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Awe and Time Perception

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Abstract

The aim of this study was to systematically examine the effect of awe-inducing stimuli on the judgment of time. Three experiments were conducted using temporal bisection tasks in which participants viewed awe-inducing and no awe-inducing images presented for different durations and were asked to judge whether their duration was similar to a short or long anchor duration. Images of panoramic landscapes and images of the faces of well-known and admired people were used in experiments 1 and 2, respectively. In experiment 3, they did not judge the duration of the images, but that of a neutral stimulus occurring during the presentation of images. In each experiment, participants rated the awe-inducing and no-awe-inducing images according to their components: admiration, beauty, awe, emotional valence, arousal, symbolic self-size, and full-body self-size. Results consistently showed significant time distortions when participants viewed the different awe-inducing images compared to the no-awe images, although the effect was weaker for the images of faces than for those of landscapes. Time distortion took the form of temporal lengthening in Experiments 1 and 2 and shortening in Experiment 3. These different temporal distortions are consistent with attention effects due to awe-inducing stimuli which capture attention to the detriment of time processing.

Keywords: time, timing, time perception, emotion, awe

Introduction

“Because beauty is an encounter, always unexpected, always un hoped-for,
only the attentive gaze can give it amazement, awe...”

Cheng (2002)

The emotion of awe is thought to modify our subjective relationship to the passage of time (Rudd et al., 2012), but does it modify our perception of duration? The aim of our study is to examine, using laboratory experiments, the effect of awe-inducing stimuli on our judgment of duration. The first problem lies in understanding the complex emotion of awe. There is no literal translation of the word awe in French. In online translators, awe is directly translated as “stupeur” or “crainte”, i.e., “amazement” or “fear” in English. By doing so they associate awe with a negative emotion that increases the level of stress. However, in psychology, awe is generally conceived of as a positive experience that reduces irritability and nervousness and changes the individual’s outlook on life by developing qualities of self-transcendence (Yaden et al., 2017; Chirico and Yaden, 2018). This life-enhancing experience has been described as having the potential to improve mental health (Arcengeli et al., 2020; Tanhan, et al., 2022; Chirico and Gaggioli, 2021). Interest in this complex emotion has therefore increased over the last two decades and researchers have begun to study it in order to try to better understand it.

There are a wide variety of sources of awe, such as sublime natural environments, a beautiful work of art, or a charismatic leader. In their seminal manuscript, Keltner and Haidt (2003) nevertheless succeeded in identifying two central features: perceived vastness and the need for accommodation. Vastness corresponds to something that is experienced as being physically or conceptually vast (e.g., in size, power, knowledge), and therefore vastly superior to oneself. Perceiving something vastly larger than oneself triggers the need for accommodation, the need to adopt a new perspective, a new thought pattern which is no longer centered on the self, which is ultimately insignificant and small. To assess this aspect of awe, Bai et al. (2017) validated two scales of self-size perception. In the first, self-size is represented by circles of different sizes. In the second, the self-dimension is represented by a full-body image depicting a man in a landscape who increases in size compared to the size of the sun. The main source of awe, and perhaps the most transcultural, is obviously sublime open landscapes (mountains, Grand Canyon), that are consequently the most used stimuli in experimental studies on awe (Allen, 2018; Schaffer et al., 2023). This type of stimulus also inspires feelings of admiration and beauty, which are difficult to dissociate from that of awe. This approach is illustrated by the Dispositional Positive Emotion Scale (DPES) (Shiota et al., 2006), which includes 6 specific items intended to measure awe: two refer to perceived beauty (I see beauty), one to admiration (I feel wonder) and only one to awe *per se* (I feel awe). The feelings of admiration and of beauty are indeed important features of awe (Chirico and Yaden, 2018).

It has been suggested that the emotion of awe, as reflected by these different features, modifies the perception of time. Rudd et al. (2012) asked their participants to answer a series of questions about the availability of time (“time is expanded”, “time is boundless”, “time is slipping”) after they had watched television depictions of people in vast situations (waterfalls, meeting with astronauts in space) (Experiment 1), after narrating a personal experience during which they had felt awe (Experiment 2), or after reading a story about an amazing experience (ascending the Eiffel Tower) (Experiment 3). In these situations, the participants reported feeling that time had expanded, meaning that they had more time available and were able to devote more time to others. Rudd et al. (2012) explained this perception of expanded time by suggesting that people are more in the present moment when they experience awe, i.e., more focused on the present. Groens’ (2020) used virtual reality with landscape films (45s) of day and night and also found that participants reported having more time available for others, highlighting that this emotion encourages prosocial values (Piff et al., 2015). However, their verbal estimates of the duration of these films in seconds did not differ between the awe and no-awe conditions. In contrast to Goren’s study, in the study conducted by Berry et al. (2015), participants estimated that more time (measured in the minutes range) had elapsed in a

condition of awe (images of natural environments, e.g., mountains) than in a no-awe condition (image of a built environment, e.g., buildings).

Interestingly, Berry et al. (2015) observed that the awe condition affected the awareness of the passage of time for long durations but not the perception of short durations. Indeed, they did not find any significant difference in the perception of durations between the awe and the no-awe condition in a temporal bisection task using anchor durations of 400 and 1600 ms. In the bisection task, participants saw awe and no-awe images presented for durations similar to, or intermediate between, a short (400 ms) and long (1600 ms) anchor duration, and were asked to judge whether their duration was more similar to the short or long anchor duration. Similarly, with the same temporal bisection task and short durations (300-750 ms), van Elk and Rotteveel (2020) did not find significant differences between the awe and the no-awe stimuli. Using another temporal task (temporal reproduction) with longer durations (2.4-6.5 s), Gill et al. (2022) also failed to observe such differences. van Elk and Rotteveel (2020) concluded that “experimentally induced awe does not affect implicit and explicit time perception”. However, not enough studies have been conducted on the perception of time and awe to make it possible to draw such a conclusion. Certain details in the methodologies used may well explain the lack of significant results. For example, these studies used stimuli that differed not only in their ability to elicit the emotion of awe but also in their visual characteristics. The awe-inducing stimuli used in most of the above studies consisted of visual scenes of open spaces (e.g., mountains), while the no-awe stimuli took the form of visual scenes of restricted spaces, e.g., buildings in Berry et al. (2015), animals or a man driving a tractor in van Elk and Rotteveel (2020), and various low-vastness images in Gill et al. (2022). The restricted scenes have consisted of small elements with clear visual contours (Klatzky et al., 2017). Perception of duration is very sensitive to context effects, including visual activity, i.e., ocular movements (Eagleman, 2005; Morrone et al., 2005). We replicated the non-significant findings of van Elk and Rotteveel in an unpublished temporal bisection task using vast and non-vast images as awe-inducing and no-awe stimuli, respectively, and this lack of results seemed to be linked to differences in eye convergence movements when viewing these different types of images. We therefore decided to further investigate the effect of awe in a temporal bisection task with short durations and stimuli matched on their visual characteristics (vast scenes, faces), but judged as inducing or not inducing awe on the small self-size scales (Bai et al., 2017) and the awe items of the DPES (Shiota et al., 2016).

To date, studies have shown that the emotion of awe modifies the subjective experience of time but have not found convincing results on the effect of awe-inducing stimuli on the more automatic processes of perception of short durations. It is therefore genuinely difficult to predict the results that will be obtained in such a temporal bisection task. In addition, awe is a complex self-conscious emotion that necessarily derives from a set of lower-level processes, i.e., from the appraisal of changes perceived at the sensory and bodily level (Schaffer et al., 2023). And these low-level processes have not yet been clearly identified. In their so-called “Awe Matryoshka” model, Chirico and Gaggioli (2021) identified what they called “electrical changes” prior to the onset of the feeling of awe. These correspond to a change in the level of arousal felt in response to awe-inducing stimuli coupled with increased parasympathetic activation that produces a slowing-down of the body accompanied by increased relaxation and a reduction in the Default Mode. However, in a recent meta-analysis, Schaffer et al. (2023) noted that although physiological activity occurs, it is sometimes consistent with an increase in parasympathetic arousal (low arousal) and sometimes with an increase in sympathetic arousal (high arousal). In “their cognitive behavioural model of awe”, Schaffer et al. (2023, p. 10) emphasized the key role of the appraisal of the experience of awe, with parasympathetic activation succeeding sympathetic activation when threat appraisal is triggered. The authors therefore concluded that cognitive functions are important in the experience of awe and that the only constant and important mechanism is related to attention. The emotion of awe would direct attention toward entities vaster than the self, thus reducing the attention devoted to personal concerns (see also Keltner and Haidt, 2003). It therefore broadens the attentional scope available for processing new information (Sung and Yih, 2016).

As we will see later, the perception of short durations relies on automatic mechanisms (internal clock system) which are very sensitive to the effects of arousal and attention. According to internal clock models (Gibbon, 1977; Gibbon et al., 1884; Treisman, 1963), the internal representation of duration depends on the number of temporal units (pulses) emitted by a pacemaker-like system and accumulated in a sort of counter (timer) via the closing and opening of an attention-controlled switch at the onset and offset, respectively, of the stimulus to be timed. According to attentional versions of the internal clock models (Thomas and Weaver, 1975; Zakay and Block 1996,1998), when alert processes (instruction, stimulus) direct attention toward temporal information, the attentional switch closes earlier, thereby increasing the perceived duration (lengthening effect). If, by contrast, attention is oriented toward non-temporal information, the closing of the attentional switch is delayed, thus decreasing the perceived duration (shortening effect). A lengthening and shortening effect can also be observed by increasing and decreasing the level of arousal, consequently speeding-up (more pulses emitted) or slowing-down (fewer pulses emitted) the internal clock system. However, internal clock models make it possible to dissociate these two mechanisms (Droit-Volet and Meck, 2007). Indeed, the attention-related mechanism is thought to produce a time distortion the magnitude of which is the same for different stimulus durations: additive effect of the awe factor and the stimulus duration factor on temporal estimates. By contrast, the speed-clock mechanism is thought to produce a distortion of time which increases in magnitude as the value of the stimulus durations increases: multiplicative effect on time estimates, i.e., interaction between the awe and the stimulus duration factors. Therefore, in accordance with our hypothesis that awe-inducing stimuli capture attention, we expected our temporal bisection task to reveal a distortion of time judgments in response to awe-inducing stimuli in comparison to no-awe stimuli. Such a finding would be consistent with an additive effect between the awe and the duration factors. In Experiment 1, we used images of open landscapes, and in Experiment 2 images of faces of famous people to test the robustness of awe-related results obtained in temporal bisection with different stimuli. In Experiment 3, we ran another bisection task to better identify the types of mechanism responsible for time distortion in participants experiencing the emotion of awe. In Experiments 1 and 2, participants judged the duration of the images and, in Experiment 3, the duration of a neutral stimulus that appeared during the presentation of the images (which were of fixed duration), so that the image and the temporal stimulus were clearly dissociated.

Experiment 1

Method

Participants

A total of 33 psychology undergraduates ($M_{age} = 19.56$, $SD = 1.74$, 30 women) from the University XXX participated in this experiment in return for course credits. A priori analysis performed using the G*Power software (version 3.1.9.6) indicated that the total sample size of 12 and 34 participants was required with a significant criterion of $\alpha = .05$ and a power of .80 for the statistical analysis (ANOVA with repeated measured) described below on the proportion of long responses and the bisection point, respectively, 30 participants per group being also a satisfactory sample size as Faul et al. (2017) argued. The participants gave their consent to participate in this experiment, which was carried out in accordance with the principles of the Helsinki Declaration and was approved by the XXX research ethics committee (IRB00011540-2021-68).

Material

The experiment took place in an isolated laboratory room. The participants were seated in front of a 17-inch computer screen (40-cm distance). Data collection, instructions and stimulus presentation were handled with E-prime software v 2.0 (Psychology Software Tools, Pittsburgh, PA, USA). The stimuli used in the temporal bisection task were a black circle (1.5 cm in diameter) on a

white background (learning phase of the bisection task) and 6 full-color images of the natural environment (28.5 cm wide and 21.5 cm high) (test phase of the bisection task) presented in the center of the computer screen.

These 6 images included 3 that elicited awe (awe image) and 3 that did not (no-awe image). The awe and the no-awe images were all images of wide-open landscapes that were matched on their visual characteristics: 2 images of mountains, and 1 image of the cosmos for the former, and 2 images of mountains and 1 image of smoke in the sky for the latter. These images were the highest scoring images from a set of 30 different photographs of natural scenes pre-tested on 12 other participants. In addition, as explained below, participants of Experiment 1 also evaluated the awe induced by these 6 images after completing the temporal bisection task.

Procedure

The participants performed a two-phase temporal bisection task consisting of a learning phase and a test phase. In the learning phase, the participants performed 8 trials with the black circle: 4 trials for a short standard duration of 400 ms and 4 trials for a long standard duration of 1600 ms. Their task was to respond “short” when they judged the stimulus duration to be the short standard duration and “long” when they judged it to be the long standard duration. They responded by pressing the corresponding button on the computer keyboard (D or K). The button-press order was counterbalanced between participants. In the test phase, the participants were presented with comparison stimulus durations (400, 600, 800, 1000, 1200, 1400, 16000 ms) and, for each comparison duration, they had to respond “short”/“long” to indicate whether they judged the comparison stimulus duration to be similar to the short or long standard duration. In addition, the 2 categories of images (awe vs. no-awe) were used for the comparison durations instead of the black circle. There was a total of 126 trials, i.e., 9 trials for each comparison duration (9 x 7) for both the awe and the no-awe images (9 x 7 x 2). Each image ($N = 3$) in each image category was presented 3 times. The trials were divided into 3 blocks of randomly presented trials. The inter-trial interval was also chosen randomly between 200 and 500 ms. All bisection trials had the same format. When the participants were ready, they pressed the space bar on the computer keyboard to start a trial after seeing the word “ready”. Then, after 200 ms, the stimulus appeared for a given duration and the participants responded by pressing the key corresponding to “short” or “long”.

After the bisection task, the participants rated their emotion of awe experienced while viewing each image using 3 items of the Dispositional Positive Emotion Scale (DPES, Shiota et al., 2006): when I see this image, I feel/see admiration/beauty/awe (Cronbach’s alpha, $\alpha_{\text{awe}} = 0.80$, $\alpha_{\text{no-awe}} = 0.89$). The participants responded to these items on a 7-point Likert scale from “totally disagree” to “totally agree”. The feeling of small self when confronted with something larger than oneself (vastness component of awe) was also assessed with 2 items from the perceived self-size scale (Bai et al., 2017): symbolic self-circle and full-body image ($\alpha_{\text{awe}} = 0.79$, $\alpha_{\text{no-awe}} = 0.90$). For the first of these scales, participants see 7 different-sized circles and choose the one that best describes how big or small they feel themselves to be. For the second, they see 7 drawings of a man whose size increases in relation to the size of the sun and must choose the one that best describes themselves. In addition, we assessed the self-reported level of arousal and emotional valence associated with the emotion of awe using the 9-point Likert IAPS (International Affective Picture Scale, Lang et al., 2005), which goes from “relaxed, limp, calm, not awake” to “stimulated, excited, alert, awake” for arousal and from “not happy, sad, unhappy, dissatisfied” to “happy, joyful, content, satisfied” for valence.

Statistical analyses

A series of *t*-tests was first conducted on the participants’ scores on the different self-reported scales used to verify that the awe images did indeed induce this emotion when compared to the no-awe images. The classical components of the emotion of awe were assessed: awe, small self-size, low

arousal, positive emotional valence. The analyses were performed on the average score for the 3 images used in each emotional category.

Regarding temporal performance in the bisection task, for each participant, we first derived a psychophysical function (bisection curve) consisting of the proportion of “long” responses [$p(\text{long})$] plotted against comparison stimulus duration. A repeated-measures ANOVA was conducted on $p(\text{long})$ with the stimulus durations ($N = 7$) and the awe factor (awe vs. no-awe) as within-subject factors. However, a difference in the proportion of long responses may result from a difference in the slope of the bisection curve (e.g., a flatter slope with more $p(\text{long})$ for shorter stimulus durations indicating lower time sensitivity), or a bias towards responding “long” or “short” for intermediate durations with no change in slope, or both (flatter slope and response bias towards “long”). We then calculated a Bisection Point (BP) and the Weber Ratio (WR), which were derived from the significant fitting of individual data to a pseudo-logistic function using Prism software (Mean $R^2_{\text{awe}} = 0.91$, $SD = 0.07$; Mean $R^2_{\text{no-awe}} = 0.91$, $SD = 0.07$). The BP is the point of subjective equality (PSE), i.e., the intermediate stimulus duration (D) for which the participant responds long as often as short [$Dp(\text{long}) = .50$]. A lower BP value means a bias towards responding “long” (lengthening effect), which is consistent with a leftward shift of the bisection curve. Conversely, a higher BP means “short” response bias (shortening effect), corresponding to a rightward shift of the bisection curve. The WR is an index of temporal sensitivity (Difference Limen/BP). Higher WR indicates lower temporal sensitivity, as illustrated by a flatter slope of the bisection curve. A repeated-measures ANOVA was conducted on BP and WR with only the awe as within-subject factor. When a lack of sphericity was observed in the ANOVAs, the Greenhouse Geisser correction was used.

In addition, in an attempt to verify that awe is the main significant predictor of the time distortions observed in our experiment, and not other dimensions (emotion valence, arousal) although they are all related, regression analyses using Multi-Level Modelling (MLM) were performed on the BP with each emotional component assessed for the images after the bisection task (mean awe, valence, arousal) taken separately as factor. Participants were always used as a random factor.

Results

Awe

Table 1a shows the mean scores of participants’ responses on the different scales assessing the emotion of awe. The results confirmed that participants reported feeling an emotion of awe when viewing the awe images, with a mean score of 6.23 ($SD = 0.49$) on the 7-point scale, and that they did not feel this emotion with the no-awe images, with a mean score of 2.15 ($SD = 0.74$) (average scores on DPES, $t(31) = 23.4$, $p < .001$, $d = 4.23$). The feeling of a smaller self-size was also greater for the awe images than for the no-awe images, both for the symbolic self-size and the body self-size scale (all $p > .001$). Viewing the awe images was also judged to be more pleasant, $t(31) = 15.68$, $p < .001$, $d = 2.77$, and to produce a lower level of arousal, $t(31) = -5.45$, $p < .001$, $d = -0.96$.

Insert Table 1 about here

Time judgment

Figure 1 shows the results for the different bisection measures: $p(\text{long})$, BP and WR. The ANOVA performed on $p(\text{long})$ showed a main effect of comparison durations, $F(6, 192) = 336.71$, $p < .0001$, $\eta^2_p = .913$, indicating that the emotion of awe did not disrupt the perception of time. More interestingly, it also showed a significant main effect of awe, $F(1, 32) = 35.76$, $p < .0001$, $\eta^2_p = .523$, with the participants responding long more often for the awe images ($M = 0.48$, $ES = 0.016$) than for the no-awe images ($M = 0.425$, $ES = 0.015$). The awe x comparison duration interaction, $F(6, 192) = 2.25$, $p = .004$, $\eta^2_p = .07$, also reached significance. This interaction resulted solely from a smaller awe - no-awe image difference in $p(\text{long})$ between the short comparison duration of 600 ms and the

intermediate comparison duration of 1000 ms (Bonferroni, $p = .02$), while no significant differences were observed between the other durations (all $p > .05$).

The results of the ANOVA on the BP showed a significantly smaller BP for the awe ($M = 950.64$, $ES = 32.17$) than for the no-awe images ($M = 1079.09$, $ES = 26.05$), $F(1, 32) = 28.06$, $p < .0001$, $\eta^2_p = .47$. This confirmed the presence of a time distortion consistent with a time-lengthening effect for the awe images compared to the no-awe images.

Regression analyses using MLM showed a significant effect of awe ($E = -31.78$, $ES = 5.73$, 95%CI[-43.43; -20.12], $t = -5.55$, $p < .001$), emotional valence ($E = -29.56$, $ES = 5.32$, 95%CI[-40.42; -18.71], $t = -5.55$, $p < .001$), and arousal although in a weaker way ($E = 22.69$, $ES = 10.33$, 95%CI[1.94; 43.45], $t = 2.20$, $p = .03$). This highlights the link between the different emotional dimensions of awe-inducing images. However, when awe and arousal were included in the same model only awe was a significant predictor of time distortions in bisection (Awe: $E = -45.43$, $ES = 17.73$, 95%CI[-81.67; -9.19], $t = -2.56$, $p = .01$; arousal: $E = -22.95$, $ES = 14.52$, 95%CI[-52.46; 6.56], $t = -1.58$, $p = .12$; awe x arousal: $E = 1.32$, $ES = 4.91$, 95%CI[-8.65; 11.29], $t = 0.27$, $p = .80$). When awe and valence or the 3 factors (awe, valence, arousal) were included in the same model, no further significant results were available (all $p > .05$).

In contrast to the BP, there was no significant awe effect on WR, $F(1, 32) = 2.21$, $p = .15$, revealing that there was no difference in temporal sensitivity between the awe and the no-awe images.

Insert Figure 1 about here

Discussion

In Experiment 1, we used images of wide-open landscapes for both the awe and the no-awe images in order to match them on visual characteristics. Indeed, the nature of eye movements can influence time perception (Eagleman, 2005; Morrone et al., 2005), and van Elk and Rotteveel (2020) did not find a significant awe effect in a temporal bisection task using images of vast spaces (as in our studies) as awe images and small elements with clear contours as no-awe images. In addition, the participants' answers on the different self-reported scales demonstrated that the awe images used in our experiment effectively induced the emotion of awe and the various associated components (Keltner and Haidt, 2003; Chirico and Yaden, 2018). The participants reported feeling awe (admiration/beauty/awe) in response to the awe images but not the no-awe images. They also experienced a smaller self-size with the awe than with the no-awe images. Looking at awe images also elicited more positive emotion and was rated as being more relaxing (low-arousing). These results replicated those found in most awe studies that have used scenes of sublime open landscapes.

The awe images used in Experiment 1 therefore induced the expected emotion of awe. When this emotion was activated, a time distortion was found in the temporal bisection task. This time distortion was in the direction of a lengthening or, in other words, an expansion of time. Indeed, the results showed that the BP was significantly lower with the awe than with the no-awe images and that participants responded long more often, thus producing a leftward shift of the bisection curve. Furthermore, the magnitude of this temporal distortion appeared to be constant regardless of the different comparison durations, except for the duration of 600 ms, for which a smaller temporal awe vs no-awe difference was found.

In summary, Experiment 1 revealed a lengthening effect when participants judged the duration of presentation of awe images relative to that of no-awe images. Before discussing these results, we considered it important to conduct a second experiment with the same temporal bisection task but using other sources of awe. Our aim was to test whether we would still observe a lengthening effect in temporal bisection with other awe-inducing stimuli, thus allowing us to generalize the effect of awe on time perception regardless of the stimuli.

Past studies have often used natural landscapes to elicit awe in their participants. The perception of vastness in the face of sublime landscapes is obviously one of the greatest sources of the experience of awe (Keltner and Haidt, 2003; Chirico and Yaden, 2018). From a functionalist point

of view, this emotion can be considered as being due to human beings' natural preference for high vantage points with panoramic views to ensure their safety and see possible enemies or predators approaching (prospect and refuge) (Keltner and Haidt, 2003). However, it would also contribute to social subordination and ensure group cohesion by uniting group members around a dominant person who is admired and respected. Certain famous charismatic people can thus inspire awe due to the admirable things that they have done in their lives (e.g., Mandella, Einstein, King, Jesus) and that far exceed what the majority of people are capable of. In France, there is for example Thomas Pesquet who is a great and very popular astronaut, or Simone Veil who was a great French stateswoman who fought for the right to abortion and experienced the Auschwitz deportation. Other people may also be well known but not admired, like François Hollande or Donald Trump. In Experiment 2, we used the same bisection task as in Experiment 1 but with images of well-known people who may or may not inspire the emotion of awe.

Experiment 2

Method

Participants

Thirty-four new students ($M_{\text{age}} = 19.65$, $SD = 2.42$) from XXX participated in this experiment in return for course credits. This experiment was validated by the XXX research ethics committee (IRB00011540-2021-68). The total sample size required was the same than that used in Experiment 1 because the experimental conditions were similar.

Material and procedure

The material and the procedure, as well as the statistical analyses, were similar to those used in Experiment 1. Only the images differed. Six images of smiling faces of people well known to the French public were used, namely 3 that induced admiration in participants (i.e., Thomas Pesquet, Simone Veil, Mandella), and 3 that did not (François Hollande, Roselyne Bachelot, Donald Trump). These images were selected (highest and lowest scores, respectively) from 19 different faces from the data of a pre-test conducted with 24 other participants. The participants of Experiment 2 again completed the temporal bisection task before evaluating these images on the DPES (admiration, beauty, awe) ($\alpha_{\text{awe}} = 0.80$, $\alpha_{\text{no-awe}} = 0.89$) (Shiota et al., 2006), and the perceived self-size scale (symbolic self-circle and full-body image) (Bai et al., 2017). Emotional valence and arousal level when viewing these different images were also assessed using the IAPS (Lang et al., 2005). The faces were matched on gender (2 men and 1 woman), age, and “physical” beauty.

Results

Awe

The participants' evaluation of the faces confirmed that the people chosen for the awe and no-awe categories were equally well known, $t(33) = 1.44$, $p = 0.19$ (Table 1b). The statistical analyses confirmed that the awe images inspired the emotion of awe ($M = 5.39$, $SD = 0.97$), while the no-awe images did not ($M = 2.55$; $SD = 0.71$), $t(33) = 16.71$, $p < 0.001$, $d = 2.87$. The score on the symbolic self-size scale was also lower for the awe than for the no-awe images as reflected by the representation of a smaller self-size, $t(33) = 2.43$, $p = 0.02$, $d = 0.42$. However, no significant difference was obtained between the awe and the no-awe images for the scores on the body self-size scale, $t(33) = 1.86$, $p = 0.07$, $d = 0.32$. This suggests that this latter scale, which represents the size of a man changing relative to the size of the sun, is not appropriate in the case of faces. Emotional valence was also judged more positively for the awe images than for the no-awe images, $t(33) = 8.21$, $p < 0.001$, $d = 1.45$. By contrast, there was no difference in the level of arousal reported for the awe and the no-awe images, with the faces being judged as being similarly arousing, $t(33) = 1.22$, $p = 0.71$, $d = 0.066$.

Time judgment

Albeit to a lesser extent, the results obtained in the temporal bisection task with faces were similar to those obtained with landscapes in Experiment 1. Indeed, Figure 2 again shows a time distortion in the direction of temporal lengthening for the awe images compared to the no-awe images, with a leftward shift of the bisection curve and a smaller BP.

The ANOVA on $p(\text{long})$ did indeed replicate the significant main effect of awe, $F(1, 33) = 4.19, p = .049, \eta^2_p = .113$, with a significant main effect of comparison durations, $F(6, 198) = 342.98, p < .0001, \eta^2_p = .91$, but no significant awe \times stimulus duration interaction, $F(6, 198) = 0.60, p = .73$. Therefore, the participants responded long more often for the awe images ($M = 0.509, ES = 0.019$) than for the no-awe images ($M = 0.489, ES = 0.019$), and the magnitude of this temporal distortion was the same regardless of the length of the comparison durations.

Accordingly, the BP was smaller for the awe images ($M = 940, ES = 31$) than for the no-awe images ($M = 983, ES = 28$), $F(1, 33) = 4.20, p = .049, \eta^2_p = .113$.

Regression analyses using MLM showed a significant effect of awe ($E = 0.053, ES = 0.20, 95\%CI[0.01; 0.96], t = 2.55, p = .02$), and emotional valence ($E = -21.23, ES = 8.82, 95\%CI[-39.23; -3.23], t = -2.41, p = .02$), while arousal just failed to be significant ($E = 24.31, ES = 12.31, 95\%CI[-0.46; 49.09], t = 1.98, p = .055$). When the 3 factors were included in the same model, only awe factor was a significant predictor of time distortion in bisection (Awe: $E = 1.04, ES = 0.47, 95\%CI[0.09; 2.00], t = 2.22, p = .03$; for the two other factors and the different interactions $p > .05$).

The results on the WR also reached significance for the faces used in Experiment 2, $F(1, 33) = 4.54, p = .041, \eta^2_p = .12$. The participants' temporal judgments were indeed less variable when they saw the faces of admired people ($M = 0.21, ES = 0.017$) than those of non-admired people ($M = 0.25, ES = 0.019$).

Insert Figure 2 about here

Discussion

The results of the temporal bisection task used in Experiment 2 showed an increase in perceived time, unaccompanied by any disruption of temporal discrimination, in response to images of people who inspired awe compared to those of people who did not inspire this emotion. The results therefore replicated the main findings of Experiment 1 while using the same temporal bisection task but with other awe-inducing stimuli (landscapes). However, the results appeared weaker in temporal bisection with images of people than with images of landscape, suggesting that images of natural environment induce the emotion of awe more effectively. Indeed, some individuals may find difficult to feel admiration towards certain people, at least those used in our experiment. Overall, nevertheless, the presentation duration of images was judged longer when the images elicited the emotion of awe, whatever the source of awe. This allows us to generalize the effect of a subjective lengthening of time in bisection to different awe-inducing stimuli.

A lengthening of time can be observed as the arousal level increases and accelerates the rhythm of the underlying clock system, as has been found in bisection studies using high-arousal emotions (fear, anger) (e.g., Fayolle et al., 2015). However, as explained in attentional models of the internal clock (Thomas and Weaver, 1975; Zakay and Block, 1996, 1998), a lengthening of time can also be observed when a larger amount of attention is devoted to stimulus duration. Mattes and Ulrich (1998) demonstrated that directing attention to the stimulus duration to be judged can indeed lengthen the perceived duration of the stimulus.

Some of our results lead us to think that the lengthening of time observed with the awe images in our experiments was not due to mechanisms linked to arousal, but rather to the higher level of attention paid to awe images. First, the participants judged the presentation duration of awe images to be longer than that of no-awe images, while the reported level of arousal was lower for the former

than for the latter (Experiment 1) or deemed equivalent to it (Experiment 2). Regression analyses confirmed that the level of arousal had little effect on time distortion. Second, the magnitude of temporal lengthening was constant for the different comparison durations (additive effect) and did not increase with the comparison durations (multiplicative effect). Numerous studies have shown that the multiplicative-type effect is characteristic of the speeding-up of clock-like systems as shown by studies on the increase in the frequency of the train of clicks which drives the clock rate (e.g., Treisman et al., 1990; Treisman and Brogan, 1992; Droit-Volet and Wearden, 2002) or on the increase in the level of arousal resulting from a very arousing emotion (Droit-Volet et al., 2013; Cui et al., 2023). By contrast, the additive-type effect is characteristic of attentional processes. According to internal clock models, when participants direct more attention toward temporal stimuli, the attentional switch that ensures the transfer of units emitted by a pacemaker-like system to the accumulator closes earlier and/or opens later and allows more of the temporal units underlying the representation of time to be accumulated (Zakay and Block, 1996, 1998). Third, cognitive studies have demonstrated that awe-eliciting stimuli capture attention (Ballew & Omoto, 2018; Sung and Yih, 2016).

However, in our experiments, participants had to judge the duration of presentation of awe images, meaning that there was no clear dissociation between the non-temporal content of an image that elicited the emotion of awe (sublime landscapes, admired people) and the duration of the image. It is thus difficult to know whether the observed lengthening of time results from attention paid to awe stimuli, prolonging their duration because participants look at them for longer, or from the specificity of the processing of the duration itself. In the various dual-task paradigms used in studies on the perception of time, there is a clearer distinction between the processing of temporal information and that of non-temporal information with, for example, participants being instructed to focus their attention on the processing of non-temporal information and ignore temporal information (e.g., Macar et al., 1994; Zakay and Tsal, 1989). To permit us to draw conclusions concerning the mechanisms underlying the effect of awe on the perception of time, we therefore conducted a third experiment in which the awe-eliciting stimulus and the stimulus duration were more clearly dissociated.

In Experiment 3, participants had to judge the duration of a white ring presented on the awe and the no-awe images, with the presentation duration of the images themselves being kept constant. In Experiment 3, we used a temporal bisection task as in Experiments 1 and 2, but tested three duration ranges: 400-1600 ms as in the previous Experiments, a shorter one (200-800 ms) and a longer one (2000-8000 ms). Our hypothesis was that if awe images capture attention, stimulus durations (white ring) in temporal bisection should be judged shorter because attention is diverted away from the processing of the stimulus to be timed. According to the prediction of the hypothesis that an additive effect occurs in the case of attention mechanisms, the magnitude of this temporal shortening should be similar in the different duration ranges.

Experiment 3

Method

Participants

The sample was composed of 90 new students ($M_{\text{age}} = 19.36$, $SD = 1.75$) who participated in this experiment in return for course credits. The data from two students were excluded because they always responded short. A priori analysis performed using the G*Power software (version 3.1.9.6) indicated that the total sample size of 87 and 36 was required with a significant criterion of $\alpha = .05$ and a power of .80 for the statistical analysis described below on the proportion of long responses and the BP, respectively. This new experiment was validated by the research ethics committee of XXX University (IRB00011540-2021-68).

Material and procedure

The material was similar to that used in Experiment 1. The images consisted of the wide-open landscapes that either did or did not elicit the emotion of awe. After the bisection task, the participants once again assessed these images on the self-reported scales described in Experiment 1. The stimulus duration was a white ring with a line width of 3 millimeters and diameter of 1 cm.

For the bisection task, participants were randomly assigned to one of the three duration range conditions: 200-800, 400-1600, and 2000-8000 ms. In the 200-800 ms condition, the short and the long standard duration presented in the learning phase were 200 and 800 ms, respectively. In the 400-1600 ms condition, they were 400 and 1600 ms, and in the 2000-8000 ms condition, they were 2000 and 8000 ms. The comparison durations used in the test phase were: 200, 300, 400, 500, 600, 700 and 800 for the 200-800-ms condition; 400, 600, 800, 1000, 1200, 1400, and 1600 for the 400-1600-ms condition; 2000, 3000, 4000, 5000, 6000, 7000 and 8000 ms for the 2000-8000-ms condition.

The temporal task was similar in the different duration conditions and also similar to the one used in Experiment 1, except for the design of stimulus presentation. In the learning phase, the standard durations were presented in the form of the white ring on a black background displayed in the center of the computer screen (8 trials, 4 for the short and 4 for the long standard duration). In the test phase, the comparison durations were always the white ring, but presented in the center of the awe or the no-awe images. The stimulus to be estimated always appeared 2500 ms after the onset of the image. The total presentation duration of the images was always 4000 ms for 200-800, 5000 ms for 400-1600, and 10500 ms for 2000-8000 ms. The total number of trials in the test phase was 126, i.e., 9 trials for each of the 7 comparison durations for the awe and the no-awe images.

The same statistical analyses as in the previous experiments were performed, except that a between-subject factor (duration range) was added in the analyses. In addition, the fitting of the pseudo-logistic function (Prism software) to individual data was not significant for two participants, with the result that their data were excluded for the BP and WR. The fitting was good for the other participants ($R^2_{\text{awe}} = 0.95$, $SD = 0.07$; $R^2_{\text{no-awe}} = 0.95$, $SD = 0.078$). The individual BP was also divided by the arithmetic mean (AM) of the duration range. Regression analyses using Multi-Level Modelling (MLM) were also performed on the BP with each emotional component assessed for the images after the bisection task (mean awe, valence, arousal) taken separately as factor. Participants were always used as a random factor.

Results

Awe

Participants' assessment scores and the statistical analyses are reported in Table 1c. The results replicated those found in Experiment 1, with the awe images being judged to induce the emotion of awe ($M = 5.86$, $SD = 0.81$), unlike the no-awe image ($M = 2.32$ ($SD = 1.1$) (average scores on DPES, $t(86) = 25.79$, $p < .001$, $d = 2.77$). Self-size was also rated smaller for the awe than for the no-awe images (symbolic self-size, $p = .05$, body self-size, $p < .001$). The awe images were also rated as being more pleasant and less arousing (both $p < .001$).

Time judgment

Figure 3 shows the bisection curves and the BP for the awe and no-awe images obtained in the 3 duration range conditions. When the stimulus to be timed appeared during the presentation of the awe images, the comparison duration was judged shorter rather than longer. Indeed, the ANOVA on $p(\text{long})$ showed a significant main effect of awe, $F(1, 85) = 12.21$ $p < .001$, $\eta^2_p = .126$, indicating that participants responded long less often for the awe images ($M = 0.457$, $ES = .012$) than for the no-awe images ($M = 0.479$, $ES = .011$). Moreover and in line with the prediction of the attention-related hypothesis (additive effect), there was a significant main effect of comparison duration, $F(6, 510) = 744.94$, $p < .0001$, $\eta^2_p = .898$, but no significant interaction between the awe factor and either the comparison duration or the duration range factor (awe x comparison duration, $F(6, 510) = 1.69$, $p = .12$, awe x duration range, $F(2, 85) = 0.148$, $p = .863$, awe x comparison duration x duration range,

$F(12, 510) = 0.529, p = .896$). There was also no significant main effect of duration range, $F(2, 85) = 0.595, p = .554$. Therefore, the comparison durations were systematically judged shorter when participants saw the awe images compared to the no-awe images, and the magnitude of the shortening effect was constant regardless of the total length of the duration to be estimated.

The statistical analyses on the BP (BP/AM) confirmed the results obtained on $p(\text{long})$, showing a significant main effect of awe, $F(1, 83) = 19.04, p < .0001, \eta^2_p = .187$, while neither the awe x duration range interaction, $F(2, 83) = 0.06, p = .94$, nor the main effect of duration range, $F(2, 83) = 0.06, p = .94$, were significant.

Regression analyses using MLM showed a significant effect of awe ($E = 23.10, ES = 8.70, 95\%CI[5.75; 40.45], t = 2.66, p = .01$), emotional valence ($E = 25.79, ES = 9.33, 95\%CI[7.13; 44.45], t = 2.76, p = .01$), but not arousal ($E = -22.17, ES = 13.71, 95\%CI[-52.76; 8.42], t = -1.61, p = .14$), indicating the close contribution of the emotion of awe and its positive valence to time distortions. However, when these two factors were included in the same model only awe tended to be a predictor of time distortions in bisection, although its interaction with emotional valence tended also to be significant (Awe: $E = -64.98, ES = 36.48, 95\%CI[-137.73; 7.75], t = -1.78, p = .079$; valence: $E = -18.73, ES = 39.97, 95\%CI[-98.25; 60.78], t = -0.49, p = .64$; awe x valence: $E = 12.50, ES = 7.03, 95\%CI[-1.50; 26.50], t = 1.78, p = .079$).

There was no significant effect for the WR (awe, $F(1, 83) = 0.247, p = .62$, awe x duration range, $F(2, 83) = 0.60, p = .55$, duration range, $F(2, 83) = 0.61, p = .545$). The last result is characteristic of the scalar property of time in temporal bisection (see Wearden and Lejeune, 2008)

Insert Figure 3 about here

Discussion

The results of Experiment 3 once again confirmed that the participants judged the images of sublime, vast landscapes to elicit the emotion of awe (admiration-beauty-awe) together with its associated facets, namely an emotion considered to be of positive valence that reduces the level of irritation and limits the focus on the self (small self). In the temporal bisection task used in Experiment 3, participants did not judge the image presentation duration as in Experiments 1 and 2, but the duration of a neutral stimulus that appeared while they viewed the images. In this new condition, participants judged the duration of the neutral stimulus to be shorter when they viewed the awe images than when they viewed the no-awe images. Indeed, they responded more often that the comparison durations were similar to the short standard duration than the long standard duration for the awe images than for the no-awe images, with the result that the bisection curves were systematically shifted to the right, with a significantly higher BP.

The shortening of estimated duration observed in Experiment 3 is not consistent with the predictions of the hypothesis of the “speeding-up of the clock”, which presupposes that the rhythm of the internal clock changes in response to variations in the level of arousal when participants experience awe. Indeed, we observed a lengthening of estimated durations in Experiment 1 and a shortening of the same durations in Experiment 2. It would therefore be illogical, or indeed absurd, to think that in one case (Experiment 1), the clock sped up because the perception of an awe image increased the participants’ level of arousal, and that in another case (Experiment 2), the same clock slowed down because the perception of the same images decreased their level of arousal. We cannot change the explanatory system at will to fit the data. On the one hand, participants systematically (in both Experiment 1 and 3) reported a decrease in the level of arousal experienced when they looked at awe images compared to no-awe images. On the other, an effect of awe on the representation of time, presumably due to changes in the rhythm of the internal clock, is thought to result in a multiplicative effect (significant interaction between the awe factor and the duration-related factors), and our results are not consistent with this type of effect. On the contrary, they are consistent with an additive effect linked to attentional mechanisms. We indeed found that the shortening of time observed in our bisection task was of the same magnitude not only for the different comparison

durations but also for the different duration range from 200 ms to 8 s used to test this hypothesis. As we will discuss later, the internal representation of a shorter duration with the awe images than the no-awe images might have been due to the participants focusing more attention on the awe images, thereby delaying the switch of attention toward the neutral stimulus to be timed. According to the attentional models of the internal clock, the later the attentional switch that allows the pulses emitted by the pacemaker to be transferred to the accumulator, the fewer pulses are accumulated and the shorter the duration is judged to be. These findings cannot be due to differences in participants' expectations with regard to the appearance of the neutral stimulus on the different images because the timing of the onset and offset of these images was always the same. In summary, the results of Experiment 3 as a whole confirmed that the perception of images that induce the emotion of awe modifies the perception of time in a temporal bisection task, because more attention was oriented towards these images.

General discussion

Experiencing awe would change the awareness of the passage of time, producing the feeling of an expansion of time and causing one to believe that one has more time available for oneself and others (Rudd et al., 2012). However, the few studies that have used psychophysics tasks classically used in experiments on time perception in animals and humans (temporal bisection task) have found no effect of the emotion of awe on the perception of short durations (Berry et al., 1995; van Elk and Rotteveel, 2020). This would suggest that this emotion affects the consciousness of time, that is to say its phenomenology (Husserl, 1964; Merleau-Ponty, 1945), but not the primary sense of duration. As explained above, this absence of significant results on the perception of duration may be due to the stimuli used in these laboratory experiments. Before any conclusions can be drawn regarding the perception of duration, it is first necessary to test other awe-inducing stimuli in the laboratory and that is what we did in our experiments. However, we can imagine that the experience of awe would obviously be easier to obtain and stronger in a natural environment than when viewing images presented on a computer as in our experiments.

In the 3 experiments that we carried out, we used new stimuli (images of open landscapes and charismatic people) which induced a feeling of awe in our participants coupled with all its usual features: perception of beauty, admiration, small self-size, positive emotion and low arousal. In our experiments, the perception of these stimuli produced temporal distortions in the participants, regardless of the type of stimuli used. However, this was less marked for images of people than for those of natural environment. In addition, our participants, psychology students, were mainly women. The effect of sex therefore needs to be tested, bearing in mind that there are often sex effects on emotions. Nevertheless, time distortion during the presentation of awe stimuli appears to be a robust phenomenon provided that the stimuli used effectively induce the emotion of awe and do not possess characteristics that interfere with the effect of this emotion on the perception of their duration (e.g., vast vs. non-vast images).

The time distortions observed in our experiment consisted of an increase in the judged presentation duration of the awe stimuli (Experiment 1 and 2). As has already been discussed on a number of occasions, there is a body of findings providing evidence that the fact that the duration of the awe images was judged longer than that of the no-awe images in our experiments might be due to cognitive attentional processes. Indeed, when more attention is directed to the duration of a stimulus, its duration is perceived as being at longer (Mattes and Ulrich, 1998). As Mattes and Ulrich (1998) wrote, attention prolongs the perceived duration of a stimulus. This is consistent with findings showing that the experience of awe decreases impulsivity (Berry et al., 2015) and increases attentional capacities (Sung and Yih, 2015), thereby facilitating individual involvement in the processing of new information (Sung and Yih, 2015). According to the Extended-Now theory (Vohs and Schmeichel, 2003; Keltner and Haidt, 2003), awe focuses people's attention on what is currently happening, beyond the self in the present. In this perspective, the perception of awe images would have increased the amount of attention directed to the processing of temporal information in the explicit temporal

judgment task, in which the participants were instructed to judge time. However, awe-inducing stimuli can also attract attention to their own non-temporal content, with the result that participants spend more time looking at the awe images, thereby increasing their perceived duration. Ogden (2013) observed a similar overestimation of the presentation duration of attractive faces (beautiful face) compared to unattractive faces (more unsightly face). It is known that the aesthetic experience involves focusing attention on the beautiful object (Markovic, 2012). The first two experiments that we conducted suffer from the limitation that they do not allow us to settle the question of whether the presentation duration of awe images is perceived as longer because they induce more efficient time processing or because more time is spent looking at these images. Further studies are needed to dissociate the effect on time judgment of the non-temporal content of the source of awe from its duration, even if the two are intertwined.

The aim of Experiment 3 was to separate the source of awe from its duration by asking participants to judge the duration of a neutral stimulus presented while they were viewing different images. In this specific condition, a clear shortening of time estimates was observed when participants viewed the awe images compared to when they viewed the no-awe images. In the theoretical framework of attentional models of the internal clock (Thomas and Weaver, 1975; Zakay and Block, 1996, 1998), shorter judgments of the stimulus duration can be explained by the later closure of the attentional switch that results from the longer period needed to distract attention away from awe images than from no-awe images. When the attentional switch takes longer to operate, this clearly means that more attention is focused on the awe images. Therefore, our last experiment supported the hypothesis that the time distortions observed during the perception of images of awe are due to the fact that these images captured more attention than the other images. The temporal effect of awe stimuli are therefore rooted in processes linked to attention. However, our results are limited to the perception of awe-inducing images presented for short durations. In a natural situation (or in virtual reality) that lasts longer, the emotion of awe could also produce a variation in the level of arousal, slowing it down. This needs to be tested with longer durations than those used in our experiments and other awe-inducing situations, in order to identify the type of mechanism underlying the emotional felt in different awe-inducing conditions.

Indeed, it is not possible to reduce the effects of awe to attentional processes. This emotion is very complex and multifaced in nature (Lazarus, 1991). In addition, there are multiple other sources of awe (e.g., religion, work of art), and these may differ between different individuals and cultures (Quinn, 1997; Van Cappellen and Saroglou, 2012). Some sources of awe can also increase levels of stress and fear, which are highly arousing, unlike those used in our studies. Ekman (1992) mentioned for some cases a mixture of wonder and fear. It is therefore important to further investigate the effect of different types of awe on time judgments. Furthermore, we investigated the effect of awe on the temporal bisection of short durations, but this may itself vary depending on the type of temporal judgment required (e.g., verbal estimation, temporal reproduction) and the durations used (tens of seconds and minutes). A new avenue of research has therefore been opened up. In conclusion, we can nevertheless claim: the 11th emotion, awe, alters the 6th sense, the sense of time.

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