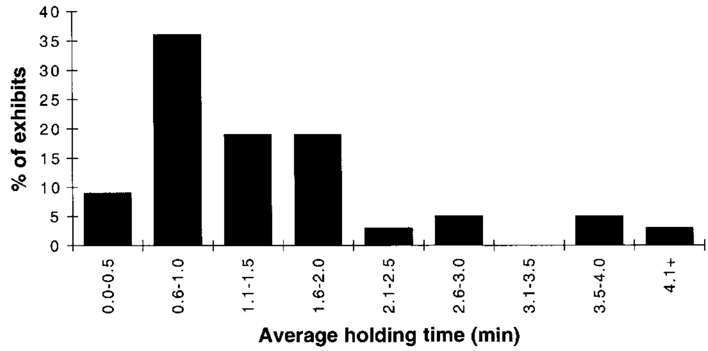

Figure 2. Distribution of average holding time. $N = 58$ exhibits.

Result 1: Open-endedness and Technological Novelty Helped Account for a Significant Portion of the Variance in Average Holding Time, Whereas User-Centeredness and Sensory Stimulation Did Not

It is clear that the characteristics of technological novelty and open-endedness help account for the variance in the amount of time that exhibits hold visitor attention. The technological novelty result is perhaps unsurprising because prior research had already established that visitors tend to spend more time at exhibits with novel phenomena or objects, in part because novelty is an important factor in intrinsic motivation and task engagement. The open-endedness result is more interesting because the implication is that visitors tend to take advantage of open-ended exhibit activities when given the opportunity to do so, although this result might also have been predicted, given the fact that user control over the task is one of the general characteristics of intrinsically motivating tasks. An example of visitors taking advantage of an exhibit's open-endedness can be found at the Design-a-Quilt exhibit (which had an average holding time of 5.0 minutes), in which visitors would often spend large amounts of time creating their own quilt patterns, after which they would typically call over family members and friends to admire their work and creativity.

More surprising might be the fact that regression results did not support the idea that sensory stimulation or user-centeredness help account for variance in average holding time. It is difficult to explain these results, although it has already been postulated that some characteristics that

Table 3
Correlations between average holding time and exhibit characteristics

	Average Holding Time	Technological Novelty	Sensory Stimulation	User-Centeredness	Open-Endedness
Average holding time					
Technological novelty	.33*				
Sensory stimulation	.05	.27*			
User-centeredness	.12	.03	.19		
Open-endedness	.38**	.21	.20	.19	

Note. $N = 58$ exhibits.
*$p < .05$, **$p < .01$.

Table 4
Regression of exhibit characteristics on average holding time

Exhibit Characteristic	Cumulative R^2	ΔR^2	F Test	Significance
Open-endedness	0.15	0.15	$F(1, 56) = 9.7$	$p < .01$
Technological novelty	0.21	0.06	$F(1, 55) = 4.7$	$p < .05$
Sensory stimulation	0.21	NS	$F(1, 54) = 0.6$	$p > .05$
User-centeredness	0.21	NS	$F(1, 54) = 0.2$	$p > .05$

Note. $N = 58$ exhibits. NS = nonsignificant.

typically attract visitor attention—bright color or loud noise, for instance, which are purely sensory in nature—are not able to hold visitor attention once the visitors are attracted to the exhibit (Shettel, 1973).

Regarding the user-centered result, it seems counterintuitive that visitors would not find vocal and visual representations of themselves interesting, but one possibility is that the self as an exhibit topic may be successful only if the associated exhibit activities are novel or open-ended in nature. For example, the Sym-u-lations exhibit, with an average holding time of 3.4 minutes, allows users to capture pictures of their faces on a computer monitor and then modify their facial symmetries in a variety of different ways. The Sym-u-lation activity is both open-ended (visitors can position themselves in front of the camera in different ways to create an endless number of pictures and symmetrical modifications) and novel (the activity gives rise to unusual representations on a computer screen); in particular, the novelty of the activity gives rise to surprising and amusing results (e.g., a funny picture of the visitor's asymmetric face) that likely feed into the intellectually and emotionally aroused state of intrinsic motivation described by Csikszentmihalyi and Hermanson (1995). In contrast, in the Self-Reflections exhibit, visitors—by wearing half-masks—can make only a small number of changes to their face and body. Because visitors would be expected to be familiar with masks and mirrors, these minor changes would be far less novel (and therefore, less intrinsically motivating) than the symmetry modifications from Sym-u-lations. So, whereas both Sym-u-lations and Self-reflections involve images of the user's body, the Self-reflections exhibit's lack of novelty and open-endedness may have contributed to the fact that its average holding time was only 30 seconds—a value far below the 3.4-minute average holding time for Sym-u-lations.

Result 2: None of the Relevant Exhibit Characteristics Accounted for a Significant Portion of the Variance in Attracting Power

Given the connections among sound, motion, novelty, relevance, and visitor attention in prior research, which can be explained by the ability of these characteristics to evoke visitor curiosity, it is somewhat surprising that in this case, the exhibit characteristics of sensory stimulation, technological novelty, and user-centeredness do not explain the variance in exhibits' attracting power. One possible explanation for this result is that the attractive power of these exhibit characteristics was overshadowed by certain environmental factors that are inherent in busy, crowded museums such as the RFSC. For instance, it is possible that the sound-emitting or moving exhibits could not compete with the background noise and motion in the RFSC, and also that the technologically novel and user-centered portions of these types of exhibits were not clearly visible (and therefore could not attract the visitors' attention) owing to the exhibits already being in use.

A posthoc correlation between the exhibits' attracting power and average holding time, $r = -0.37, p < .01$, lends some credence to this interpretation. The negative correlation indicates that exhibits with larger average holding times tended to attract fewer visitors than those exhibits with smaller average holding times. This lines up with the hypothesis that environmental factors rather than exhibit characteristics may have accounted for much of the variance in attracting power because of the implication that visitors tended to pass over exhibits already in use (typically, exhibits with larger average holding times) and instead chose to interact with exhibits that were available (typically, exhibits with smaller average holding times). In this study, the Surf the Net exhibit provides an example of this phenomenon. With an average holding time of 4.2 minutes, this technologically novel exhibit—in which visitors could use the Internet at a desktop computer—was often in use, with 1–2 visitors typically waiting in line to use the exhibit. As a result, new visitors to the exhibit area would often pass this exhibit by and instead stop at an exhibit that was less busy. Therefore, although it is certainly the case that busy exhibits might attract the curiosity of passing visitors, the idea that visitors might also pass over busy exhibits in favor of less busy exhibits is a hypothesis that could be tested in future studies on the effect of environmental factors on visitor attention.

Result 3: A Large Portion of the Variance in Both Attracting Power and Average Holding Time Remains Unexplained

The final important result is that, as is nearly always the case with regression analyses, a large portion of the variance in the dependent variable(s) remains unexplained. Such was certainly the case with attracting power, in which all of the variance remains unexplained, and was also the case for average holding time, in which 79% of the variance remains unexplained.

In this study, the method of investigating the relationship between exhibit characteristics and visitor attention was both observational and unobtrusive. This method was intentionally chosen so that visitor behavior would be as natural as possible during the period of observation, which in turn would lead to attraction and average time data with a high degree of validity. On the other hand, in future studies, additional factors could be identified through up-close observation of visitor conversations and interactions (e.g., Diamond, 1986) or postvisit or during-visit interviews with visitors. Such qualitative methods would allow researchers to identify other factors that might have contributed to this unexplained variance in visitor attention, including prior knowledge of the exhibit content, interest in exhibit content, and visitor perception of the exhibit (e.g., visitors may not perceive particular exhibits to be open-ended, even though they are meant to be). Such methods would also bring to light the quality of visitor interactions—with both the exhibit and each other—and the precise ways in which these interactions contribute to visitors' development of knowledge, interest, and intrinsic motivation at a given exhibit.

Conclusion

The present study allowed us to fine-tune our understanding of the museum visit by investigating the effects of particular exhibit characteristics on visitor attention. More specifically, four exhibit categories (characteristics) were identified and carefully defined, after which the relationships among these categories and variances in attracting power and average holding time were investigated. These four categories—technological novelty, open-endedness, user-centeredness, and sensory stimulation—can be used in future studies on visitor experiences with interactive exhibits, where these categories might contribute to science educators' understanding of visitor behavior, visitor learning, and visitor interactions at these exhibits.

Another contribution of this study was its unique analysis of exhibit characteristics and visitor attention. What made the analysis possible was that visitors were able to interact with a large ensemble of exhibits—one that contained enough interexhibit variation to allow for valid statistical analysis. In other words, the exhibits in this ensemble needed to possess a variety of well-defined exhibit characteristics, and there also needed to be enough exhibits per category so that the regression analysis would be powerful enough to detect significant results. To further examine the effect of particular exhibit characteristics on visitor behavior, a possible next step would be to create a new ensemble of exhibits—one that contained exhibits that differed from each other in the characteristics of interest. By tracking visitors through this new ensemble of exhibits, one could then isolate the effect of the characteristics of interest. To do so properly, however, it is suggested that such a research project should control or account for the types of mitigating environmental factors observed in the present study. For instance, one could introduce an additional factor for exhibit availability that would identify whether exhibits are in use by other visitors during a tracking. The findings of such carefully controlled exhibit/environment studies have practical applications; the better we understand the relationship between exhibit characteristics, museum environment, and visitor attention, the more we are able to design effective exhibits and predict the success of exhibitions.

Warm, gracious thanks to Elsa Feher for her guidance and support and for her insightful comments on earlier versions of the manuscript. Thanks also to Randy Philipp, Leonie Rennie, and certain anonymous reviewers for their helpful comments and suggestions.

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