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Awe & Memories of Learning in Science and Art Museums

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Abstract

This study looks at the types of awe guests feel when they leave art and science cultural institutions of various sizes and context, and how it may be related to what they remember learning. We surveyed 899 guests at the end of their visit and 550 of them again about one week later. Measures included a scale of awe-related perceptions (both positive and negative) along with questions about memories guests have about what they learned during their visit. Results show awe-related perceptions were consistent across institutions with only one significant difference, even when grouped by context (art vs. science). Guests' memories of profound educational and emotional experiences were weakly related to the amount and types of awe they felt. This connection was strongest with memories of emotional connections and being surprised. We also found connections to social experiences and that prior knowledge was a strong, consistent predictor of positive awe.

Introduction

As a feeling of reverential respect mixed with fear or wonder (Oxford English Dictionary, n.d.), awe is a complex emotion. It can be elicited in a myriad of ways and its impact can be transformational, both positively and negatively. Awe is inherent in museum and cultural centers (McLean, 1995; Freedman, 2000). It is one of the most commonly used descriptors of powerful guest experiences and often is a goal of exhibit designers. Studying awe is to study one of the most profound and sublime aspects of the museum experience.

Museums and their programming are often designed explicitly to induce awe and similar emotions in their guests. Museum architects often juxtapose spatial size to induce awe by having guests walk down smaller, narrow spaces before entering into a large, open space. Eye-tracking studies have found that feelings of awe are related to how guests look at a museum space (Krogh-Jespersen, Quinn, Krenzer, Nguyen, Greenslit & Price, 2020). Also, guests come to museums "with expectations to see wondrous things that they cannot see in their everyday lives" (Smith, 2014) and are ready for new experiences. This combination of feeling awe while also being open to new ideas describes an ideal environment for learning.

As part of a suite of epistemic emotions, awe has been shown to support critical thinking (Griskevicius, et al., 2010; Shiota, 2016), prosocial behavior (Piff, Dietze, Feinberg, Stancato, & Keltner, 2015) and science learning (McPhetres, 2019; Valdesolo, Shtulman, & Baron, 2017). Emotions in general have been shown to enhance science achievement by encouraging engagement (Sinatra, Broughton, & Lombardi, 2014) and motivation (Coleman, 2014; Pintrinch, 2003). In museums and similar settings, emotions have long been linked to learning and other

cognitive outcomes (Falk & Gillespie, 2009; Rappolt-Schlictmann, Evans, Reich, & Cahill, 2017; Watson, 2016).

Since awe is such a natural part of the museum experience, and its potential impacts on learning may have serious implications for museums, we thought it important to study its impact on guests. In an earlier study, we looked at how awe differs among specific exhibits at a science museum (Price, Greenslit, Quinn, Applebaum, Krogh-Jespersen, Krenzer, & Ibtasar, 2019). In this study, we wanted to explore the following questions: 1. How does awe differ at the museum level (and between types of museums) and 2. How does it impact longer term memories of the visit? The goal is to look at how various facets of awe change among museums writ large (including science centers and cultural institutions), as well as how that change may impact memories of what they learned as measured about one week later. We measured four aspects of awe and linked them to memories analyzed through two learning frameworks commonly used in informal learning settings. Finally, we looked for relationships with demographic and behavioral variables. Our hypothesis was that awe would be substantially different between art and science museums due to the different nature of their content and types of experiences (e.g. science museums having more multisensory and energetic exhibition spaces may lead to more varying levels and types of awe, while art museums may have more consistent levels and types of awe) and that any awe would lead to stronger memories of learning due to additional emotional engagement. There have not been many studies comparing the emotional or learning impacts of art and science museums.

Literature Review

Awe as an Emotion

First consciously felt around ages of 4-5 (Greenacre, 1956), awe is one of the most complex of emotions due to its entanglement of both positive and negative characteristics (Lichtenberg, 2015). The Merriam-Webster dictionary defines awe as "an emotion variously combining dread, veneration, and wonder that is inspired by authority or by the sacred and sublime." The Free Dictionary defines it as "A feeling of respect or reverence mixed with dread and wonder, often inspired by something majestic or powerful."

Although there is some disagreement in the affective field, many researchers have come to see awe in a certain way. It is generally considered a self-transcendent emotion that encourages individuals to focus attention outside of themselves and to extend beyond their momentary needs and desires. Such emotions are assumed to be conducive to binding individuals to others—whether the "other" is an individual, a group, a social institution, a culture, or even more broadly to humankind. This view is guided by a functionalist approach to emotion (e.g., Ekman, 1992), which assumes that emotions function to support adaptive responses to threats and opportunities, particularly as emotions help individuals coordinate with others to meet the challenges and reap the benefits of group living (Keltner & Lerner, 2010).

In one of the first foundational analyses of awe, Keltner and Haidt (2003) identified two key features of stimuli that are among the most common intraindividual perceptions of awe experiences: perceived vastness and need for accommodation. *Vast* stimuli challenge the individual's understanding of the world—not only by virtue of sheer physical size (e.g., the Grand Canyon), but also in terms of sensory detail (e.g., a complex work of art), social or historical importance (e.g., an event that affects thousands of people), explanatory power and conceptual breadth (e.g., a complex theory), or even just volume of unexpected information (Shiota, Thrash, Danvers, & Dombrowski, 2014). Given that this physical, perceptual, or

psychological vastness is not easily grasped within one's current or typical understanding of the world, vast stimuli require cognitive accommodation or updating of one's worldview to establish meaning. As a result of this need for accommodation, awe draws attention toward the event to be understood. In so doing, it also draws attention away from the self, consequently provoking the individual to view their own needs and desires—indeed, even their own sense of self—as maybe even being trivial in the grand scheme of things. Shiota, Keltner, and Mossman (2007) found that, in a US sample, almost half of the awe experiences reported by participants involved a focus on others. In non-Western cultures, the proportion of awe-inducing experiences that involve other-focused appraisals may be even higher (Stellar, Gordon, Anderson, Piff, McNeil & Keltner, 2018).

Befitting its complex nature, awe can have a wide variety of triggers and consequences. It can be inspired by physical spaces (Lazarus, 1991), mental concepts (Shiota et al., 2014), strong memories (Piff et al., 2015), art (Katz, 2019), spiritual experiences (Caldwell-Harris, Wilson, LoTempio, & Beit-Hallahmi, 2011), social interactions (Schurtz, Blincoe, Smith, Powell, Combs, & Kim, 2012) and much more. And it can elicit states of contemplation (Pearsall, 2007), humility (Stellar, et al., 2018), generosity (Piff et al., 2015), and many other positive emotions while also leading to negative feelings such as fear (Bonner & Friedman, 2011), dread (Gordon, Stellar, Anderson, McNeil, Loew & Keltner, 2017) and horror (Taylor & Uchida, 2019).

In this study, we see awe as a wide mixture of mostly positive and sometimes negative affect that grabs hold of a guest's full attention. In the literature, it is most often related to surprise (Valdesolo, et al., 2017), but we do not treat surprise as a prerequisite for awe. It is often induced in museums through the design of physical space and/or an experience that is relatively unique (but not always surprising) to the facility, while being influenced by the guests' prior

knowledge and expectations of the visit. Its impact can emotionally move or frighten guests, but in all cases focuses their attention on a physical stimulus or experience (which can be physical or social).

Awe and Learning

Emotions are a key part of learning. Vygotsky considered emotion as an inseparable part of cognition and thought (Vygotsky, 1926, 1997). They help guide decision making (Lerner, Li, Valdesolo, & Kassam, 2015) by activating appraisal tendencies that influence subsequent perception and judgement (Lerner & Keltner, 2000). In a compelling review of the impact of emotion on learning, Cavanagh (2016, p. 40) said, "Memory's bias for emotion is one of the most reliable effects we have in psychology." Physiologically, emotions are related to specific hormonal responses that support memory construction (Cahill, Prins, Weber, & McGaugh, 1994). "In the last ten years, neuroscientists have shown just how intimately related our memory system is with our emotional system" (Levitin, 2006, p. 166). Emotions can focus attention and thus reduce distractions in working memory (Lindström & Bohlin, 2011) and they are an essential component of motivation (Meyer & Turner, 2002). In the classroom, they also play an important role in the social atmosphere. Emotional contagion spreads from instructor to student or between students (Becker, Goetz, Morger, & Ranellucci, 2014). Such effects are even stronger in close knit groups like families (Hatfield, Carpenter, & Rapson, 2014), which are more commonly present in informal learning settings like museums.

Recently, awe has received a lot of attention due to its possible application to education. Awe has recently been proposed as an emotional catalyst for learning in general (Coleman, 2014) and science learning in particular (Gottlieb, Keltner, & Lombrozo, 2018; McPhetres, 2019; Valdesolo et al., 2017). Emotions are often considered a critical element of scientific conceptual

change (Zembylas, 2005; Treagust & Duit, 2008). In one of his last public talks, which he titled *Wonder and Skepticism*, Carl Sagan described the moment when, as a child, he considered the distance to the stars: "The dazzling idea of a universe vast beyond imagining swept over me. It has stayed with me ever since. I sensed awe" (Sagan, 1995). Ann Druyan, his writing partner and an independently established expert in science education, believes that awe and wonder are key to skepticism and belief in science (Grothe, 2006).

Awe is often considered an epistemic or knowledge emotion (Silvia, 2008; Valdesolo et al., 2016). Knowledge emotions are produced from cognitive qualities of knowledge tasks and knowledge-generating activities (Trevors, Muis, Pekrun, Sinatra, & Winne, 2016) and include not only awe, but also related emotions and social-emotional states such as curiosity, confusion, surprise and others (Litman, 2005; Pekrun, Vogl, Muis, & Sinatra, 2016). Epistemic emotions and related affect can instigate and stabilize learning in science (Jaber & Hammer, 2016a, 2016b). Such emotions often operate in tandem. For example, awe, confusion and surprise can be potentially mixed or co-occur at the same time. Events that evoke awe are those that cannot be comprehended fully within pre-existing knowledge schemas. Moreover, these awe-inducing events can create uncertainty that often lead to curiosity and interest. Indeed, such feelings of uncertainty have been identified as particularly important for education around controversial scientific topics, such as evolution (Ha, Haury, & Nehm, 2012) and climate change (Lombardi & Sinatra, 2012). However, as befitting the Jekyll-and-Hyde nature of awe, the self-transcendent aspects of awe can also actually increase belief in mysticism, even when introduced in a scientific context (Johnson et al., 2019).

Because awe is sometimes associated with surprise and disequilibration, it can prompt a learner to be more open to new ideas and/or question prior knowledge schemas. Surprise

violations of expectations, aka expectancy violations, in particular have been shown to stimulate learning and changes in personal beliefs in both children and adults (Lorini & Castelfranchi, 2007; Stahl & Feigenson, 2015). This can lead to accommodation through the integration of new knowledge into past schemas (Piaget & Cook, 1952). In addition to theoretical perspectives, empirical evidence also supports the role of awe in promoting critical thinking and learning. Young adults who were cued to remember memories of feeling awe were less likely to be persuaded by weak arguments subsequently presented to them when compared to individuals in a control condition (Griskevicius et al., 2010). Those who feel awe have been found to rely less on preexisting knowledge, inserting fewer "false" but schema-consistent details into memory recollections (Danvers & Shiota, 2017). Awe can also cue acknowledgements of how much one does not yet know about the world and thereby increasing skepticism about what is being presented to them (Price et al., 2019). Awe has also been shown to increase awareness of one's knowledge gaps and thereby possibly impact interest in learning more (McPhetres, 2019).

Museums, Affect and Long-Term Learning

In the past decades, there have been more calls to study long-term learning in museums. Museums need to study how they are being integrated into everyday life (Stevenson, 1991) and need to acknowledge that learning is cumulative (Rennie, Feber, Dierking, & Falk, 2003) and not easily isolated in time (Falk, Koke, Price, & Pattison, 2018). Many theories and models for both short and long-term learning in museum settings have been developed over the years (Falk & Dierking, 2018; Hooper-Greenhill, 2004b). Two well-established frameworks are the Contextual Model of Learning (CML; Dierking & Falk, 1992; Falk & Dierking, 2016) and the Generic Learning Outcomes model (GLO; Hooper-Greenhill, 2004a). CML is a framework that focuses on three key variables to learning in a free choice environment: the guest's personal,

sociocultural, and physical contexts (with a time domain element subsequently added). GLO was developed as a broad framework for learning in museums to reflect the diverse nature of museum visits and visitors. GLO consists of five elements that lead to and provide evidence of learning –activities related to the visit that take place before and after the visit itself; change in knowledge and understanding; attitudes and values; inspiration and creativity; activity, behavior and progressions. These are not the only models, but they are currently among the leaders in the field as overarching frameworks to develop and measure learning experiences broadly.

For this study, we consider emotion as a psychological construction of lots of factors (memories, physical, social, etc.) with considerable inter- and intra-personal diversity in how one constructs it. And affect as an associated neurophysiological state of feeling (Russel, 2009). In museums and other informal learning environments, positive affect, such as arousal, have been linked to greater long-term learning in science (Falk et al., 2009; Price, Lee, SubbaRao, Aguilera, & Kasal, 2015; Rappolt-Schlictmann et al., 2017; Staus, 2012), conservation (Ballantyne, Packer, Hughes, & Dierking, 2007), history (Sakr, Jewitt, & Price, 2016) and aesthetic contexts (Greene, Kisoda, & Bowen, 2014). Anderson, Storksdieck, and Spock (2007) found long term guest memories are associated mostly with their social context but that sharing emotions in particular "helps shape and enforce memories… of a museum visit" (p. 202). Staus and Falk (2017) found that emotions help learning by supporting memory but, surprisingly, did not impact attention. Meredith, Fortner, and Mullins (1997) proposed a model of learning in informal science environments where affect is intertwined with evaluation at the moment that a learner is making a decision about a perception they just made in the setting. Because affect leads to motivation, it can support more long-term learning. But it also means satisfying related motivational desire is an important quality of the affective experience.

The emotional effect of the exhibit is one of three key factors in shaping long term memories of visits (the other two being periodic recall of the memories and the degree to which the visit met expectations) (Anderson et al., 2007). Falk and Dierking (1997) found strong memories of museum field trips, sometimes lasting decades. And they found strong relationships between cognition and affect – sometimes the memories were related to very specific feelings guests had during the visit. Ballantyne, Packer, and Sutherland (2011) found that, during wildlife experiences (zoos, aquariums, wildlife tourism, etc.), reinforcing a guest's sense of awe in particular can evoke powerful and enduring memories.

The theory behind our hypothesis begins with the assumption that awe is prevalent in museums and that similar emotional perceptions have been shown to enhance long-term learning in museum and other informal settings. Thus, we expected that greater awe would be related to stronger memories of what guests learned. This is important to the informal learning field because awe-invoking experiences are both more common in informal environments and also one of the unique attributes those environments offer guests. Our study is designed to test our assumptions about the prevalence of awe and to dig deeper into the facets of awe that guests experience and how awe may be related to both context of the setting and also of what guests remember.

Method

To answer our research questions, we used a post- and delayed-post with nonequivalent groups (different institutions) design that allowed us to do both within-groups and between-groups comparisons and correlations. Since this is a study about the overall experience, we opted to measure awe as guests were leaving at the end of their visit. And since it is a study

of memories of learning, we compared those measures of awe they felt while the memories were actively being formed with the memories themselves, as recalled a week later.

Study Context

Data collection took place at eight museums, science centers and cultural institutions of various sizes in three major cities in the United States (Table 1). In response to calls to account for the complexity of learning across locations and time (Falk et al., 2018), we chose to collect data across a wide variety of locations and to include a delayed measure. Sites were chosen according to programming (science, nature, modern art, contemporary art, cultural heritage, etc.) and scale (as measured by annual attendance) in terms of audience attendance. Guests were recruited as they left each institution, usually near exit doors. Participants were e-mailed a link to the delayed-post survey about one week later and were incentivized with a $10 Amazon gift card for completing both surveys.

Measures

Two instruments were used in this study: a post-survey and a delayed-post survey. The post-survey included three sections - demographics; a situational awe scale; and a section about what guests remember about their visit and what they knew in advance. The delayed post-survey contained all of the sections in the post-survey, except for the demographic section. Some items were reworded to reflect change from present to past tense. There was also a question about guests' likelihood to feel awe, but this was omitted from analysis[1].

[1] Results of that measure are available in Price & Greenslit (2019).

Demographics. Demographic questions include age, how many other times they had visited a similar institution in the last 12 months, gender and formal educational background. Gender used a format that offered options for female, male, non-binary/third gender, self-description, and prefer-not-to-say (Human Rights Campaign, 2016). Formal educational background was asked on a 6-pt scale that included "Less than high school degree", "High school degree or equivalent (e.g., GED)", "Associates degree (2-year or equivalent)", "Bachelor's degree (4-year or equivalent)", "Master's degree or equivalent", "M.D./J.D./PhD or equivalent".

Situational Awe Scale. Awe-related perceptions were measured using the S*ituational Awe Scale (SAS).* Existing measures of awe (Piff et al., 2015; Shiota et al., 2007) show good predictive validity but neglect two aspects of the emotion: its negative side and its physical correlates related to excitement (e.g., chills, goosebumps) (Gordon et al., 2017). The SAS was constructed as a broader measure of awe (Krenzer, Krogh-Jespersen, Greenslit, Price, & Quinn, 2019). Through exploratory (N = 580) and confirmatory (N = 235) factor analysis, the scale construction process yielded four factors: 1) awe as connecting (e.g. "I feel free"); 2) awe as isolating (e.g. "I feel confined"); 3) chills and physical metaphors of awe (e.g. "My heart is racing"); and 4) diminished self (e.g. "The world seems vast.")[2] (Quinn & Krenzer, 2017). Hereafter, these factors are referred to as Connecting, Isolating, Physical, and Diminished Self,

[2] Principal Axis Factoring (PAF) with varimaxrotation, eigenvalues greater than 1, and maximum iterations at 25 resulted in Kaiser-Meyer-Olkin(KMO) = .955; Bartlett's Test of Sphericity gave a $\chi 2(1540) = 17{,}328$, $p < .001$. The four factors accounted for 45.75% of the variance: awe as connecting = 15.11%, isolating = 7.48%, physical metaphors = 1.6%, diminished self = 1.4%. CFA fits were: awe as connecting: 1.13*, isolating = 0.153, physical metaphors = 1.13* and diminished self = 0.53*. The original SAS ended up with 18 items with factor loadings >0.4 which were used in this study (Quinn et al., 2017). Subsequently, a 15-item version was designed to provide better balance between and tighter construct clarity within the four subscales (Krenzer et al., 2019), but has little impact on the psychometric properties or predictive power of the scale.

respectively. The total SAS section contained 18 items presented with a 7-point Likert scale labeled from “Disagree Strongly” to “Agree Strongly” and prompted with “Rate how much you disagree or agree with the statement in terms of how you feel right now.” The full scale is included as Online Supplemental Material.

Memories of Learning and Prior Knowledge. The prior knowledge, learning, and memories section consisted of a mix of constructed-response (CR) and Likert items related to what guests remember of their visit. The first CR item was “What is something you learned today? Describe it as you would to a friend who did not attend” (hereafter: Learn). This was included to elicit a self-report measure of learning. It was followed up with our prior knowledge item: “How much did you already know about that topic before today?” This item used a 7-pt scale from “Nothing” to “A lot”. The next CR item was “What is something that connected with you today? Describe it as you would to a friend who did not attend” (hereafter: Connect), included as a measure of a key emotional moment for them. The next CR item was “If you could talk to a Director of Exhibits right now, what would you say to them?” (Hereafter: Exhibits). Specific wording of this item was adjusted to make it relevant for each institution. This item has been used for decades by evaluations at the Museum of Modern Art (Smith, 2014) and we felt served as a broad measure of interest and what was most salient to them about their visit. The last CR item was “What was something unexpected about your visit?”(hereafter: Unexpected), and was included since many operational definitions of awe link it with elements of surprise and expectancy violation. The four items were designed first to create very broad measures of learning and secondly to be related to our operational definition of awe that has elements of emotion, surprise and learning.

Participants

In total, 899 guests completed the post-survey and 550 guests completed the delayed-post survey (on average 7.7 [*SD* = 2.3] days later). Guests identified as 59% female, 37% male, <1% nonbinary; 4% preferred not to say or did not answer. The average age was 35 (*SD* = 15) years old. Guests visited a similar institution an average of 3.6 (*SD* = 9.9) times in the last 12 months. On our scale, the median formal educational background was a bachelor's degree. A comparison between those who took only the post-survey and the delayed post-survey found traditionally statistically significant differences in mean age and prior visits to museums according to ANOVAs, $F(881) = 11.99$, $p < .001$ and $F(872) = 4.94$, $p = .03$, respectively. The delayed-post survey group was 4% more female and had visited a similar institution in the last 12 months an average of 1.5 times more often.

Data Analysis

All guest data was used in our analysis of awe between institutions. Only data from guests who also took the delayed post-test was used in our analysis of long-term learning.

Likert data was transferred to integer scores starting at 0 and increasing by one per response option (e.g.7-pt scale ranged from 0-6) and treated as interval data. Composite scores for each of the SAS factors were computed by taking the means from all items in each factor and are treated as continuous. For between-institution analysis, we combined institutions into three groups: art museums, science institutions and science institutions with animals. The latter category was established to distinguish between awe related to scientific topics and awe related to seeing live animals.

The CR items were each coded by two researchers according to a common rubric with 7 categories (hereafter: learning codes; Table 2). Each aspect of the rubric was coded as a 1 (present in the response) or 0 (not present). Empty or incomprehensible responses were coded as not present. The researchers refined the rubric using pilot data. Then two researchers coded the first 20% of the data for each question independently and computed IRR via percentage agreement, which ranged from a low of 89% for the Sociocultural Context category to a high of 95% for the Activity, Behavior, and Progression categories. The rest of the data was coded by a single researcher.

The coding rubric was developed based on the CML and GLO learning frameworks from the museum research literature. Regarding the CML, we created coding categories for guests' personal and sociocultural contexts as defined in their framework. After pilot testing, we opted not to include a category for the physical context because we found it was almost never discussed in response to our questions. We also created categories for each of the five elements of GLO because this project spanned a wide variety of institutional types with a large potential audience, so we felt a flexible, broad approach would be more effective at identifying patterns in responses. Thus, we have seven total coded rubric categories.

Our statistical analysis uses techniques from the General Linear Model. We began with a simple correlation analysis between SAS factors of awe and prior knowledge. Next, we ran ANOVAs with the institutions (and institutional type – art or science) as independent variables and the awe factor means as the dependent variables. Then, to look for relationships between awe on the post-survey and responses to the learning items on the delayed-post survey, we ran separate ordinary least squares regressions with delayed-post survey SAS factor means as the

dependent variables due to their continuous nature. Each SAS factor mean was predicted by each delayed-post survey rubric code (with CR responses categorized as code-present versus code-absent), and controls for prior knowledge and the institutional type. Overall, we consider the SAS factors as being distinct from each other and the learning items as measuring different types of memories. This was supported by the fact that we noticed no instance of a guest giving a similar answer to all four items.

In response to calls to de-emphasize the arbitrary $p = .05$ significance threshold (Wasserstein & Lazar, 2016; McShane, Gal, Gelman, Robert, & Tackett, 2019), we report all p-values (to 2 decimal places) and also include a label of "traditionally significant" to any differences at the $p < .05$ level and still report and interpret differences slightly outside that level and that we feel are important when considered in context. And, more importantly, our interpretation of informative results will not rely solely on comparison to those values but will also include looking at trends and context.

Results

Institutional Awe

Guests reported consistent, moderate levels of awe on post-surveys across institutions (Table 3). Connecting and Diminished Self awe were the most common types of awe experienced by guests, followed by Physical and Isolating awe, respectively. We also found consistent levels of awe between art and science (with or without animals) institutions (Figures 1, 2). The only traditionally significant differences are in the Diminished Self factor of awe, where art museums score lower than science museums [$F(1,896) = 15.75$, $p = <.01$]. However,

the effect size is small, $\eta^2_p = .02$, reflecting that the levels of Diminished Self awe reported for art museums were still similarly high. Because of the similar findings of science institutions with or without animals, later analysis will only include comparisons between art and all science museums.

Awe and Memories of Learning

Overall, the mean learning codes were low for most rubric categories on all four CR items (Table 4). On average, we identified a total of five learning codes per visitor across all categories. A major exception is the presence of references to knowledge and understanding in 75% of the responses to the Learn item, which is likely influenced by the close coupling of the item's topic with the rubric category. Of the awe factors, Connecting and Diminished Self had the highest presence of the learning codes, followed by Physical and finally Isolating awe. Table 5 displays the average awe reported when a learning code was assigned to a response. Regressions for each of the four CR items are in Tables 6, 7, 8 and 9. There are four regressions (one per awe factor) per item for a total of 16. Inspecting the columns can get a sense of what codes can predict awe. We also controlled for prior knowledge and type of institution (art or science). We tested for collinearity using variance inflation factor analysis and all factors on all tests were <2, indicating very low levels of collinearity.

Factors of awe. For the Connecting factor on the SAS, the only traditionally significant relationship when controlling for prior knowledge and museum type was the relationship with the Knowledge code for the Learning item ($b = .52$, $p < .001$). This means guests who reported higher levels of Connecting awe were more likely to report a change in knowledge or understanding when asked about something they learned during the visit.

For the Isolating factor on the SAS, the results were more varied. For the Learning item, the Inspiration code had a traditionally significant, negative relation (b = -0.42, p = .03), meaning the more isolated a guest felt, the less likely they were to report being inspired by something they learned. The Isolating factor also had a negative relationship to the Connecting item and Social code, (b = -0.25, p = 0.097), meaning isolating awe limited how social guests felt during moments of emotional connection. Finally, the Personal code was a positive predictor of the Isolating factor (b = 0.43, p = 0.06) on the Unexpected item, meaning guests were more likely to assign a personal meaning to what they learned when they reported more isolating awe. There were no relationships with the Exhibits item.

The Physical factor also showed variable results across CR items. For the Learning item, the Knowledge code was related to the Physical factor (b = 0.27, p = 0.07). Similar to the Connecting factor, this means guests reporting more Physical awe were more likely to have acquired more knowledge or understanding about something they learned during the visit. We found a traditionally significant relationship between the social learning code and Physical awe for the Exhibits item, (b = 0.60, p = 0.03), meaning guests who reported higher levels of physical sensations of awe were more likely to have a social component to the big takeaway they had for their visit. Finally, Physical awe saw positive relationships between Attitudes and Inspiration codes, respectively, for the Unexpected item (b = 0.3, p = 0.45 for Attitudes and b = 0.29, p = 0.07 for Inspiration). This means guests reporting awe related to physical responses were more likely to report feeling inspired or a change in attitudes and values when surprised by something during their visit.

The Diminished Self factor had the most relationships with our learning codes. For the Learning item, the Before and After code was traditionally significantly negatively related to Diminished Self (b = -0.37, p = 0.03), while Knowledge was traditionally significantly positively related to Diminished Self (b = 0.28, p = 0.02). This means guests reporting more diminished self awe were *less* likely to make references to things they learned outside of the museum but were more likely to discuss how what they learned led to more knowledge and understanding, that is they were more focused on the Museum experience. For the Connecting item, the Social code had a negative borderline traditional relationship to the Diminished Self factor (b = -0.26, p = 0.05), meaning guests reporting more Diminished Self awe were less likely to mention a social interaction as part of something they connected with that day. Also, for the same item the Attitudes code was traditionally significantly positively related to the Diminished Self factor (b = 0.26, p = 0.01), meaning guests who reported more Diminished Self awe were more likely to discuss a change in attitudes and values in that same connecting experience. Finally, we also found that the Attitudes code was related to the Diminished Self factor for the Unexpected CR item (b = 0.21, p = 0.09), meaning guests feeling more Diminished Self awe were likely to discuss values and understanding when describing something that surprised them during their visit. There were no relationships with the Exhibits item.

Prior Knowledge and Museum Type

Prior knowledge was a traditionally significant predictor of awe across all regressions predicting Connecting and Physical awe. Our correlation analysis found the effect to be positive and small (according to Cohen's guidelines), for the Connecting [r = .14, p = .001], and Physical [r = .15, p < .001] awe factors, meaning more prior knowledge led to higher levels of awe

related to being connected to others and physical sensations of awe (ex: excitement). The effect of museum type was only traditionally significant for all regressions predicting Diminished Self, such that guests in science museums indicated they experienced more Diminished Self awe than guests in art museums.

Discussion

To answer our research questions, we measured awe-related perceptions as guests left the institution and looked for relationships between these scores and memories of learning they held a week later. Those memories were analyzed by looking for elements of learning as defined by two major informal learning frameworks. We found a consistent pattern among institutions in the type and amount of awe guests report as they left at the end of their visit. They reported higher levels of awe associated with the more positive facets such as feeling connected to the world or feeling small in a vast world. They reported neutral levels of awe related to physical metaphors, such as feeling chills, and lower levels of negatively valanced awe.

We expected to see higher levels of physical awe at the zoo and aquariums which have significant outdoor components which can cause physiological responses (wind, temperature, etc.), but did not find it. We also expected more awe, of any type, to be associated with live animals due to the added empathy associated with them but did not find that either. There has been considerable work done recently studying empathy at zoos and aquariums (Young, Khalil, & Wharton, 2018) and interest in the role of empathy in art museums is growing as well (Greenberger, 2017; Greene et al., 2014). A similar cross-institutional study on empathy in place of awe may be warranted to investigate how empathy differs among contexts. Institutional type (science or art) did have an impact on the amount of awe guest report related to feeling small

(Diminished Self). Art institutions showed less Diminished Self awe than science institutions. This could be due to different architectures, exhibit experience, content and guest populations. However, this difference is the only one we found between museum types. We wonder if a follow up study that includes performance centers, theaters and cultural institutions without exhibits at all, along with a control condition, may show similar levels of awe. Others have shown that the stronger emotions associated with awe are more aligned with a personal openness to experiences than with any particular context (Silvia, Fayn, Nusbaum, & Beaty, 2015). This also leads to a question about whether awe can be triggered by anticipation of the experience. Is awe simply part of the guest experience at cultural institutions because guests are expecting something new and interesting? Indeed, Price, et al. (2019) found some guests report awe even when they first arrive and have not yet left an underground parking garage.

We did not notice much Isolating awe, which is comprised of the more negative aspects of awe-related perceptions. Others have reported negative awe-related reactions to large-scale architecture (Joye & Dewitte, 2016) and that negative awe can be triggered by large crowds (Rudomin, Millán, Hernández, Díaz, & Rivera, 2008). And some of our institutions have both. Thus, we expected perhaps to find differences in isolating awe based on the scope and size of the institutions in our study. But we did not see it. We did not see across-the-board relationships between learning and Isolating awe. But the relationships we did see were always negative, suggesting that as learning increased, isolating awe decreased, though we cannot comment on causality between the two. Studies have found that negatively valanced emotions and moods can impede both short term (Kensinger & Corkin, 2003) and longer-term learning (Nielson & Powless, 2007). But in some cases, they can actually facilitate learning (Botvinick, 2007; Gendolla & Brickman, 2005; Gendolla & Silvestrini, 2011; Sutherland & Mather, 2012; Van

Steenbergen, Band, & Hommel, 2010). A more nuanced study of the impact of negatively valanced awe is warranted, even if it is just an initial step into more complex analysis that goes beyond valence and arousal.

We also found a relationship between physical awe and memories about something unexpected happening on their visit. We know that some definitions of awe include a surprise component (Shiota et al., 2007) and others have postulated that physical reactions to awe can be related to the magnitude of the surprise (Yaden, Kaufman, Hyde, Chirico, Gaggioli, Zhang & Keltner, 2019). Our results could be evidence that surprise is more related to physical aspects of awe than the other facets. We also know there are social components of awe (e.g. seeing the world through the eyes of a child) (Schurtz et al., 2012; Silvia et al., 2015), so were not surprised to see that sociocultural references in guest responses were one of the categories most consistently related to awe.

Of all the aspects of awe we measured, the experience of feeling small in a vast world had the most relationships with learning. Guests who felt small were more likely to discuss social interactions and implications of what they learned and also that what they learned was related to their values and understanding. This aspect of awe is usually one of the first that people think about when they imagine/remember awe-inducing experiences. Among the first ten results of a Google image search for “feeling awe”, 7 are of large vistas (usually with a small person standing in the front, center). Shiota, et al. (2007) found that guests standing next to a dinosaur skeleton tended to think about themselves in a broader way. Piff, et al., (2015) suggests that shift could be vital to collaboration and cooperation in social groups, which may be why we see more responses about the social aspect of what guests learned.

Increased prior knowledge was positively related to two aspects of awe. This is important because it challenges the notion that awe *requires* surprise. Awe can also be fostered by an appreciation about how much is being learned in that experience. Awe is assumed to arise when current experience cannot be assimilated within existing knowledge but can be accommodated (Schneider, 2017). To the extent that individuals have strong schemas, they should be better able to detect knowledge gaps. As such, prior knowledge can promote the experience of awe without necessarily relying on an element of surprise. Curiosity, which can be driven by prior knowledge (Wade and Kidd, 2019), is often considered an antecedent to awe (Valdesolo et al., 2017).

When these results of long-term impact are combined with our prior results showing in-the-moment awe differentiates between exhibits (Price, et al., 2019; Krogh-Jespersen, et al., 2020), we posit that positive awe is tightly interwoven with the learning process and is not restricted to particular stages. Those who want to use awe in learning experiences should look for opportunities throughout the experience and not fall into the trap of studying or creating a single awe moment. For example, exhibit designers should shy away from using awe only at the entrance of an exhibit or during a single big reveal and instead look for areas where awe can be embedded throughout. This supports findings by Staus et al. (2012, 2017) that learning messages presented during a highly arousing experience has greater learning potential than messages presented after such an experience. We also think awe-induced moments should include triggers that are based on the social aspects of awe and not limited to only large, over-the-top exhibit spaces. In this way, guests who sometimes feel uncomfortable in those spaces can feel their own awe while also cueing different types of learning that are linked to all the facets of awe. Even though the relationships between awe and learning may be sporadic and smaller in magnitude, they nevertheless exist and are consistently positive. This reliability gives us confidence that awe

has a role to play in learning. It may be complex to apply, and is certainly complex to study, but the potential impact is there and waiting to be used by educators.

Finally, researchers should consider studying awe in more ecologically valid, real world environments (Anderson, 2016). Like us, others have also shown differences in results from psychological studies done in laboratories vs. museums (Makin, 2017; Pelowski, Forster, Tinio, Scholl, & Leder, 2017; Silvia, 2017). Awe, when produced by memory (subject recall) or by association (asking subjects to imagine an experience based on a cue) is fundamentally a different experience than in situ awe. More research on awe in museum and cultural institutions is needed both from the institutional perspective, but also from the perspective of the field which needs to expand its awe-in-the-wild experiences to those beyond nature. Such institutions are also well situated to respond to calls to study the social implications of awe (Schneider, 2017), which by their very nature of often confront important social issues (granted, sometimes inadvertently).

This study did not test the causal relationship between awe experience and memory, which is a logical next step. Another key limitation is simply how broad our approach was in context. The participating institutions represent a wide swath of museums and similar institutions, as such any measurable association would also need to be broad. Now that we know awe is consistent across such settings, a more focused study can include direct learning measures. Also, broad studies of this type increase the possibility of Type 1 errors (Westfall & Yarkoni, 2016). This is one reason why we try to deemphasize direct interpretation of individual results and also look at trends.. Also, our data pass homogeneity of variance tests, of which failure can be a sign of increased chance of Type 1 errors. Another limitation is how we measure

and interpret the prior knowledge of guests, which relied on a self-report item. Wade, et al. (2019) found that a learner's estimate of their prior knowledge of a subject can be a better measure of intrinsic curiosity than an objective measurement of their knowledge on the same subject. Still, a larger scale would be more reliable and a direct measure could be more valid.

Conclusion

Museums are in the business of awe. Our study shows they consistently inspire positive awe-related perceptions and affect while avoiding many of the negative facets of awe. This consistency exists across institution type, size and geographic area, which suggests awe may be related to aspects outside of the specific contextual experiences. Guest memories of what they learned during their visit were related to various types of awe, including experiences that elicited a type of awe that made guests feel emotionally or physically connected to the exhibit. We also found that prior knowledge was a predictor of awe related to emotional connection and physical responses. Surprise and prior knowledge can both generate awe, but through different facets. The only difference we found between types of museums was the amount of awe guests reported related to feeling small (diminished self) were higher in science museums. When considered overall, the results suggest awe-related emotional perceptions and affect may subtly, yet positively, be related to memories of learning of guests. As opposed to being treated as a simple emotion driven by novel, "got ya!" moments, awe should be considered a complex emotion that can be induced in a number of different ways, each with its own unique relationship with what guests take from their visit.

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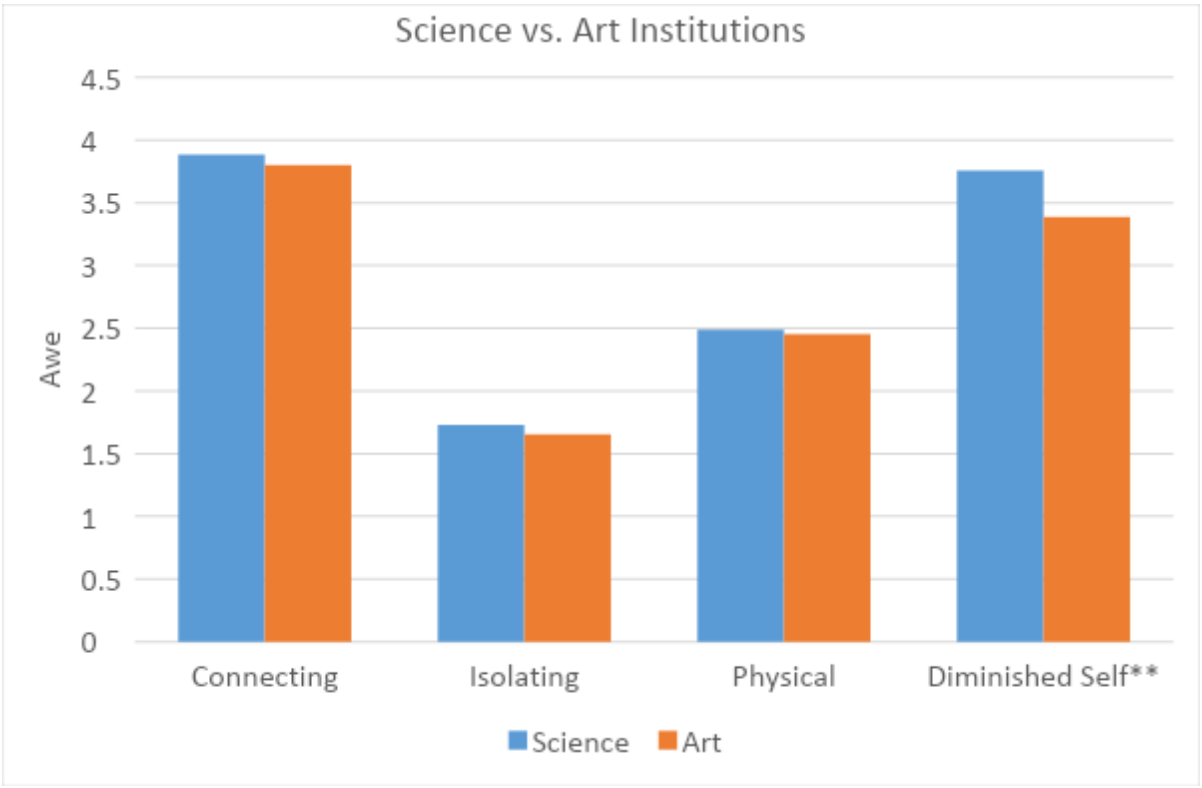

Figure 1. Awe post-survey means across institution type. **p<.01

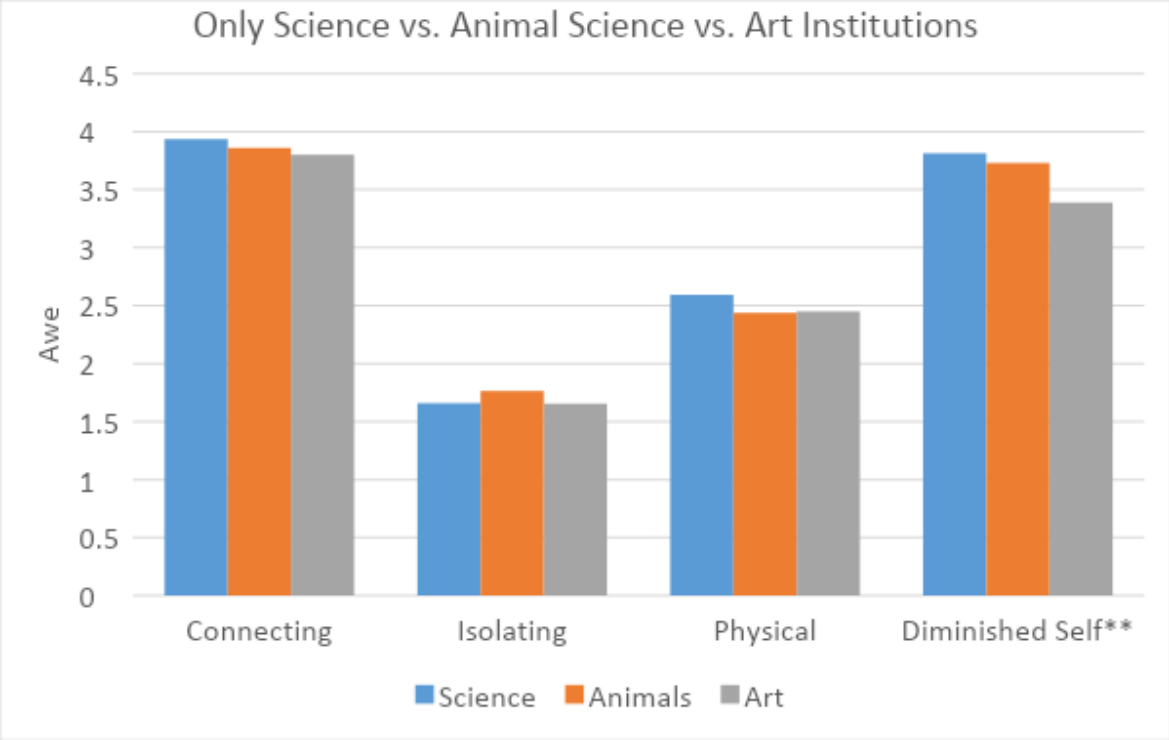

Figure 2. Awe post-survey means across institution type (expanded to separate science institutions with animals). **p<.01

Table 1.

Participating institutions and sample sizes. Each number represents guests and X represents the category in which we placed the institution.

Participating Institution	Approximate Annual Attendance (guests)	N		Art Museum	Science Institution	Science Institution – No Animals	Science Institution – With Animals
		Post-Survey	Delayed Post-Survey				
Denver Zoo	2,200,000	187	97		X		X
Shedd Aquarium	2,000,000	154	76		X		X
Museum of Science and Industry, Chicago	1,500,000	158	116		X	X	
Art Institute of Chicago	1,500,000	51	30	X			
Minneapolis Institute of Art	750,000	123	77	X			
Museum of Contemporary Art Chicago	370,000	91	57	X			

National Museum of Mexican Art	130,000	104	70	X
DePaul Art Museum	12,000	31	27	X

Table 2.

Coding rubric and manuscript keywords (in parenthesis) for the constructed-response items. The Description is that which was used by our coding team and Examples are taken from the data.

Code	Description	Example
Personal Context (Personal)	Why they visited; Visitors' background of *prior experiences and knowledge* for example, but also "individual (personal) interests, attitudes and *motivations* for and toward visiting"; More about the visitor.	"What day, turning into night in a grand Parisian salon, felt like. But I think I already knew." "I learned of what a great place this is! I have not been here for years and I could stay for hours upon hours!" "I learned every time I come back and see the marble sculpture of "The Veiled Lady" I am in awe."
Visitor's Sociocultural Context (Social)	References to the visitors' cultural background, the cultural setting of an exhibit as well as the social interactions between people taking place during the visit. Such social interactions can include those between friends or family members that visit together, between (unfamiliar) visitors and between visitors and museum staff.	"Being with my family in a very comfortable environment that allows learning at all levels." "I came as part of a team building exercise + used the escape room app - I learned how tech can connect visitors to a 'traditional' museum landscape" "More about my ancestors."
Before and After References (Before and After)	References to anything outside of the museum visit. E.g. Prior learning/knowledge, interests and attitudes they brought with them, expectations. Learning by itself isn't enough, but "learning more" is, because it implies prior knowledge.	"Rachel and Nathan enjoyed the Reading Planet very much. Rachel made her own paper and took a sample of it into the library." "Learned more about Ishimoto's Chicago-related work." "I have not been here for years and I could stay for hours…"
Knowledge and Understanding (Knowledge)	Learning new facts or information, or using prior knowledge in new ways. Coming to a deeper understanding. Knowing "what" or knowing "about". Well-known information may take on a new relevance or be made meaningful in a new way. Should be about facts or knowledge, not simply emotion. Needs to be specific, not "I learned a lot from the exhibit" or "I learned about	"I gained an insight into life in major cities and how it is different to my life," "We thoroughly enjoyed our visit and learnt a lot of what you do and how we can benefit if we want to research anything ourselves"

	math". Note: For the "what did you learn" question, learning can be implied. "Sea lions has ears, seals have not!" can be implied as something they learned. But not for other questions.	"The submarine touched me, learning how these soldiers had to exist for 90 days is unimaginable."
Attitudes and Values (Attitude)	Change in feelings, perceptions, or opinions about self, other people and things, and the wider world. Being able to give reasons for actions and personal viewpoints. Increase in empathy, capacity for tolerance. Increased motivation. About attitudes towards self, others, the organization. Note: For the "what did you learn" question, the "change" part can be implied. "That there are many ways injustice + Isolating can be fought against + expressed through art!" can be implied as a change (something they learned). But not for other questions.	"Gained an insight into life in major cities and how it is different to my life." "…it's about noticing a work of art that I've seen a million times before but in a different way." "The Fernandes work likewise deepened my appreciation of his questions about colonialism/dance." "It was interesting to see the similarities and differences of the European Regions." "It is exciting to see him become so eager to learn." "Denver zoo is beautiful"
Inspiration and Creativity (Inspiration)	Evidence of being surprised while using a library, archive or museum. Evidence of innovative thoughts, actions or things. Evidence of inspiration, exploration, experimentation and making.	"I think you spend most of your life living from one day to the next, thinking about bills, thinking about going to work, driving up and down the motorway or something – you go to an art gallery and you are living and experiencing art. It's a higher form of living" "I learned more about internment camps. Where one was (in Colorado). Acquainted myself with a new artist/photographer…"
Activity, Behavior, Progression (Activity)	What guests do, intend to do or have done. The way people balance and manage their lives, including their work, study or family contexts.	"Being with my family in a very comfortable environment that allows learning at all levels." "I didn't usually take my time to read/learn about where the animals are from. Reading their info/background makes it more interesting to me." "The zoo has a vast collection of animals that need our cooperation & help to ensure the survival of all of us."

Table 3.

Post-survey awe scores across institutions. Means represent scores on a 6-point scale.

	Connecting		Physical		Isolating		Diminished Self	
	M	SD	M	SD	M	SD	M	SD
Denver Zoo	4.00	1.12	2.27	1.39	1.51	1.22	3.75	1.09
Shedd Aquarium	3.72	1.23	2.60	1.40	2.01	1.43	3.70	1.34
Museum of Science and Industry, Chicago	3.93	1.22	2.60	1.49	1.66	1.29	3.81	1.14
Art Institute of Chicago	3.99	.93	2.57	1.38	1.59	1.38	3.39	.99
Minneapolis Institute of Art	3.90	1.09	2.39	1.55	1.04	1.06	3.75	1.10
Museum of Contemporary Art Chicago	3.25	1.13	2.34	1.45	2.23	1.43	3.43	1.17
National Museum of Mexican Art	4.25	1.17	2.86	1.43	1.85	1.22	3.20	1.20
DePaul Art Museum	3.61	1.01	2.10	1.48	1.56	1.15	3.16	1.34
All Science Museums & Cultural Centers	3.89	1.19	2.49	1.43	1.73	1.32	3.76	1.19
All Art Museums & Cultural Centers	4.00	1.15	2.45	1.48	1.65	1.32	3.39	1.17
Science Museums & Cultural Centers with Live Animals	3.86	1.18	2.44	1.40	1.76	1.34	3.73	1.21

Table 4.

Descriptive statistics for constructed-response items on the delayed-post survey (n = 550). Means represent responses with that code present.

	Learned		Connected		Exhibits		Unexpected	
	M	SD	M	SD	M	SD	M	SD
Personal Context	.14	.67	.25	.43	.11	.31	.09	.28
Sociocultural Context	.14	.34	.19	.39	.06	.24	.06	.24
Before and After	.12	.33	.17	.38	.07	.25	.17	.38
Knowledge and Understanding	.75	.43	.17	.38	.02	.13	.06	.24
Attitudes and Values	.36	.48	.47	.50	.52	.50	.22	.42
Inspiration and Creativity	.11	.31	.15	.36	.21	.41	.22	.42
Activity, Behavior and Progressions	.07	.26	.11	.31	.06	.23	.07	.26

Table 5.

Means (and standard deviations) for awe reported when that particular learning code was present in a guest response.

Learning Code	Awe Factor			
	Connecting	Isolating	Physical	Diminished Self

	What is something you learned today?			
Personal	3.77 (1.24)	1.51 (1.37)	2.31 (1.34)	3.33 (1.36)
Sociocultural	3.95 (1.11)	1.40 (1.29)	2.40 (1.65)	3.46 (1.37)
Before and After	3.81 (1.11)	1.74 (1.37)	2.43 (1.29)	3.26 (1.26)
Knowledge	3.97 (1.07)	1.54 (1.25)	2.53 (1.46)	3.70 (1.13)
Attitude	3.95 (1.15)	1.72 (1.35)	2.52 (1.52)	3.62 (1.21)
Inspiration	3.92 (1.36)	1.36 (1.33)	2.44 (1.64)	3.69 (1.30)
Activity	3.86 (1.01)	1.73 (1.41)	2.28 (1.28)	3.52 (1.13)
	What is something that connected with you today?			
Personal	3.90 (1.16)	1.64 (1.29)	2.58 (1.53)	3.62 (1.15)
Sociocultural	4.14 (1.14)	1.40 (1.27)	2.58 (1.52)	3.41 (1.24)
Before and After	3.91 (1.09)	1.53 (1.26)	2.53 (1.58)	3.73 (1.13)
Knowledge	4.07 (0.92)	1.64 (1.26)	2.58 (1.45)	3.71 (0.98)
Attitude	3.98 (1.02)	1.58 (1.32)	2.50 (1.49)	3.76 (1.08)
Inspiration	4.00 (0.94)	1.57 (1.25)	2.42 (1.55)	3.78 (1.15)
Activity	3.82 (1.15)	1.34 (1.25)	2.52 (1.46)	3.58 (1.15)
	If you could talk to a Director of Exhibits right now, what would you say to them?			
Personal	3.99 (1.11)	1.36 (1.42)	2.48 (1.52)	3.54 (1.34)
Sociocultural	4.27 (0.99)	1.53 (1.20)	3.18 (1.49)	3.60 (1.13)
Before and After	3.92 (1.12)	1.24 (1.33)	2.53 (1.67)	3.36 (1.41)
Knowledge	3.96 (1.18)	1.07 (1.11)	3.26 (1.83)	4.26 (1.21)
Attitude	3.95 (1.12)	1.50 (1.26)	2.50 (1.45)	3.66 (1.15)
Inspiration	3.85 (1.11)	1.49 (1.28)	2.61 (1.62)	3.74 (1.12)
Activity	4.31 (1.11)	1.34 (1.24)	2.35 (1.46)	3.64 (1.41)
	What was something unexpected about your visit?			
Personal	3.75 (1.11)	1.92 (1.27)	2.87 (1.28)	3.82 (0.95)
Sociocultural	3.97 (1.04)	1.70 (1.43)	2.51 (1.52)	3.46 (1.28)
Before and After	3.85 (1.06)	1.65 (1.30)	2.77 (1.50)	3.71 (1.10)
Knowledge	4.19 (0.91)	1.48 (1.33)	2.42 (1.47)	3.83 (1.05)
Attitude	3.99 (1.01)	1.62 (1.30)	2.78 (1.52)	3.78 (1.17)
Inspiration	3.85 (1.11)	1.54 (1.30)	2.81 (1.45)	3.68 (1.09)
Activity	3.87 (0.95)	1.62 (1.32)	2.57 (1.24)	3.77 (1.08)

Table 6.

Regression table for the Learning CR item, broken down by awe factor.

	Estimate	Standard Error	t value	Pr(>|t|)
		Connecting Awe Factor		
(Intercept)	3.17	0.15	21.85	< 0.001***
Personal	-0.11	0.18	-0.59	0.56
Sociocultural	0.05	0.15	0.37	0.71
Before and After	-0.12	0.16	-0.77	0.44
Knowledge	0.52	0.11	4.48	<0.001***
Attitude	0.19	0.11	1.69	0.09~
Inspiration	0.02	0.17	0.10	0.92
Activity	0.05	0.20	0.23	0.82
Museum Type	-0.09	0.10	-0.86	0.39
Prior Knowledge (Delayed)	0.11	0.03	4.21	<0.001***
adjusted $r^2 = 0.05$				
		Oppress Awe Factor		
(Intercept)	1.66	0.17	9.71	< 0.001***
Personal	-0.2	0.22	-0.92	0.36
Sociocultural	-0.25	0.17	-1.46	0.15
Before and After	0.18	0.18	0.99	0.32
Knowledge	-0.18	0.14	-1.33	0.19
Attitude	0.2	0.12	1.62	0.11
Inspiration	-0.42	0.19	-2.15	0.03*
Activity	0.3	0.24	1.29	0.20
Museum Type	0.03	0.12	0.26	0.80
Prior Knowledge (Delayed)	0.01	0.03	0.44	0.66
adjusted $r^2 = 0.01$				
		Physical Awe Factor		
(Intercept)	1.92	0.19	10.06	< 0.001***
Personal	-0.08	0.24	-0.34	0.73
Sociocultural	-0.18	0.19	-0.95	0.34
Before and After	-0.11	0.2	-0.54	0.59
Knowledge	0.27	0.15	1.8	0.07~
Attitude	0.06	0.14	0.43	0.67
Inspiration	-0.1	0.22	-0.45	0.66
Activity	-0.11	0.26	-0.43	0.67
Museum Type	0.08	0.13	0.6	0.55
Prior Knowledge (Delayed)	0.14	0.03	4.01	< .001***
adjusted $r^2 = 0.02$				
		Diminished self		
(Intercept)	3.54	0.15	23.28	< 0.001***
Personal	-0.26	0.19	-1.38	0.17
Sociocultural	-0.07	0.15	-0.45	0.66
Before and After	-0.37	0.16	-2.25	0.03*
Knowledge	0.28	0.12	2.32	0.02*
Attitude	0.08	0.11	0.73	0.47
Inspiration	0.24	0.17	1.37	0.17

Activity	0.04	0.21	0.19	0.85
Museum Type	-0.36	0.11	-3.4	< 0.001***
Prior Knowledge (Delayed)	0.03	0.03	1.08	0.28
adjusted r^2 = 0.04				

Table 7.

Regression table for the Connected CR item, broken down by awe factor.

	Estimate	Std. Error	t-value	p-value
		Connecting Awe Factor		
(Intercept)	3.56	0.11	33.62	< 0.001***
Personal	-0.03	0.12	-0.22	0.82
Sociocultural	0.33	0.13	2.6	0.01
Before and After	-0.01	0.14	-0.1	0.92
Knowledge	0.2	0.13	1.54	0.12
Attitude	0.13	0.1	1.32	0.19
Inspiration	0.07	0.14	0.52	0.6
Activity	-0.16	0.16	-0.99	0.32
Museum Type	-0.14	0.1	-1.46	0.15
Prior Knowledge (Delayed)	0.09	0.03	3.45	< 0.001***
adjusted r^2 = 0.03				
		Isolating Awe Factor		
(Intercept)	1.56	0.12	12.63	< 0.001***
Personal	0.2	0.14	1.4	0.16
Sociocultural	-0.25	0.15	-1.66	0.097~
Before and After	-0.08	0.17	-0.48	0.63
Knowledge	0.11	0.15	0.72	0.47
Attitude	0.05	0.12	0.44	0.66
Inspiration	-0.04	0.16	-0.25	0.8
Activity	-0.27	0.19	-1.47	0.14
Museum Type	-0.01	0.11	-0.11	0.92
Prior Knowledge (Delayed)	0.01	0.03	0.43	0.67
adjusted r^2 = -0.004				
		Physical Awe Factor		
(Intercept)	2.13	0.14	15.44	< 0.001***
Personal	0.14	0.16	0.84	0.40
Sociocultural	0.05	0.17	0.33	0.74
Before and After	-0.04	0.18	-0.21	0.83
Knowledge	0.14	0.17	0.85	0.39
Attitude	0.01	0.13	0.09	0.93
Inspiration	-0.16	0.18	-0.86	0.39
Activity	0.01	0.21	0.04	0.97
Museum Type	-0.01	0.13	-0.11	0.91

Prior Knowledge (Delayed)	0.11	0.03	3.49	< 0.001***
adjusted r^2 = 0.01				
	Diminished Self Factor			
(Intercept)	3.68	0.11	33.46	< 0.001***
Personal	0.03	0.13	0.26	0.79
Sociocultural	-0.26	0.13	-1.94	0.05~
Before and After	0.12	0.15	0.82	0.42
Knowledge	0.06	0.13	0.48	0.63
Attitude	0.26	0.1	2.52	0.01*
Inspiration	0.09	0.14	0.63	0.53
Activity	-0.14	0.17	-0.85	0.40
Museum Type	-0.34	0.1	-3.42	< 0.001***
Prior Knowledge (Delayed)	0	0.03	0.1	0.92
adjusted r^2 = 0.03				

Table 8.

Regression table for the Exhibits CR item, broken down by awe factor.

	Estimate	Std. Error	t-value	p-value
	Connecting Awe Factor			
(Intercept)	3.60	0.11	33.02	< 0.001***
Personal	0.06	0.19	0.34	0.74
Sociocultural	0.34	0.21	1.63	0.10
Before and After	-0.09	0.23	-0.38	0.70
Knowledge	-0.13	0.39	-0.35	0.73
Attitude	0.14	0.10	1.44	0.15
Inspiration	-0.12	0.12	-0.96	0.34
Activity	0.45	0.22	2.11	0.04
Museum Type	-0.11	0.10	-1.18	0.24
Prior Knowledge (Delayed)	0.09	0.03	3.37	<0.001***
adjusted r^2 = 0.03				
	Isolating Awe Factor			
(Intercept)	1.69	0.13	13.29	< 0.001***
Personal	-0.12	0.22	-0.53	0.60
Sociocultural	0.10	0.25	0.42	0.67
Before and After	-0.18	0.27	-0.66	0.51
Knowledge	-0.36	0.45	-0.80	0.43
Attitude	-0.16	0.11	-1.38	0.17
Inspiration	-0.11	0.14	-0.79	0.43
Activity	-0.16	0.25	-0.64	0.52
Museum Type	0.004	0.11	-0.04	0.97
Prior Knowledge (Delayed)	0.01	0.03	0.48	0.63
adjusted r^2 = -0.004				

	Physical Awe Factor			
(Intercept)	2.15	0.14	15.25	< 0.001***
Personal	-0.06	0.24	-0.24	0.81
Sociocultural	0.60	0.27	2.19	0.03*
Before and After	-0.03	0.30	-0.09	0.93
Knowledge	0.53	0.50	1.06	0.29
Attitude	0.02	0.13	0.20	0.84
Inspiration	0.07	0.16	0.42	0.68
Activity	-0.23	0.28	-0.82	0.41
Museum Type	-0.05	0.13	-0.36	0.72
Prior Knowledge (Delayed)	0.11	0.03	3.41	< 0.001***
adjusted $r^2 = 0.02$				
	Diminished Self Awe Factor			
(Intercept)	3.72	0.11	32.76	< 0.001***
Personal	-0.06	0.20	-0.33	0.74
Sociocultural	0.01	0.22	0.06	0.95
Before and After	-0.25	0.24	-1.05	0.29
Knowledge	0.66	0.4	1.63	0.10
Attitude	0.11	0.1	1.06	0.29
Inspiration	0.18	0.13	1.39	0.17
Activity	-0.11	0.23	-0.50	0.62
Museum Type	-0.37	0.10	-3.65	< 0.001***
Prior Knowledge (Delayed)	0.01	0.03	0.22	0.83
adjusted $r^2 = 0.02$				

Table 9.

Regression table for the Unexpected CR item, broken down by awe factor.

	Estimate	Std. Error	t-value	p-value
		Connecting Awe Factor		
(Intercept)	3.63	0.1	35.78	< 0.001***
Personal	-0.25	0.19	-1.31	0.19
Sociocultural	0.07	0.21	0.35	0.73
Before and After	0	0.14	0.03	0.98
Knowledge	0.32	0.2	1.63	0.10
Attitude	0.16	0.12	1.41	0.16
Inspiration	0.12	0.12	0.98	0.33
Activity	0.04	0.19	0.23	0.82
Museum Type	-0.1	0.1	-1.03	0.30
Prior Knowledge (Delayed)	0.08	0.03	3.22	0.001**
adjusted r^2 = 0.02				
		Oppress Awe Factor		
(Intercept)	1.56	0.12	13.2	< 0.001***
Personal	0.43	0.23	1.9	0.06~
Sociocultural	0.03	0.24	0.11	0.92
Before and After	-0.01	0.17	-0.08	0.94
Knowledge	-0.12	0.23	-0.54	0.59
Attitude	0.01	0.14	0.09	0.93
Inspiration	-0.13	0.14	-0.93	0.35
Activity	0.05	0.22	0.24	0.81
Museum Type	-0.02	0.11	-0.22	0.83
Prior Knowledge (Delayed)	0.01	0.03	0.47	0.64
adjusted r^2 = -0.006				
		Physical Awe Factor		
(Intercept)	2.01	0.13	15.48	< 0.001***
Personal	0.21	0.25	0.86	0.39
Sociocultural	-0.21	0.27	-0.77	0.44
Before and After	0.16	0.18	0.87	0.39
Knowledge	-0.04	0.25	-0.15	0.88
Attitude	0.3	0.15	2.01	0.045*
Inspiration	0.29	0.16	1.85	0.07~
Activity	0.09	0.25	0.38	0.71
Museum Type	-0.02	0.12	-0.18	0.86
Prior Knowledge (Delayed)	0.12	0.03	3.56	< 0.001***
adjusted r^2 = 0.03				
		Diminished Self Factor		
(Intercept)	3.7	0.11	35.18	< 0.001***
Personal	0.17	0.2	0.82	0.41
Sociocultural	-0.2	0.22	-0.93	0.35
Before and After	0.04	0.15	0.29	0.77

Knowledge	0.27	0.21	1.33	0.19
Attitude	0.21	0.12	1.72	0.09~
Inspiration	0.02	0.13	0.18	0.85
Activity	0.06	0.2	0.32	0.75
Museum Type	-0.36	0.1	-3.59	< 0.001***
Prior Knowledge (Delayed)	0.01	0.03	0.31	0.76
adjusted $r^2 = 0.02$				

Online Supplementary Material

Situational Awe Scale (SAS)[3]

Connection	I felt free. I felt liberated. I felt a closer sense of my identity, who I am. I felt psychologically connected to everyone/everything around me. I felt physically connected to everyone/everything around me. Everything seemed connected.
Isolation	I felt confined. I felt tense. I felt suffocated I felt oppressed. Everything seemed disjointed.
Physical Analogs (i.e. Chills)	My heart was racing. My breath was taken away. I felt chills. I felt goosebumps.
Diminished Self	I felt physically smaller. I felt like I was trivial, in the grand scheme of things. The world seemed vast.

[3] This is the original SAS, which had 18 items (Author & Krenzer, 2017) and was used in this study. Subsequently, a 15-item version was designed to provide better balance between and tighter construct clarity (Author, et al., in prep) within the four subscales, but has little impact on the psychometric properties or predictive power of the scale.