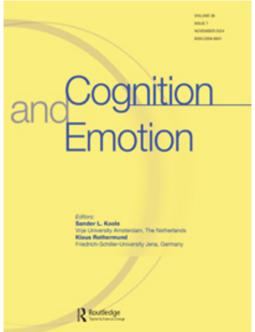

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Impact of awe on topic interest and recognition memory for information in planetarium films

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ABSTRACT
We investigated the impact of situational awe on topic-specific interest and recognition memory for information presented in immersive planetarium films. Adult participants (*N* = 131) were recruited among science centre visitors who were going to view one of the films shown in the science centre's planetarium. Participants responded to questions about prior knowledge, topic-specific interest in the film and background information before viewing one of the three planetarium films. After the film, they completed the topic-specific interest scale, epistemically-related emotion scales, situation-specific awe scale, critical thinking disposition scale and a recognition task of the film contents. The results showed that during viewing planetarium films participants experienced awe, but the strength of this emotion varied among films. Additionally, situation-specific awe was strongly associated with another epistemic emotion, namely surprise. As for the recognition task performance, awe decreased error and nonsense detection, and increased false recognition of inferential statements. Finally, awe was found to substantially increase topic-specific interest. These results present evidence that awe has potential to prompt individuals to become more interested in science-related topics.

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Epistemic emotion; awe; topic interest; recognition memory; science museum

Awe has been named an epistemic emotion (e.g. McPhetres, 2019) and is thought to be an antecedent of science learning (Coleman, 2014). Despite the general recognition of the importance of emotions to learning and memory (e.g. Fiedler & Beier, 2014), very little is known about how specific epistemic emotions such as awe impact the cognitive processes underlying learning (Muis et al., 2015). We set to examine whether awe, experienced while visiting a science centre, has potential for boosting learning and fostering science interest. Specifically, we studied the impact of situational awe induced by a planetarium film on recognition memory for science-related information and on interest for the topic of the film.

Awe and other epistemic emotions

Epistemic emotions refer to emotions related to knowledge and understanding, and which often arise in learning contexts (Pekrun et al., 2017). For example, conflicting knowledge or very complex information may induce anxiety or boredom – or more positive feelings like curiosity and enjoyment (Muis et al., 2015; Pekrun et al., 2017). Different epistemic emotions induce different types of cognitive

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processing, which is why they are expected to influence learning outcomes (e.g. Muis et al., 2015). For example, positive activating emotion like curiosity should increase "deeper" processing of the to-be-learned material, resulting in better understanding and memory, whereas negative de-activating emotion like boredom should lead to shallower processing and poorer comprehension (Muis et al., 2015).

Awe is a specific type of epistemic emotion (Valdesolo, 2022), elicited when we perceive or experience something that goes beyond our current understanding, requiring from us to seek new knowledge or adjust our existing knowledge to make sense of the experience. According to Keltner and Haidt (2003), awe has two core components: perception of vastness and a need for accommodation of the existing knowledge structures. For example, panoramic nature scenes are common elicitors of awe (Shiota et al., 2007).

Awe may be accompanied by other emotions (Keltner & Haidt, 2003; Shiota et al., 2007), such as surprise (Luke, 2021), curiosity (Anderson et al., 2020), as well as admiration and elevation (Keltner & Haidt, 2003). Even though awe may be related to negative feelings like isolation (Krogh-Jespersen et al., 2020) or fear (Keltner & Haidt, 2003), awe often co-occurs with other positive emotions (Luke, 2021; Price et al., 2021). For instance, in addition to awe, visitors of art museums reported pleasant emotions such as curiosity, joy and excitement (Luke, 2021). The exact nature of the awe experience depends on the nature of the context and the triggering event (Krogh-Jespersen et al., 2020).

Effects of awe on memory performance

Emotions have an impact on the cognitive processes underlying learning and memory (e.g. Fiedler & Beier, 2014). Positive emotions have been proposed to foster global information processing (Isbell, 2004), while negative emotions are claimed to support local and detailed consideration of information (Forgas, 1995). The effects of emotions on learning and memory can be interpreted from the perspective of two types of processing: assimilation and accommodation (Fiedler, 2001; Fiedler & Beier, 2014). Positive emotions are believed to facilitate assimilation, in which individuals extrapolate their existing knowledge to explain novel information they have encountered (Fiedler, 2001). Negative emotions, on the other hand, facilitate accommodative processing, in which individuals revise their existing knowledge structures in response to novel information (Fiedler & Beier, 2014).

It has been suggested that unlike other positive emotions, awe should trigger accommodative processing (e.g. Keltner & Haidt, 2003; Valdesolo, 2022). Griskevicius et al. (2010) induced awe experimentally, which made participants less susceptible to persuasion by weak arguments, indicating that awe increased systematic processing and critical evaluation of information. Shiota et al. (2007) found that people who are more likely to experience awe are more willing to modify their existing knowledge structures. These findings suggest that awe increases systematic and accommodative processing.

Danvers and Shiota (2017) examined how experimentally induced awe influences memory for a story. Participants were assigned into three groups in which they watched either an awe-inducing, a positive emotion-inducing, or a neutral video. After the video, the participants listened to a story about a couple going out for dinner and completed a recognition task of the story contents. Some items were false memory lures that were not presented in the story, even though they fit a typical script for visiting a restaurant. Danvers and Shiota (2017) expected that if awe increases assimilative processing, then participants in the awe condition should be more susceptible to falsely recognising lures fitting the general restaurant schema. In contrast, if awe increases accommodative processing, then participants in the awe condition should accurately recognise that the lures were not included in the story. The results showed that awe was related to higher accuracy in the recognition task, indicating that awe enhances accommodative processing of information (Keltner & Haidt, 2003; Valdesolo, 2022).

Previous experimental studies have examined memory for information that is not relevant to the awe-inducing event (e.g. Danvers & Shiota, 2017; Griskevicius et al., 2010), leaving open the question of whether awe impacts memory for the information that elicits the emotion. We examined whether awe experienced during viewing of a film is associated with recognition memory performance for the information presented in it. This is important, as it helps in understanding the immediate effects of emotional reactions on memory processes.

Individual differences in awe and its effects on memory

Experiencing awe also depends on the characteristics of the individual (e.g. Price et al., 2019; Price et al., 2021; Shiota et al., 2007). We considered two factors that may contribute to individual differences in awe: prior knowledge and critical thinking disposition.

Prior knowledge may stimulate awe by helping to recognise knowledge gaps, especially when facing complex or novel information (Price et al., 2019). In support of this notion, familiarity with the topic of the exhibition was a strong predictor of awe among museum visitors (Price et al., 2021). Furthermore, prior knowledge facilitates integrating novel information to memory, especially if it fits in with previous knowledge and interests (Alexander et al., 1994). Prior knowledge is also necessary for making inferences – without relevant knowledge, it is not possible to fill in the gaps in the presented information (McNamara & Kintsch, 1996). In other words, prior knowledge supports assimilative processing of information. Prior knowledge may thus be a crucial factor in how awe impacts memory: it potentially increases experiences of awe, as well as facilitates assimilative processing. We examined the interaction between awe and prior knowledge on recognition memory to gain insights into how awe impacts memory processes.

Another potentially important factor in experiencing awe is an individual's disposition to novel information, such as critical thinking disposition. Price et al. (2019) suggested that persons who tend to consider evidence carefully and systematically might be more prone to experience certain aspects of awe. They examined museum visitors and found that individual differences in critical thinking disposition were associated with experiencing positive aspects of awe during the visit. However, very little is known about how critical thinking disposition may be related to awe and its effects on memory. Some supporting evidence comes from a study on need for cognitive closure (Shiota et al., 2007), which refers to an individual's tendency to tolerate uncertainty and willingness to modify pre-existing knowledge structures. Low need for cognitive closure was linked with higher awe-proneness, suggesting that a personal trait to approach information with a willingness to engage in accommodative processing is linked with awe.

Awe as a catalyst for topic interest

Epistemic emotions like awe are important in stimulating topic interest (McPhetres, 2019). McPhetres (2019) examined how awe-inducing nature videos influence perceptions of knowledge gaps and interest in science and science-related activities. In comparison to neutral videos, awe-inducing videos increased awareness of knowledge gaps, which in turn increased participants' science interest. Momentary experiences of awe might thus trigger a longer-lasting interest in a topic, which is why awe has been claimed to be a catalyst for interest in science and a moving force of scientific inquiry (e.g. Coleman, 2014).

In summary, awe may trigger topic-specific interest in science and the natural world. Understanding how interest can be triggered and fostered is important for promoting science centre attendance and science learning. We examined whether situational awe increases interest in topics relevant to the awe-inducing experience.

Present study

Awe might have positive effects on learning and memory (Coleman, 2014; Danvers & Shiota, 2017). Furthermore, awe is often associated with other positive epistemic emotions, such as curiosity (Anderson et al., 2020). However, the empirical evidence is still sparse, and it is unclear whether awe enhances assimilative or accommodative memory processes, and whether it can trigger further topic-specific interest in the awe-inducing phenomenon. The purpose of the present research was to study the impact of situational awe on memory and topic-specific interest in an ecologically valid context. To this end, the study was conducted in a science centre hosting a modern planetarium. The planetarium offers an immersive film experience, which can be expected to induce awe. As the topics of the films are related to natural sciences, they are ecologically valid material for testing memory and interest in science-related information.

The research questions (RQs) of this study are:

1. Do planetarium films induce awe, and are individual differences in prior knowledge and critical thinking related to experiencing awe?
2. What epistemic emotions co-occur with awe?
3. Does awe influence memory for information presented in the film, and does its impact depend on individual differences in prior knowledge and critical thinking disposition?
4. Does situational awe increase topic-specific interest towards the topic of the film?

Participants were science centre visitors who had chosen to watch one of the planetarium films. The participants rated their prior knowledge and interest in the topic of the film, and completed a situational awe scale (SAS; Krenzer et al., 2020), epistemic emotions scale (EES, Pekrun et al., 2017), topic-specific interest scale (TSIS; Schiefele & Krapp, 1996), and a recognition memory test for information presented in the film.

We used a recognition memory paradigm that allowed us to test whether awe enhances accommodative or assimilative memory processes. In the task, participants were presented with four types of stimuli: (1) phrases that were included in the film, (2) inferential phrases, which were based on information presented in the film but which were not actually presented in it, (3) phrases containing detail errors, which were created by slightly modifying the wording of some phrases presented in the film and (4) nonsense phrases, which contradict general knowledge about the natural world. Participants' task was to answer whether the phrase appeared in the film they saw earlier or not.

We expected that prior knowledge (Price et al., 2021) and critical thinking disposition (Price et al., 2019) would be positively correlated with experiencing awe. We also expected other epistemic emotions to accompany awe. As for recognition memory performance, we hypothesised that if awe increases accommodation of information, then higher awe should be associated with better recognition performance for phrases that were presented in the film and in detecting detail errors. In contrast, if awe increases assimilative processing, then higher awe should increase recognition errors of inferential phrases. We did not have a priori hypotheses regarding the interactions between awe, prior knowledge and critical thinking disposition. Finally, we expected that situational awe would enhance topic-specific interest in the awe-inducing phenomenon.

Methods

Participants

184 visitors of a science centre located in Southern Finland completed the questionnaire. Participants were excluded due to not giving consent for the data to be included into the analysis; having either seen the same planetarium film sometime before or any other film on the same day; their native language not being Finnish; being underage; or not mentioning their gender or notified being other (for exact numbers, refer to the Supplementary materials). Thus, the total number of participants in the analyses was 131 (45 males, 86 females; $M_{age} = 37.40$ years, SD = 11.52 years; $max_{age} = 73$, $min_{age} = 18$). Out of 131 participants, the "Dynamic Earth" (from now on referred to as the "Earth") film was watched by 43; the "Aurora" was viewed by 42; and film "Beyond the Sun" (from now on the "Stars") – by 46 participants.

The study was approved in advance by the Ethics Committee for Human Sciences at the University of Turku, Finland. All participants gave their informed consent before participation.

Materials

Planetarium films

Data was collected in the Science Centre Heureka (Vantaa, Finland). At the time of data collection three planetarium films were shown. The "Earth" was about our planet's climate system. This film was 24 min long, and the information presented by the narrator in it comprised 135 sentences that contained 1051 words. The "Aurora" was about the origin, physical nature and mythology of northern lights. Its duration was 21 min, and the narrated part contained 62 sentences and 557 words. The "Stars" was about the most remote parts of the Universe, stars and planets that can be found there. It was 26 min long, and its script consisted of 228 sentences and 1304 words. The voiceover for the films was in Finnish. All of the films contained musical accompaniment, panoramic views, close-ups and rapid zooms out, as well as dramatic changes in luminosity such as rapid transfers from intense brightness to darkness in connection with the processes occurring in the Universe.

Situational Awe Scale

The situational awe scale (SAS; Krenzer et al., 2020) originally created and validated in English was translated into Finnish and back-translated into English by the members of the research team, native in Finnish and proficient in English, up until they agreed that the translation terms accurately resembled the original. The SAS consists of four subscales: connection (e.g. "I felt physically connected to everyone/everything around me"), oppression (e.g. "I felt confined"), chills (e.g. "I felt goosebumps"), and diminished self (e.g. "I felt physically smaller"). The participants were asked to rate how they felt during watching the film on a 5-point Likert scale (1

= "not at all", 5 = "very much"). The order of the statements was randomised for every participant. A total score across all items and separate scores for each subscale were calculated by taking an average of the responses. Cronbach alphas for the total score (α = .85), Connection (α = .80), and Chills (α = .84) were in the acceptable range. For Diminished Self (α = .55) and Oppression (α = .50) subscales the alphas were low.

Critical Thinking Disposition Scale

The Critical Thinking Disposition Scale (CTDS; Sosu, 2013) was translated from English into Finnish following the same procedure as the SAS. The CTDS assessed individual's disposition to approach information critically and it consisted of 11 items (e.g. "I usually try to think about the bigger picture during a discussion", "I often think about my actions to see whether I could improve them"). The participants rated the statements on a 5-point Likert scale (1 = "not at all", 5 = "very much"). The order of the items was randomised for every participant. A sum score of all items was calculated to compute a total CTDS score, and its internal consistency was acceptable (α = .86).

Prior knowledge

Prior knowledge (PK) was measured with one self-assessment question about participants' knowledge on the topic of the planetarium film. For example, for "Aurora", participants were asked "To what extent do you consider yourself knowledgeable about northern lights?". The rating was made on a 5-point Likert scale from 1 ("I don't know anything") to 5 ("I know a lot about the topic").

Topic Specific Interest Scale

The Topic Specific Interest Scale (TSIS; Schiefele & Krapp, 1996) was translated from English into Finnish in the same way as the SAS and the CTDS. The TSIS measured participants' interest in the topic of the film and it consisted of ten items assessing how bored, stimulated, interested, indifferent, involved, and engaged participants expected to feel or felt while watching the film, and how meaningful, unimportant, useful, and worthless the film topic was to them. Responses were given on a 5-point Likert scale (1 = "not at all", 5 = "very much"). A sum score of all items was computed to get a total TSIS score, which had good internal consistency (α = .83).

Epistemically-Related Emotion Scales

The Epistemically-related Emotion Scale (EES, Pekrun et al., 2017) was translated from English into Finnish as described above for the other scales originally developed in English. In the EES, participants rated to what extent they experienced each of the seven epistemically related emotions: surprise, curiosity, enjoyment, confusion, anxiety, frustration, and boredom. Responses were given on a 5-point Likert scale (1 = "not at all", 5 = "very much"). Two items of EES (i.e. interest and boredom) overlapped with items of the feeling-related subscale of the TSIS and were only asked once in the post-test.

Recognition memory

A recognition task was developed to test memory for the contents of the three planetarium films for the purpose of this study. In this task, the participants were asked to determine whether the statement presented to them was mentioned in the film in exactly the same wording (yes/no). The recognition task comprised four types of statements: (1) old statements in exactly the same wording as presented in the film; (2) detail errors, which were modified statements that were originally included in the film, but with one detail switched to contain an error; (3) nonsense statements that could not possibly be mentioned in the film as they contradicted general knowledge about the natural world; (4) inferences that were not mentioned in the film as such, but which could have been made from the information presented in the film. There were five items of each type for each three films, totalling 60 recognition task items. Each participant responded only to the items related to the film they saw (i.e. 20 items). More detailed information about the task creation is in the Supplementary materials.

Procedure

The study included pre- and post-tests conducted before and immediately after the participants watched a planetarium film. The questionnaires (in Finnish) were presented on a tablet computer using Gorilla software (https://app.gorilla.sc/). Responding was anonymous. Each participant was assigned an ID code used to link the pre- and post-test answers. The pre-test took approximately 5–8 min and post-test approximately 10–12 min.

Potential participants were approached by research assistants at the planetarium entrance and asked whether they would like to participate in this study. After acquainting themselves with the information about this study and giving their consent to participation, the participants were asked to complete the pre-test before watching the film. The pre-test questions contained participants' estimate about their PK, TSIS, and demographics (age, gender, and whether their native language is Finnish).

Upon exiting the planetarium after watching the film, the same participants completed the post-test. The post-test contained TSIS, EES, SAS, CTDS, and the recognition task. As the information sheet and the consent form did not specify that we were particularly interested in awe to avoid priming effect, after the post-test the participants read more about the purpose of this study and were asked to give their consent to the answers being used in data analysis.

The study was preregistered at OSF (https://osf.io/zts9k) prior to data collection. Several changes were made to preregistered protocol. These are detailed in the Supplementary materials.

Statistical analyses

The data were analysed using linear regression (RQ1 and RQ2) and (generalised) linear-mixed effects (LME) models (RQ3 and RQ4) with R statistical software (version 4.3.2; R Core Team, 2022) and LME4 (version 1.1-35.1; Bates et al., 2015) package. The plots have been created with the ggplot2 (version 3.4.4; Wickham, 2016) package. In the following, we will briefly describe models used for answering each Research Question. For more detailed descriptions, please refer to the Supplementary materials. For each model, participant's age and gender were included as control variables. Age was a continuous variable that was centred and gender was dummy coded with female as baseline. Film used simple coding with Aurora as baseline in RQ1 and RQ3 models.

To answer RQ1, we predicted SAS total score and two of its subscales (Connection and Chills) on basis of PK and CTDS. For the SAS total and the subscales we subtracted 1 from each value so that the score of 0 corresponded to no awe whatsoever. The final models were of form:

$$\text{SAS} \sim 1 + \text{PK} + \text{CTDS} + \text{age} + \text{gender} + \text{film}$$

To answer RQ2, we first checked the correlations between SAS total score and the epistemic emotions. We then predicted the SAS scores on the basis of epistemic emotions significantly correlating with SAS. In the same way as in RQ1, we subtracted 1 from each SAS value. The final model was of the form:

$$\text{SAS} \sim 1 + \text{surprise} + \text{curiosity} + \text{enjoyment} + \text{confusion} + \text{anxiety} + \text{boredom} + \text{age} + \text{gender}.$$

To answer RQ3, we ran generalised linear mixed models to predict the accuracy of responses (1/0) on basis of item type (Old, Error, Nonsense, and Inference), SAS total scores, PK, and CTDS. As the expected response to Old items was a "yes", and "no" to the other three item types, separate analyses were conducted for Old items and all the other item types. The model for Old items was of the form:

$$\text{accuracy} \sim 1 + \text{SAS} + \text{PK} + \text{CTDS} + \text{film} + \text{SAS:PK} + \text{SAS:CTDS} + \text{age} + \text{gender} + (1|\text{participant}) + (1|\text{item\_id}).$$

For the model with the other three item types, the model was of the form:

$$\text{accuracy} \sim 1 + \text{item\_type} + \text{SAS} + \text{PK} + \text{CTDS} + \text{film} + \text{item\_type:SAS} + \text{item\_type:PK} + \text{item\_type:CTDS} + \text{item\_type:SAS:PK} + \text{item\_type:SAS:CTDS} + \text{age} + \text{gender} + (1|\text{participant}) + (1|\text{item\_id}).$$

To answer RQ4, we predicted the TSI scores on basis of Time (pre/post-test), SAS total scores, PK, and CTDS. The final model was of the form:

$$\text{TSI} \sim \text{time} * \text{SAS} * \text{PK} + \text{time} * \text{SAS} * \text{CTDS} + \text{age} + \text{gender} + (1|\text{participant}).$$

The exact degrees of freedom are difficult to determine for the t and z-statistics estimated by mixed-effects models, leading to problems in determining exact p-values (Baayen et al., 2008). Consequently, degrees of freedom or p-values are not reported; statistical significance at the 0.05 level is indicated by values of t and $z > |1.96|$.

The analysis script and data are available online at: https://osf.io/z84ua

Results

Descriptive statistics of all measures and the final models for each RQ are presented in the Supplementary materials. In the following, we will go over the important effects.

RQ1: Do planetarium films induce awe, and are individual differences in prior knowledge and critical thinking related to experiencing awe?

As indicated by model intercepts differing from zero, participants reported feeling awe (SAS total score $t = 12.49$; Connection $t = 11.23$; Chills $t = 7.08$), during viewing the planetarium films. There were some differences between the films: For SAS total score and Connection subscale, the film "Aurora" elicited higher awe than "Stars" ($t = -2.25$ for total score, $t = -2.77$ for Connection). For Connection subscale, higher critical thinking disposition was associated with higher connection ($t = 3.16$), and experiences of connection increased with age ($t = 2.27$). For the Chills subscale, there were no reliable effects.

RQ2. What epistemic emotions co-occur with awe?

The SAS scores correlated significantly with all the epistemic emotions apart from frustration, and anxiety (Table 1). The LME model is presented in the Supplementary materials. When controlling for the level of the other epistemic emotions, the only emotion explaining variance in SAS was surprise ($t = 3.72$). Higher levels of surprise were associated with higher SAS scores.

RQ3: Does awe enhance recognition memory?

For Old items, none of the predictors proved significant, which may be due to a ceiling effect (M = 93%) in the correct responses to Old items.

For the other item types (correct answer was false), a significant main effect of SAS total score ($z = -1.98$) indicated that higher levels of awe were associated with lower accuracy. Furthermore, there was an effect of Item Type (smallest $|z| = 2.62$) and an interaction between Item Type and PK ($z = -2.42$), which is depicted in Figure 1a. For Nonsense and Error items, higher PK was associated with higher accuracy, while for Inferences, higher PK was associated with lower accuracy.

RQ4: Does awe increase topic-specific interest towards the topic of the film?

In addition to simple effects of SAS total score ($t = 2.01$), CTDS ($t = 2.45$), and PK ($t = 3.44$) on Topic Specific Interest, there was an interaction between Time and SAS total score ($t = 4.17$), which is depicted in Figure 1b. In this figure, the difference between pre-test and post-test in Topic Specific Interest is presented so that the positive values denote increase and negative values decrease in Topic Specific Interest. The Topic Specific Interest scores got higher for those who experienced substantial awe whereas for those who had lower levels of awe, Topic Specific Interest decreased.

Discussion

Previous studies have investigated awe mostly in laboratory environments. However, these studies have been criticised for their limited capacity to yield results that could be generalised to real-life settings (Price et al., 2019). It has been recommended to extend the investigation of awe to real-world circumstances (Price et al., 2021). We examined how awe experienced in a planetarium influences memory for information presented in the planetarium film and the topic-specific interest in the topic of the film.

Do planetarium films induce awe, and are individual differences in prior knowledge and critical thinking related to experiencing awe?

The results of this study indicate that films shown in the planetarium induce awe, but the strength of

Table 1. Correlations between epistemic emotions and SAS total score.

	Surprise	Curiosity	Enjoyment	Confusion	Anxiety	Frustration	Boredom	SAS
Surprise	1.000	.409***	.338***	.344***	.096	−.088	−.249**	.512***
Curiosity	.409***	1.000	.411***	.110	.190*	−.025	−.498***	.435***
Enjoyment	.338***	.411***	1.000	−.167	−.152	−.265**	−.344***	.336***
Confusion	.344***	.110	−.167	1.000	.227**	.055	−.074	.209*
Anxiety	.096	.190*	−.152	.227**	1.000	.524***	−.019	.157
Frustration	−.088	−.025	−.265**	.055	.524***	1.000	.188*	.016
Boredom	−.249**	−.498***	−.344***	−.074	−.019	.188*	1.000	−.321***
SAS	.512***	.435***	.336***	.209*	.157	.016	−.321***	1.000

Note. * < .05, ** < .01, *** < .001.

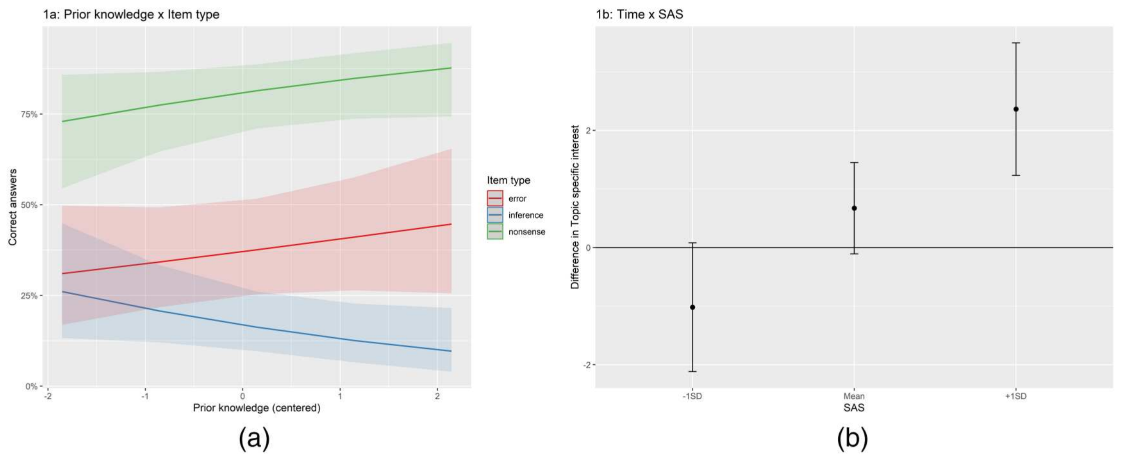

Figure 1. (a) Predicted values of correct answers in different item types as a function of Prior Knowledge. The shaded areas denote 95% confidence intervals. (b) Difference between pre-test and post-test in Topic Specific Interest as a function of Situational Awe Scale. Positive values denote increase in Topic Specific Interest. The error bars denote 95% confidence intervals.

situational awe experience varies from one film to another. "Aurora" films elicited stronger awe than the film "Stars". A closer examination of the contents of these films revealed that the script for Aurora contained substantially longer sentences than the one that yielded lesser awe, even though the total duration of all three films was approximately the same, and they all contained panoramic views and rapid camera movements. These research outcomes are consistent with the findings that awe experiences vary depending on the topical contents of the exhibitions (Krogh-Jespersen et al., 2020; Price et al., 2019), but offer new insights into the contribution of other possible factors such as information complexity into the strength of situational awe. Additionally, there was a positive association between one's disposition to critical thinking and feeling connected to universal entities. These findings are in line with research suggesting that there is a link between proneness to critical thinking and positive aspects of situational awe during a museum visit (Price et al., 2019).

What epistemic emotions co-occur with awe?

Similar to Luke (2021) and Price et al. (2021), situational awe experiences in the planetarium entailed a constellation of emotions pertaining to learning. The emotions that correlated with awe were of positive valence such as surprise and enjoyment, as well as of negative valence such as confusion. Consistent with the view that, depending on the topical contents of the exhibition, some emotions may not arise during the museum visit (Krogh-Jespersen et al., 2020; Price et al., 2021), planetary films did not trigger frustration and anxiety. We also found an inverse relation between awe and boredom. Importantly, when we controlled for the levels of epistemic emotions reported during the visit, surprise was the only one that predicted situational awe. In fact, a definition proposed for awe earlier included an element of surprise as a constituent part of awe experiences (Shiota et al., 2007), suggesting that these epistemic emotions might be mutually reinforcing. The current finding offers more evidence to the assumption that appraisals of the event as unexpected may trigger situational awe (Valdesolo et al., 2017).

Does awe influence memory for information presented in the film, and does its impact depend on individual differences in prior knowledge and critical thinking disposition?

While there was no evidence for an association between awe and recognition of old items, higher awe was linked with poorer performance in detecting detail errors, nonsense and inference statements. These effects did not depend on prior knowledge or critical thinking disposition. We had hypothesised that if awe increases accommodation of information, higher awe should be associated with better recognition performance for phrases presented in the film and in detecting detail errors. In contrast, if awe increases assimilative processing, higher awe should increase recognition errors of inferential phrases. The results showed that higher awe led to making more acceptance errors to detail error items, indicating that awe does not increase accurate processing of information. The finding that awe was related also to increased acceptance of both inference and nonsense statements indicates that awe does not necessarily increase assimilative processing either, but may make the participants more inclined to produce affirmative answers.

Situational awe has been found to facilitate conformity to the majority choice (Yang et al., 2021), and in making evaluative judgements that followed the majority opinion (Prade & Saroglou, 2023). Additionally, situational awe has been found to lead to a positive shift in humility indicating a tendency for people to feel humbler in the face of vastness (Stellar et al., 2018). The recognition memory task results obtained in this study seem to indicate that individuals who experienced higher awe were more inclined to give affirmative answers to the questions. It brings us to believe that situationally experienced awe may have confirmation bias as one of its consequences. Unfortunately, the ceiling effect in the old items does not allow us to arrive at a decisive conclusion with this regard. In order to alleviate the ceiling effect, old items should be made harder. One potential solution is to introduce a longer time interval between film exposure and testing, which may increase the difficulty level of the questions.

It should be noted that prior knowledge increased the likelihood of false recognition of inferential items, which aligns well with previous research suggesting that prior knowledge facilitates inferential processing and assimilation (McNamara & Kintsch, 1996). This suggests that at least the inferential items were sensitive enough to detect individual differences in the recognition performance.

Does situational awe increase topic-specific interest towards the topic of the film?

Awe was found to significantly boost topic-specific interest. These results show that awe increases personal interest in the specific phenomenon that induced this emotion. These results offer insights into the mechanisms of how situationally experienced awe is related to learning activities (Coleman, 2014), and also provide empirical support to the discussion of how experiencing awe can serve as an impetus for further scientific inquiry and promote exploration in the domain of science (Coleman, 2014; McPhetres, 2019).

Science museums offer diverse, dynamic and immersive spaces specially designed to engage visitors in exploration of the exhibits and interaction with the surrounding environment. Naturalistic exposure to awe-inducing stimuli has been indicated as a means to trigger this emotion (Pérez et al., 2023). We believe that one of the important constituents of science-themed films shown in the science centre planetarium is the sense of presence that they create. By being demonstrated on a 360° hemisphere shaped screen that fills all of the observer's visual field, these films bring the spectators into the epicentre of events. Indeed, wide field of view is deemed central for producing immersive experiences that elicit awe (Kahn & Cargile, 2021). Apart from this, we consider the presence of dynamic action created by close ups and zooms out, music, and changes in luminosity, to be another factor contributing to the successful awe induction. Of interest, it has been put forward that music itself may be a source of aesthetic awe (Konečni, 2008). Finally, for awe being an epistemic emotion, information complexity may be the key ingredient for fostering awe in the science centre. To this end, we side with the view that information-rich stimuli, that are also perceptually or conceptually complex, contribute to the perception of vastness and create favourable conditions for experiencing awe (e.g. Shiota et al., 2007). This conceptualisation may be especially applicable to science centres and science-themed exhibitions.

Limitations

First, we could not examine all of the subcategories of the situational awe, due to the lack of internal consistency in two subscales. Nonetheless, the total score of the situational awe and its two subscales, namely Connection and Chills, showed good reliability. One needs to keep in mind that our generalisations should apply to the overall situational awe and these two dimensions.

Second, due to the ceiling effect in the recognition memory task performance for old items, it is hard to unambiguously interpret the recognition memory results. More research is needed to further investigate the role that awe plays in memory effects.

Next, one should be cautious with the interpretation of the differences in the degree of immersiveness each film offered to the viewers as it is hard to provide an exact estimation of this parameter, and we did not measure it directly. Nonetheless, despite the lack of information on this part, we do assume that all three planetarium films were rather immersive as they were all shown on a 360° screen, contained music and panoramic views of the Universe.

Finally, correlational approach should not be interpreted as evidence for causality. Future studies should examine the effects of awe on topic-specific interest experimentally, for example by comparing awe-inducing and "neutral" conditions. As this study was conducted in a real-life setting in a planetarium with highly awe-inducing films, this type of design was not possible.

Conclusion

While the current results do not provide definite evidence about the association between awe and recognition memory, the results showing that awe increases topic-specific interest highlight the utility of situationally experienced awe in sparking interest towards science-related topics. Practical implications indicate clear benefits of designing immersive exhibitions that trigger awe and foster future involvement with science.

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Data availability statement

The analysis script and data are available at: https://osf.io/z84ua

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