Time-Based Behaviors at an Interactive Science Museum: Exploring the Differences between Weekday/Weekend and Family/Nonfamily Visitors

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ABSTRACT: The purpose of this study was to determine if time-based learning-associated visitor behaviors at interactive science museums differ across weekend/weekday groups and family/nonfamily groups. Forty-seven visitors were tracked through two interactive, thematic exhibitions at the Reuben Fleet Science Center. Statistical analysis of five separate dependent measures showed that: (a) regardless of the day of the visit, families spent more time than nonfamilies in individual exhibitions and in the science museum as a whole; (b) there was a separation of weekday visitors into two distinct groups: family visitors who spent, on average, almost 2 minutes per exhibit, and nonfamily visitors who spent, on average, less than 1 minute per exhibit; and (c) weekend family and nonfamily visitors did not differ in their average time spent per exhibit. These results are explained by a difference in visitor agendas and the crowded nature of weekend visits. *Sci Ed* **81:**689–701, 1997.

INTRODUCTION

Science museums provide an opportunity for visitors to learn about the nature and substance of science. As open-ended, unstructured environments (Wellington, 1990), science museums allow for freedom of action. But how much activity in the museum is learning-related? One method of answering this question is to establish the existence of predictable patterns (Falk, Koran, Dierking, & Dreblow, 1985) of "learning-associated" (Boisvert & Slez, 1994, 1995) or "learning-related" (McManus, 1987, 1988) visitor behaviors; such behaviors consist of patterns spread across an entire visit (e.g., patterns of attention; Falk, 1991) and individual behaviors at a single exhibit (pointing, touching, or reading). Time is often used as an unobtrusive, powerful measure of visitor behaviors (Falk, 1982; Serrell, 1995).

A good portion of the existing literature in learning-associated museum research (behavioral

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or otherwise) has dealt with a special subgroup of all science museum visitors: school children on field trips (e.g., Beiers & McRobbie, 1992; Falk, 1983a; Flexer & Borun, 1984; Stronck, 1983; Wright, 1980). However, there now exists a growing body of research centered around the learning-associated behaviors of nonschool visitors: families, couples, and peer groups (e.g., Dierking & Falk, 1994; McManus, 1987, 1988). The present study contributes to this body of research by investigating time-based behaviors of such visitors at an interactive science museum, the Reuben Fleet Science Center.

In particular, this study aims to answer the following research questions:

1. Do family and nonfamily visitors differ in their time-based behaviors?
2. Do weekend and weekday visitors differ in their time-based behaviors?

The specific time-based behaviors under investigation are: total time in the science museum; total time per exhibition; time per exhibit; and the fraction of the time that visitors are engaged with exhibits. One behavior not related to time is also included: fraction of the exhibition with which visitors become engaged.

Time-Based Visitor Behaviors

Many researchers report time-based behaviors (e.g., total time in the museum, average time per exhibit) as a way to provide background information on a particular research site. Stevenson (1991) noted that most visitors spent about an hour in the Launch Pad, an interactive science museum in London, with times ranging between 40 and 90 minutes. Diamond (1986) found that the average total time for family members was slightly over 2 hours at both the Lawrence Hall of Science (220 exhibits) and the Exploratorium (600 exhibits). Combining data from both institutions, Diamond found that 57% of exhibit interactions were less than 1 minute long, whereas 18% of exhibit interactions were over 3 minutes long.

Other studies have specifically focused on how groups (couples, singletons, etc.) compare with one another. In her study of 1572 individuals at the British Museum (Natural History), McManus (1987) discovered that couples, adult peer groups, and groups with at least one child were "likely" to visit an exhibit for at least 30 seconds, 45 seconds, and 60 seconds, respectively. After tracking 154 visitors through the Human Body Discovery Space (HBDS) in Boston's Museum of Science, Boisvert and Slez (1994) determined that neither the day of the week (weekend/weekday) nor type of social group (familes, peers, singletons) influenced the amount of time that visitors spent in the HBDS (10–13 minutes, on average) or the fraction of the exhibition with which visitors spent at least 5 seconds (less than 16%).

In this study, I include one additional measure that is not usually reported: the fraction of time that visitors are engaged with exhibits. In connection with science museums, Stevenson (1991) is one of the few researchers to mention (albeit briefly) this time-based behavior. During their visits to the Launch Pad, Stevenson found that children spent 53% of their time interacting with exhibits—twice as long as the adults. In addition, children and adults spent 29% and 44% (respectively) of their time observing others and 15% and 27% (respectively) of their time moving. In an analysis of visitor attention patterns at the Florida State Museum of Natural History, Falk et al. (1985) sampled visitor attention at three-minute intervals and found that the fraction of visitors who were focused on exhibits on those intervals ranged from 42% to 70%.

Relationship between Visitor Behavior and Learning

Studies linking exhibit time and learning are few and far between. Cone and Kendall (1978) conducted interviews with family visitors to the Science Museum of Minnesota and were able to establish a relationship between time spent at an exhibit and exhibit recall: average visit time for exhibits that were mentioned during interviews was significantly greater than the average visit time for those exhibits not mentioned. Now, exhibit recall does not necessarily imply understanding—but it is reasonable to assume that memories of specific exhibits allow visitors to make connections between past visits and future events (e.g., a television program on Galileo might reinforce and expand the knowledge that was gained from experience with an exhibit on planetary motion).

In a study seeking to establish a direct link between time spent at an exhibit and learning, Falk (1983b) analyzed the behavior of school children at a single exhibit and was able to show a significant correlation ($r = 0.651$, $p < 0.0001$) between exhibit time (under a sigmoid transformation) and the difference between pretest/posttest scores. A more complicated regression analysis of both time and behavior was shown to accurately predict student learning ($R^2 = 0.568$). However, as a population, there was no evidence of significant learning based on the mean difference between pretest/posttest scores. Along similar lines, Peart (1984) was able to show a high positive Spearman correlation ($r_s = 0.80$) between knowledge gain and holding power (the ratio of actual viewing time to the required minimum viewing time), although the correlation was not significant. More recently, a study of families at four different museums (aquarium, zoological garden, academy of natural sciences, science museum) led Borun, Chambers, and Cleghorn (1996) to conclude that learning is significantly related to time spent at an exhibit.

BACKGROUND

Each year the science museum at the Reuben Fleet Space Theater and Science Center receives over 600,000 visitors. Visitors who buy tickets to the big-screen OMNIMAX movie presentations can visit the science museum for an extra dollar. Otherwise, a general ticket to the museum costs $2.50. The science museum is a small- to medium-sized (12,000-square-foot) facility.

Exhibitions at the Science Center are both thematic and interactive. A thematic exhibition supplies a conceptual framework for the visitor; this framework ("theme") houses the entire set of exhibits under a single conceptual umbrella, whereby each exhibit is able to complement and reinforce the other thematic exhibits. In contrast, individual exhibits of a nonthematic exhibition are intended to be stand-alone learning sites. Descriptions of the thematic exhibitions in this study (*Symmetry* and *Signals*) are provided in the Appendix.

Interactive exhibits are a step beyond "hands-on" exhibits that merely require physical manipulation. Interactive exhibits are intended to be "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 further interaction through feedback (Rennie & McClafferty, 1996). For example, in the Dial-a-Wave exhibit in the *Signals* exhibition, the variable parameters were the amplitudes, frequencies, and phases of two separate waves. As visitors changed these parameters, they received visual feedback in the form of changing waveforms on a computer screen. The *Symmetry* and *Signals* exhibitions were designed such that each of their individual exhibits had interactive components of this sort.

METHODS

Participants

During the first 4 months of 1996, 47 visitors were tracked through two thematic exhibitions[1] (*Symmetry* and *Signals*) at the Reuben Fleet Science Center in San Diego, California. School groups were excluded from the study. Visitors who did not spend time in both exhibitions were also excluded.

Visitors were chosen such that: (a) the sample was evenly divided between males and females; and (b) ages were evenly distributed across four age groups: 8–18, 19–35, 36–60, and 61+. Visitors were classified by day of visit (weekday/weekend) and social group (family/nonfamily). Family groups were multigenerational: grandparents with grandchildren, single mothers with children, adults with elderly parents, etc. Nonfamily groups consisted of couples (husband/wife or boyfriend/girlfriend) and groups of friends. The one solitary visitor was classified as a family visitor. Age and group-type classifications were assessed visually.

The number of participants per visitor category (weekday families, etc.) is shown in Table 1.

Procedure

Using the following sampling procedure, I tracked one visitor per group. To start, I tracked the first 8–18-year-old male (regardless of social group) to pass through the entrance. Once the visitor left the science museum, I tracked the first 8–18-year-old female to pass through the entrance. Next, I tracked a male in the 19–35 age group. In this manner, I repeatedly cycled through both sexes and all four age groups until a total of 47 visitors were tracked.[2]

For each visitor, I recorded the following data: the path taken through the exhibition; the time spent at each exhibit; and the time spent on social and resting activities. Visitors were not aware that they were under observation.

As visitors moved about the exhibition, their involvement with exhibits ranged from a cursory glance to a rich interaction. For the purposes of analysis, I included only those exhibit interactions where visitors became *engaged.* A visitor was considered to be engaged with an exhibit when she or he spent at least 5 seconds either: (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 not uncommon in time-based behavioral studies.

TABLE 1
Number of Participants per Visitor Group

	Family	Nonfamily	Total
Weekday	13	8	21
Weekend	18	8	26
Total	31	16	47

[1]Besides the 62 exhibits contained within the two thematic exhibitions (*Symmetry* and *Signals*), the Science Center housed an additional 17 nonthematic exhibits. These exhibits were located in a room that was separate from the other display areas. The amount of time that visitors spent in this separate room was recorded, although individual exhibit times were not recorded.

[2]One 61+ year old female was inadvertently omitted from the study.

DATA ANALYSIS

As a first step, I analyzed the effect of social group (family/nonfamily) and day of visit (weekday/weekend) on the total time spent in the science museum. A 2 (day) × 2 (social group) ANOVA design was used, using total time in the science museum as the dependent measure. Total time was logarithmically transformed (new total time = log_{10} [total time]; see pp. 85–86 in Tabachnick & Fidell, 1989) to meet the statistical assumptions of normality; originally, the distribution of total time was heavily skewed toward the low end (i.e., an extreme positive skew).

Furthermore, I examined the effect of day, social group, and exhibition on the remaining four dependent variables: total time in the exhibition (*Symmetry* or *Signals*), average time per exhibit, fraction of exhibition with which visitors became engaged, and fraction of time engaged with exhibits. A 2 (day) × 2 (social group) × 2 (exhibition) MANOVA analysis was performed on each of the four dependent measures. Exhibition is the within-subjects factor. For the MANOVA analyses, two of the heavily skewed (nonnormal) measures were logarithmically transformed: time spent in the exhibition and average time per exhibit. The other two measures (fraction of time engaged, fraction of exhibition engaged) were not transformed; these measures met the statistical assumptions of normality.

The four dependent measures were defined as follows:

1. *Total time in the exhibition* (time difference between the visitor's entrance and exit). Total time included resting, interacting, talking, walking, and browsing.
2. *Average time per exhibit* [(total time engaged with exhibits) ÷ (number of exhibits engaged)]. Note that time per exhibit is *not* averaged over total time in the exhibition, but instead averaged over the actual time that visitors spent engaged with exhibits.
3. *Fraction of exhibition with which visitors became engaged* [(number of exhibits with which visitors became engaged) ÷ (number of exhibits on the floor in working order)]. *Symmetry* usually had 26 (out of 26) exhibits on the floor in working order. Out of 36 possible *Signals* exhibits, the number of working exhibits at any given time ranged anywhere from 28 to 34 exhibits.
4. *Fraction of time engaged with exhibits* [(total time engaged with exhibits)÷(total time in the exhibition)].

RESULTS

The distribution of total time that visitors spent in the science museum is shown in Figure 1. Total time averaged over all visitors was 47 minutes. The longest visit lasted 2 hours and 23 minutes, whereas the shortest lasted 12 minutes.

Table 2 is a summary by day and social group of total time in the science museum. The average total time in the science museum for families was significantly greater than the average total time in the science museum for nonfamilies (couples and friends), $F(1, 43) = 7.45$, $p < 0.05$. An overall comparison of family and nonfamily visitors is summarized in Figure 2, a graph of two survival curves (Menninger, 1990). Average total time in the science museum for weekend visitors was not significantly different than the average total time in the science museum for weekday visitors, $F(1, 43) = 0.31$, $p > 0.05$. The survival curves for weekday and weekend visitors are shown in Figure 3.

Tables 3–6 are summaries by day and social group of the four remaining dependent measures: total time in the exhibition; time per exhibit; the fraction of time that visitors were engaged with exhibits; and the fraction of the exhibition with which visitors became engaged.

In the first MANOVA analysis, the average time per exhibition for families was significantly

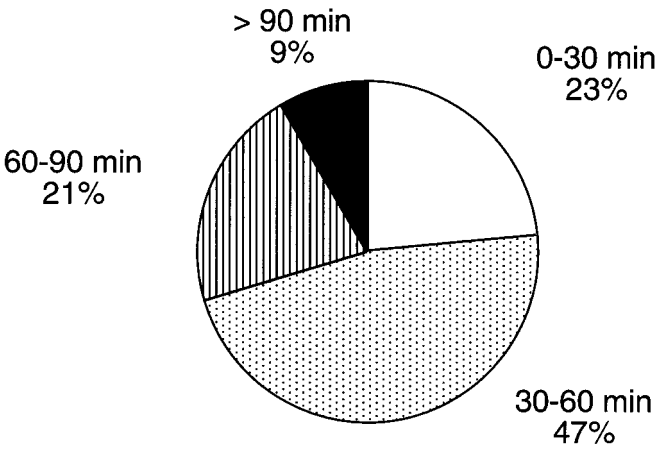

Figure 1. Distribution of total time in the science museum.

greater than the average time per exhibition for nonfamilies, $F(1, 43) = 6.38$, $p < 0.05$. Average total time per exhibition for weekend visitors was not significantly different than average total time per exhibition for weekday visitors, $F(1, 43) = 0.04$, $p > 0.05$.

In the analysis of time per exhibit, a significant day by social group interaction was found, $F(1, 43) = 4.26$, $p < 0.05$. On weekdays, average time per exhibit for family visitors was significantly greater than the average time per exhibit for nonfamily visitors, $F(1, 19) = 13.19$, $p < 0.01$. On weekends, no statistical differences were found between family visitors and nonfamily visitors, $F(1, 24) = 0.86$, $p > 0.05$. The combined (*Symmetry* and *Signals*) time per exhibit distribution of 1026 exhibit interactions is presented in Figure 4.[3] The average interaction lasted 1.4 minutes.[4]

In the analysis of the fraction of exhibition with which visitors became engaged, no statistical differences were found between families and nonfamilies, $F(1, 43) = 0.48$, $p > 0.05$, or weekday and weekend visitors, $F(1, 43) = 0.08$, $p > 0.05$.

TABLE 2
Mean Total Time in the Science Museum

	Family	Nonfamily	Average
Weekday	61	31	46
Weekend	52	41	47
Average	57[a]	36[a]	47

Note. All times are in minutes.
[a]These values are statistically different from one another.

[3]The time per exhibit distribution for the Science Center is very similar to the combined Exploratorium/Lawrence Hall of Science distribution reported by Diamond (1986, p. 144).

[4]Although an average time per exhibit of 1.4 minutes may not appear to be exceptional, it is almost three times as great as the 30-second average frequently reported by Natural History museums with noninteractive dioramas (Cone & Kendall, 1978; Naqvy, Venugopal, Falk, & Dierking, 1991). In general, research indicates that a significant statistical relationship exists between the interactive nature of exhibits and time per exhibit (e.g., McManus, 1988; Melton, 1972).

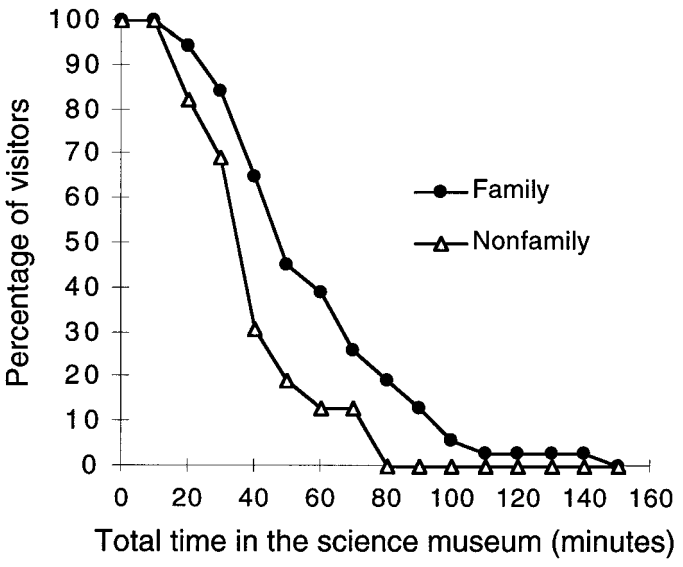

Figure 2. Survival curves for family and nonfamily visitors. The survival curves represent the percentage of visitors who spent *at least* a certain amount of time in the science museum. For example, 84% of family visitors and 69% of nonfamily visitors spent at least 30 minutes in the science museum. $N = 47$.

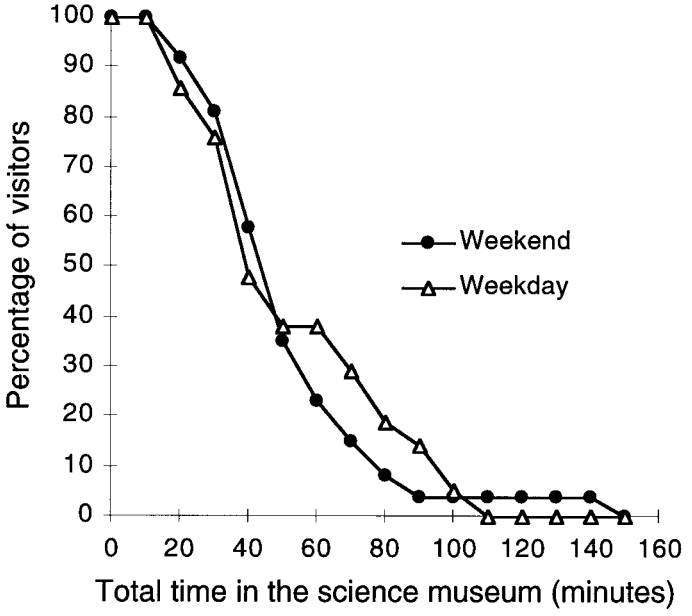

Figure 3. Survival curves for weekend and weekday visitors. The survival curves represent the percentage of visitors who spent *at least* a certain amount of time in the science museum. For example, 92% of weekend visitors and 86% of weekday visitors spent at least 20 minutes in the science museum. $N = 47$.

TABLE 3
Mean Total Time per Exhibition

	Family	Nonfamily	Average
Weekday	24	13	19
Weekend	20	17	19
Average	22[a]	15[a]	19

Note. All times are in minutes. Values are averaged across both exhibitions.
[a]These values are statistically different from one another.

DISCUSSION

In this study, it was found that visitors were, on average, engaged with exhibits 72% of their time in the exhibitions. This percentage is roughly comparable to Stevenson's results (above) of 82% for children (53% of the time interacting + 29% watching others) and 71% for adults (27% of the time interacting + 44% watching others). The average fraction of the exhibition with which visitors became engaged (0.39) was larger than the fraction reported for the HDBS (less than 0.16) in Boston (Boisvert & Slez, 1994).

The statistical comparison between family/nonfamily groups and weekend/weekday groups makes three points rather clear:

1. Regardless of the day of the visit, families spent more time than nonfamilies in individual exhibitions and in the science museum as a whole.
2. There was a separation of weekday visitors into two distinct groups: (a) family visitors who spent, on average, almost 2 minutes per exhibit; and (b) nonfamily visitors who spent, on average, less than 1 minute per exhibit.
3. Weekend family and nonfamily visitors did not differ in their average time spent per exhibit.

Due to the statistical nature of this study, I am hesitant to offer reasons as to why this state of affairs should exist. However, for the sake of parsimony, I suggest that all three results might be explained by a combination of two factors: visitor learning agenda and the number of visitors physically present in the museum. In short, I suggest that the behavioral nature of weekend visits is determined primarily by the science center's crowded conditions, whereas the behavioral nature of weekday visits—where crowds are less of an issue—is determined primarily by the agendas of the visitor groups.

Falk and Dierking (1992) describe the "visitor agenda" as the series of desires, beliefs, and expectations for what a visit will hold. In a review of research conducted in informal science

TABLE 4
Mean Time per Exhibit

	Family	Nonfamily	Average
Weekday	1.9[a]	0.9[a]	1.4
Weekend	1.3	1.2	1.3
Average	1.6	1.1	1.4

Note. All times are in minutes. Values are averaged over both exhibitions.
[a]These values are statistically different from one another.

TABLE 5
Mean Fraction of Time Engaged with Exhibits

	Family	Nonfamily	Average
Weekday	0.78	0.67	0.73
Weekend	0.72	0.70	0.71
Average	0.75	0.69	0.72

Note. Differences between means are statistically insignificant. Values are averaged over both exhibitions.

settings, Dierking and Falk (1994) argue that family agendas include a strong desire to view exhibits; furthermore, they claim that strong evidence exists that families adopt "learning agendas" when visiting informal free-choice settings. In comparison, little is currently known about the agendas of nonfamily visitors. The results of this study, however, may provide some insight into how the agendas between the two groups might differ.

The significant 20-minute difference in the average total time between family and nonfamily groups (across both weekdays and weekends) provides some support for the fact that, at the Reuben Fleet Science Center (RFSC), the agendas of nonfamily visitors are not as focused on the museum as the agendas of family visitors. A contextual factor that might explain this difference in agendas is the presence of an OMNIMAX theater.

In a comparison between visitors whose "primary destinations" were the science museum and OMNIMAX theater, respectively, Feher and Thompson (1992) determined that science museum visitors placed more emphasis than OMNIMAX visitors on the educational aspects of an otherwise recreational visit (in other words, the agendas of the two groups differed from one another). In terms of percentages, only 31% of visitors during the first 5 months of 1996 went to the science museum without also seeing an OMNIMAX movie (here, remember that visitors have the option of including a visit to the science museum for an extra $1.00 with the purchase of a movie ticket).

Unfortunately, studies have not been conducted at the RFSC as to whether families are more or less likely than nonfamilies to have the science museum as their "primary destination." Yet, while collecting data, it was often noticed that nonfamily visitors cut their museum visits short when it was announced over a loudspeaker that the next OMNIMAX movie was about to begin. Family visitors were less likely to exhibit this behavior. In addition, 94% of family visitors and 44% of nonfamily visitors returned to one or more exhibits to interact with the exhibit(s) again, indicating an increased focus on exhibits in the family group; this difference is statistically significant, $\chi^2(1, N = 47) = 14.9$, $p < 0.05$. Such evidence suggests that nonfamily visitors are *primarily* concerned with the OMNIMAX aspect of their visit to the RFSC—and, therefore, less likely than family groups to spend a lot of time in the science museum.

TABLE 6
Mean Fraction of the Exhibition with Which Visitors Became Engaged

	Family	Nonfamily	Average
Weekday	0.39	0.36	0.38
Weekend	0.40	0.37	0.39
Average	0.40	0.37	0.39

Note. Differences between means are statistically insignificant. Values are averaged over both exhibitions.

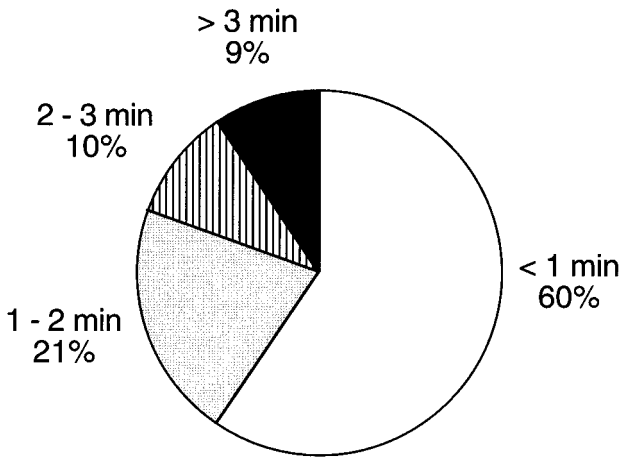

Figure 4. Combined time per exhibit distribution of 1026 exhibit interactions. Interactions under 5 seconds in duration were not recorded.

In and of itself, though, a difference in agendas based on a "primary" emphasis on either the OMNIMAX theater or science museum does not explain the second and third statistically significant results. It is not until one also considers the difference in the number of people physically present on weekends and weekdays that these results appear reasonable.

At the RFSC, many more visitors are present on weekend visits than weekday visits. In 1996, between January and May, 88,503 visitors attended the science museum on weekdays and 56,966 visitors attended the science museum on weekends.[5] This means that the number of visitors per day was, on average, much higher on weekends than on weekdays. In fact, on weekends, it was not uncommon for lines to form at the two or three most popular exhibits in each exhibition. Yet, this increase in visitors per day on weekends is, by itself, unremarkable. It is the interaction between the increased number of visitors and the difference between visitor agendas that is important, as follows.

Weekend family visitors may not be able to adequately fulfill their learning agendas if there is a large number of visitors in the museum. In a crowd, visitors feel the pressure to move quickly from one exhibit to another to allow other visitors their turn to interact with exhibits.[6] Consequently, visitors intent on learning would be expected to spend less time at the exhibits than they would otherwise. In fact, there is a distinct possibility that, for these visitors (families), the average time per exhibit would be lowered to the point where it becomes indistinguishable from the average time per exhibit for visitors whose agendas do not contain a primary focus on exhibits (nonfamilies). This, of course, is the result that was found for family and nonfamily groups on weekend visits to the RFSC.

Under less crowded conditions (i.e., weekdays), one would expect learning-associated visitor behaviors to be determined almost entirely by visitors' agendas. Without the social and physical pressures of large crowds, visitors with learning agendas would spend more time per exhibit than visitors whose agendas lacked a focus on exhibits. This is one possible explana-

[5]These figures do not include school children. Data were usually recorded when school children were absent.

[6]This is just one possible effect of the general phenomenon known as "crowding stress" (e.g. Epstein, 1981). Crowding stress is a function of perception, occurring only when a situation is perceived to be excessively crowded.

tion for the significant difference in average time per exhibit between family and nonfamily weekday visitors.[7]

Indeed, a recent evaluation conducted by Anderson et al. (1997) supports this interpretation. When visitors were asked how they would improve an exhibition at the National Air and Space Museum, 25% of the visitors suggested that, due to its excessively crowded conditions, the gallery needed either more space or fewer visitors. In particular, one visitor remarked that "More space is needed to reduce the sense of urgency to move onto the next exhibit." On the other hand, this is not to imply that crowds of all sizes lead to negative museum experiences. Anderson (personal communication, 1997) points out that moderately sized crowds support positive experiences because of increased interaction between visitors.

To continue with the present study, however, other factors might explain the differences between visitors. Nonfamily visitors might consider the science museum to be "for kids," and would therefore be less likely to spend much time either in the museum as a whole or at individual exhibits. Or, adults in family groups might be willing to put forth great effort at the exhibits to teach their children; without this obligation, individuals in nonfamily groups might not exert such effort. Finally, it might be the case that nonfamily groups simply learn faster than family groups. It makes a certain degree of sense that children—potentially, the least knowledgeable members of a group—would "slow down" the learning process at any given exhibit, thus driving up the average time per exhibit for family visitors.

SUGGESTIONS FOR FURTHER RESEARCH

As stated earlier, little is known about the museum agendas of couples and groups of peers (i.e., nonfamily groups). This statistical study of learning-associated behaviors suggests that the agendas of family groups are more exhibit- and learning-centered than the agendas of nonfamily groups. Following the lead of McManus (1987), studies with large samples should be undertaken so that differences within the nonfamily category (i.e., between couples and groups of peers) can be documented.

Another interesting question is whether visitor behavior differs across exhibitions. Preliminary analysis of "exhibition" as a within-subjects variable (Sandifer, 1997) indicates that such a difference does exist. Such studies would help to determine to what extent, based on learning-associated behaviors, one exhibition is better than another.

Finally, there is the subject of learning itself. Using only statistics, it is impossible to determine how little or how much visitors learn in their visit to science museums. Interviews are necessary to complement the statistical analysis of learning-associated behaviors, such as the time-based behaviors presented in this study. It is this combination of both quantitative and qualitative research that will provide the most complete characterization of visitor learning in science museums.

Warm, gracious thanks to Elsa Feher for suggesting the research problem, for her constant feedback, and for her kind permission to use the Reuben Fleet Science Center as a research site. Special thanks to Judy Sowder, Randy Philipp, Sandi Abell, and Melissa Dancy for insightful comments on an early version of this manuscript.

[7]Note that these results differ from those of Boisvert and Slez (1994). However, Boston's Museum of Science—the site for their study—differs from the Reuben Fleet Science Center both in its much larger size and its relationship between museum and movie theater.

APPENDIX

Description of the *Symmetry* and *Signals* Exhibitions

At the time this study was conducted, *Symmetry* and *Signals* were the interactive, thematic exhibitions on display at the Reuben Fleet Science Center. Both exhibitions had been built by in-house staff under the direction of Elsa Feher, the museum director. The *Symmetry* exhibition, completed in 1993, contained 26 interactive stand-alone exhibits. At the time this study was conducted, the *Signals* exhibition, completed in 1997, contained 36 interactive stand-alone exhibits.

The underlying theme of *Symmetry* was defined in the following manner: a thing is symmetric if there is something you can do to it that leaves it looking the same as before. The "thing" may be an object, a pattern, a sound, a movement or action, or a law of nature. The "something you can do to it" is to flip or reflect it in a mirror, to turn it, to slide it, to shrink or enlarge it, or put it on tape and run the tape backwards. Specific exhibits included crystals, mirrors, dance patterns, and other examples of rotational, translational, and reflective symmetries.

The underlying theme of *Signals* was defined in the following manner: signals are changes of some kind (e.g., fluctuations in the intensity of a light wave) that convey information. A signal is transformed and encoded so that it can be sent effectively. At the receiving end, the signal must be detected, decoded, and transformed again to gain access to the information carried. *Signals* exhibits illustrated phenomena such as properties of waves, resonance, binary numbers, analog and digital storage, and frequency and amplitude modulation.

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