Associations Between Self-Reported Awe and Heart Rate

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Associations Between Self-Reported Awe and Heart Rate

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Thesis submitted
to the Eberly College of Arts and Sciences
at West Virginia University

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Master of Science
in
Psychology – Life-Span Developmental Psychology

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ABSTRACT

Associations Between Self-Reported Awe and Heart Rate

Laura Bernstein

Fredrickson’s (1998, 2013) broaden and build theory states that positive emotions can expand our social and cognitive awareness and provide health benefits. Some positive emotions, such as awe, may operate differently. We sought to understand how subjective reports of awe, induced through videos, correlate with HR. We know that HR tends to decrease with age (Umetani et al., 1998), individuals have less physiological reactivity as they age (Blanchard-Fields, 2007), and older adults report more positive emotions than negative emotions (Mroczek & Kolarz, 1998). Given these findings, we were interested in understanding whether there were age differences in self-reported awe and HR during an awe induction. Our sample consisted of 20 women in two age groups: early mid-life (M age = 43.1) and later mid-life adults (M age = 61.9). Participants watched both a neutral and an awe-inducing video while we assessed continuous HR. Participants provided self-reported awe at multiple points throughout the protocol. There was a significant correlation between HR during the awe video and self-reported awe immediately following the awe video ($\rho = -.447, p = .024$), supporting our first hypothesis. We did not find support for our second hypothesis in that we did not find age differences in self-reported awe following the awe video ($U = 63.95, p = .295$) or HR during ($U = 27.00, p = .095$) or after ($U = 31.00, p = .175$) the awe video. Our findings suggest that higher levels of awe might be associated with lower HR. Future studies with increased sample sizes should disentangle the effects of video order and emotion induction. Additional indices of HR and increased diversity in sample characteristics will also be informative.
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Associations Between Self-Reported Awe and Heart Rate

Living a healthy and happy life is something that individuals strive for throughout their lifespan. Health and well-being can influence one another, and the ways to achieve them can change as people age. Positive emotions can improve physical health, as evidenced by their correlations with objective health measures (e.g., healthy cardiovascular activity, Boehm & Kubzansky, 2012) and subjective health measures (e.g., more positive self-reported health Pettit et al., 2001). Subjective and objective health measures tap into unique elements of health and well-being. Subjective, self-report measures may provide a unique insight into an individual's overall well-being because individuals are often in tune with their bodies (Jylhä, 2009). Like self-reported health, self-reported levels of positive emotion may provide unique insight into an individual's current state of mind. Researchers can further explore the impact of positive emotions on objective health measures, such as cardiovascular activity, to better understand the link between subjective and objective health. Further understanding the association between emotion and health can help inform interventions that seek to improve the health and well-being of individuals. Additionally, by examining these associations in diverse age groups, we can apply these interventions across the lifespan and promote the experience of healthy aging.

Measuring Health

Health is a broad concept that includes both objective and subjective measures. Objective measures can provide insight into physical health, such as levels of cardiovascular activity, presence of chronic diseases, or blood pressure. Resting heart rate (RHR), for example, is associated with disease and longevity such that lower RHR is correlated with reduced mortality and a lower risk of cardiovascular disease (Barbieri et al., 2002; Jensen, 2019; Levine, 1997). Individuals can also self-report their perceived health, quality of life, or functionality. Subjective
reports of health can provide insight into the impact of one's physical state that objective
measures may not capture. Self-rated health (SRH) is predictive of mortality, such that those who
rate their health positively tend to live longer (Kaplan & Camacho, 1983; Mossey & Shapiro,
2011). This association persists even when controlling for smoking status, cancer diagnosis, and
diabetes status (Idler & Kasl, 1991). Poorer SRH is associated with various diseases, such as
cardio-cerebral vascular diseases, visual impairment, and mental illness (Wu et al., 2013). These
findings suggest that there is overlap in the ability of objective and subjective measures to
predict overall health and well-being. Each type of health operationalization offers insight into an
individual's overall well-being, and by examining both types simultaneously, researchers can
provide a more holistic explanation of health.

To provide insight into physiological processes in the body, the present study uses heart rate
(HR) as a variable of interest. HR influences cardiac output, which is calculated by multiplying
stroke volume by HR. HR helps maintain necessary blood volume, blood pressure, and
oxygenation to all body organs (Jensen, 2019). HR represents the time elapsed between two heart
contractions, also referred to as the R-R interval, or the time between two R-waves (Acharya &
Krishnan, 2004). HR represents a connection between the brain and heart, given that the
parasympathetic nervous system influences HR through the vagus nerve (Purves et al., 2001).
Increased parasympathetic nervous system activity is associated with lower levels of HR
(Wehrwin et al., 2016). HR is also influenced by the sympathetic nervous system, but in the
opposite direction.

A lower resting HR is associated with improved health outcomes (Jensen, 2019; Levine,
1997), and studies that have successfully reduced participant HR have demonstrated this
reduction is associated with a reduced risk of disease. Intervention studies that provide some
participants with ivabradine, a drug aimed at lowering HR, have shown that reduction in HR in intervention groups is associated with a decreased risk of admission to the hospital for cardiovascular-related events (Fox et al., 2008; Swedberg et al., 2010). Additionally, heart rate reactivity, or the change in HR in response to stimuli, has implications for health outcomes. Increased reactivity to stressful events is associated with an increased risk of hypertension (Cinciripini, 1986) and cardiovascular disease (Krantz & Manuck, 1984). These findings suggest that lower HR levels, both at rest and in response to stimuli, are associated with optimal cardiovascular health.

HR demonstrates both age and sex differences. HR tends to decrease with age (Umetani et al., 1998), although age differences in HR are not as pronounced as those found in heart rate variability (HRV; Ryan et al., 1994; Umetani et al., 1998; See Appendix C for an overview of HRV). Women tend to have a higher mean HR, indicated by a smaller mean interval between R-waves (Koenig & Thayer, 2016). Age may moderate these sex differences. Umetani and colleagues (1998) found that women exhibited faster HR than men, but only among those younger than 50 years old. Researchers have attempted to understand the mechanisms behind these sex differences (Du et al., 2006). Their research suggests that the vagus nerve of the parasympathetic nervous system plays a more significant role in the autonomic control of both the human and animal female heart compared to the male heart (Du et al., 2006; Koenig & Thayer, 2016). This suggests that differences found in HR may be biologically based, and interventions that utilize HR as a variable of interest may need to be tailored based on participants’ sex.
Positive Emotions and Physical Health

Physical health exhibits relations with both the experience of positive mood (i.e., positive affect) and with specific positive emotions. Positive affect is associated with a lower risk of mortality (Zhang & Han, 2016), a lower risk of cardiovascular disease (Boehm & Kubzansky, 2012), a higher likelihood of survival in those with diabetes (Moskowitz et al., 2008), and less self-reported pain in those with chronic illness (Pressman et al., 2019; Strand et al., 2007). Positive emotions are associated with resistance to acute illness (e.g., a cold, Cohen et al., 2003) and chronic illness (Kawamoto & Doi, 2002; Palmore, 1969; Pressman & Cohen, 2005).

Rosenberg (1998) argued that emotional states (i.e. specific positive or negative emotions) and affective (i.e. positive or negative affect) states are distinct and require different levels of analysis. Given this distinction, understanding how positive affect and positive emotions uniquely impact health is essential. Much of the work examining how positivity impacts health assesses positive affect rather than specific positive emotions (Pressman & Cohen, 2005). We know that different emotions have unique influences on physiology, with the emotion of surprise eliciting significantly higher HR levels than feelings of pain or boredom (Jang et al., 2015). Positive and negative emotions have unique impacts on patterns of HRV. Feelings of anger are associated with an increase in the ratio of low to high-frequency patterns. In contrast, feelings of appreciation are associated with higher rates of middle and high-frequency patterns (McCraty et al., 1995).

Although the field has long known that emotional states are part of subjective well-being (Bradley & Lang, 2009; Diener, 2009), Fredrickson’s (1998) broaden and build theory suggested that the effects of positive emotions are distinct from those of negative emotions. She argued that positive emotions broadened individuals’ thought-action repertoire by expanding their attentional...
and cognitive scope and increasing the flexibility of their information processing. This broadening then allows them to increase the scope of their actions, acting in ways that are outside of their typical range of behaviors. This theory also argues that the experience of positive emotions builds physical, intellectual, and social resources (Fredrickson, 1998).

One way positive emotions might influence health is by mitigating the effects of negative emotions. The experience of negative emotions, such as hostility and anger, is accompanied by increased cardiovascular reactivity to stress (Engebretson et al., 1989; Fredrickson et al., 2001), which is associated with an increased risk for cardiovascular disease (Blascovich & Katkin, 1993). In one study with 60 female undergraduate students, Fredrickson and Levenson (1998) explored whether positive emotions could lessen that negative effect. In this study, participants viewed emotionally-balanced film clips. Those who watched a positive video immediately after the negative video showed a quicker return to baseline levels of cardiac activity than those who watched a neutral or sad video clip (Fredrickson et al., 2000; Fredrickson & Levenson, 1998). These data support the undoing hypothesis, which states that positive emotions can undo, or bring back to baseline, the increase in heart rate after negative emotions (Fredrickson et al., 2000; Fredrickson & Levenson, 1998).

There have been efforts to replicate these findings with mixed results. These findings were replicated in racially diverse samples that included male and female participants (Tugade & Fredrickson, 2000). This finding is significant given that HR measurements through the skin are less accurate in individuals with a darker skin tone (Shcherbina et al., 2017). However, a critical review of the undoing hypothesis found inconsistent support with an equal number of studies providing support, partial support, or no support for the hypothesis (Cavanagh & Larkin, 2018). It is likely the case that individual characteristics, types of stimuli, and type of stressor task
employed influence cardiovascular recovery consisted with the undoing hypothesis (Cavanagh & Larkin, 2018).

Although Fredrickson's work links positive emotions to HR and health, the focus has been on global positive emotions. As Bradley and Lang (1994) noted and Cowen and Keltner (2017) demonstrated, positive emotions differ in valence, arousal, and frequency. Examining specific emotions may provide an avenue for more effective interventions.

**Awe**

One such emotion is awe. Awe is a self-transcendent emotion, eliciting the feeling that one is a part of something larger than themselves (Allen, 2018). Keltner and Haidt (2003) determined that awe is comprised of two experiences: perceived vastness and a need for accommodation. Perceived vastness results from an individual viewing something large in size, beauty, or impressiveness. They can view a beautiful landscape, religious landmark, or even a notable figure. Although awe may be induced or evoked by dramatic scenes of tornadoes, storms, or fires, such "negative awe" is not frequently studied in the lab (Allen, 2018). After viewing this sight, one needs to accommodate their current schema or understanding of the world because their current knowledge does not account for the vastness of such an object or experience (Allen, 2018; Keltner & Haidt, 2003). Keltner and Haidt (2003) argue that these two experiences distinguishes awe from other positive emotions.

The experience of awe can influence a wide variety of psychological outcomes. This feeling of awe can be induced through images of nature or vast landscapes (Campos et al., 2013; Piff et al., 2015; Shiota et al., 2007). Individuals who experience positive awe through nature or art often report feeling small or insignificant compared to their environment or other individuals (Piff et al., 2015; Shiota et al., 2007). This "small self" might partially explain increased feelings
of humility (Stellar et al., 2017) and connectedness to others (Krause & Hayward, 2015) that is also associated with awe (Allen, 2018). Feelings of awe can also lead to an expanded future time perspective (Rudd et al., 2012), improved mood (Joye & Bolderdijk, 2015), and increased levels of well-being (Gordon et al., 2017).

While the association between positive emotions as a whole and physiology has garnered moderate interest, interest in understanding the impact of awe on physiological constructs is more recent. To our knowledge, only one study has examined the autonomic effects of awe. This study found that awe is associated with a lengthened pre-ejection period (PEP) and decreased respiratory sinus arrhythmia (RSA), both of which are consistent with an increase of the activity of the parasympathetic nervous system and a withdrawal of activity of the sympathetic nervous system (Shiota et al., 2011). However, this study also found that inducing awe increased respiration rate, which is indicative of an increase in the activity of the sympathetic nervous system (Shiota et al., 2011). More work is needed to examine these autonomic effects.

Experiences of awe are also associated with piloerection, more commonly referred to as goosebumps (Benedek & Kaernbach, 2011; Schurtz et al., 2012). Long-term experiences of awe are also associated with lower levels of the pro-inflammatory cytokine IL-6 (Allen, 2018; Stellar et al., 2015), providing more support for the use of awe inductions to improve health.

Some researchers have begun to study how awe is distinct from other positive emotions. Shiota and colleagues (2017) theorized that individuals experience awe in response to acquiring new and complex information, which makes it distinct from other positive emotions. Additionally, the study examining the autonomic influences of awe found that a lengthened PEP was only associated with awe and not the other positive emotions of enthusiasm, attachment love, nurturant love, or amusement (Shiota et al., 2011). While more work is needed to
understand how awe elicits specific patterns of neural mechanisms and physiology, it is likely that awe has some degree of overlap with other positive emotions. Ekman and Cordaro (2011) argue that there is overlap in the positive emotions of wonder and awe in that when wonder combines with fear, individuals experience awe (Allen, 2018). Additionally, the feeling of elevation is thought to have some overlap with awe in that individuals feel elevated when they witness a morally good act. However, Keltner and Haidt (2003) state that awe is distinct because it includes the experience of perceived vastness.

Age Differences

Currently, few studies have examined the association between positive emotions and health in diverse age groups. The current literature primarily uses samples of college students who vary in many ways from middle-aged and older adults. We know that the way individuals experience emotions changes as they age. Carstensen's (1992) socioemotional selectivity theory (SST) states that as people age, their perception of their future becomes more limited (Lang & Carstensen, 2002), which causes them to adjust their priorities. They spend more time and effort focused on what brings them emotional satisfaction and less time on unpleasant tasks or relationships. As a result, they tend to prune their social networks to those that bring them the most joy. Additionally, they tend to devote more cognitive resources to positive stimuli and pay less attention to what is negative (Carstensen et al., 2003).

Additionally, there is evidence for a "positivity effect" as individuals age. By the time individuals reach the age of about 60, they tend to experience fewer negative emotions (Mroczek & Kolarz, 1998). They tend to use both motivation and cognitive control to pay more attention to positive stimuli (Mather & Carstensen, 2003), allowing them to remember more positive than negative stimuli in laboratory settings (Mather & Carstensen, 2003). Older adults (age 63-86) are
also less likely than younger adults (age 18-40) to dwell on negative information and negative appraisals about themselves made by others (Charles & Carstensen, 2008, 2010). However, researchers did not include middle-aged adults in the sample. Adults between 47 and 102 tend to recall more positive autobiographical memories than they did fourteen years earlier (Kennedy et al., 2004). Despite increases in chronic illness and overall health concerns (He & Larsen, 2014), subjective well-being does not decrease with age (Kunzmann et al., 2000) as some might expect.

Recent work has started examining age differences in the experience of awe along with how older adults uniquely experience awe. Work from our lab suggests that older adults experience higher levels of awe in response to both awe-inducing and happiness-inducing videos (Ebert et al., 2021). Awe is more likely to impact cognitive and emotional well-being positively in older adults (Bernstein & Patrick, 2021). Interventions aimed at increasing levels of awe in older adults have successfully improved levels of positive prosocial emotions and decreased daily distress (Sturm et al., 2020). Although within religious awe, some evidence suggests only small age effects (Krause & Hayward, 2015a, 2015b; Van Cappellen et al., 2016).

Given that older adults tend to focus more on positive information and experiences (Carstensen et al., 2003; Mroczek & Kolarz, 1998), it is understandable that they are more susceptible to feelings of awe (Ebert et al., 2021). However, Lachman (2004) argues that middle adulthood, typically from ages 40 to 60, is a transition into old age. It is important to understand unique experiences and phenomena during this developmental period. Jung described midlife as a critical period during which individuation occurs and is essential for linking early and later periods of life (Jung, 1933). Midlife is a distinct developmental period from early and late adulthood in that gains and losses are relatively proportional (Baltes et al., 2006; Lachman et al., 2015). Lachman and colleagues (2015) point out that middle-aged adults directly influence both
younger and older generations (i.e., both their children and parents), so understanding and promoting health for these individuals may impact a wide range of the population. Given that there is little empirical work studying awe across middle and late adulthood and that work focused on emotional aging does not always consider those in midlife, a better understanding of positive emotions during this transitional period of adulthood is needed.

**Present Study**

Positive emotions influence health, physiology, and specific measures of autonomic reactivity, such as HR. While research has explored the association between more general positive affect and physical health (Cohen & Pressman, 2006; Pressman & Cohen, 2005; Pressman et al., 2019), it is essential to distinguish between positive affect and specific positive emotions. There is evidence that individual emotions uniquely impact these physiological measures. Awe, an elevating emotion that can lead to cognitive accommodation, is one specific positive emotion that has received more recent interest.

Limited work suggests awe is associated with less autonomic reactivity (Shiota et al., 2011). However, only a single study has examined the influence of awe on autonomic nervous system activity. We were interested in extending investigations of awe to understand how the cardiovascular system responds to awe induction and to clarify the relation between objective and subjective reactions to awe-inducing stimuli. Our first research question asked:

1. How do participants' subjective ratings of awe correlate with HR after awe induction? We predicted that there would be significant inverse correlations between self-reported awe and HR following awe induction such that higher levels of self-reported awe would be correlated with lower average HR.
2. We also sought to fill the gap in knowledge regarding how middle-aged adults experience both awe and autonomic reactivity to positive emotions. Our second research question asked: are there age differences among middle-aged adults in self-reported awe and HR following awe induction? We predicted that late mid-life adults would display higher levels of self-reported awe and lower HR levels after watching the awe video. Thus, the present study seeks to understand further the mechanism whereby emotions influence health within a developmental context.
Methods

Sample

Recruitment. Because there are known sex differences in HR (Koenig & Thayer, 2016), and we focused on a smaller sample, we restricted recruitment to women only. We recruited women between the ages of 30 and 70. We first recruited women from previous studies in our lab. We then advertised our study in a news release sent to the entire university community. We also advertised our study to a university-affiliated organization aimed to promote learning and engagement in community members in mid and late adulthood. Finally, we also asked participants and researchers to notify family and friends about the study. Potential participants first filled out a health-screening survey. Individuals who suffered from high blood pressure or heart disease or took medications interfering with cardiovascular activity or blood pressure along with medications for ADHD were excluded.

We conducted an a priori power analysis using G*Power (Faul, Erdfelder, Buchner & Lang, 2009). With one between-subjects variable (age) and a power of .85, we found that a total sample of 36 participants (18 in each age group) would be necessary. This would achieve an effect size of .26. Due to recruitment challenges related to the COVID-19 pandemic, total of 20 adult females participated in the study (M age = 53.5 years, SD = 11.2). The sample included nine early mid-life women (ages 33-49 years; M age = 43.1 years SD = 4.5) and 11 later mid-life women (ages 51-67 years; M age = 61.9 years, SD = 6.9). None of the women identified as Hispanic. The sample was primarily White (90%), and one (5%) identified as Black or African American and and one (5%) identified as Asian or East Asian. Full demographic information is included in Table 1 in Appendix E.
In addition to the exclusion criteria outlined above, participants were asked to avoid consuming caffeine the morning of the study as to avoid potential influence on HR. We also asked participants if they smoked a cigarette in the past hour and all participants answered “no.”

**Measures**

*Heart Rate (HR).* A Polar Model H10 heart rate monitor (Lake Success, New York) was used to measure the number of heart beats per minute (Shaffer & Ginsberg, 2017). The Polar monitor is a valid measurement of HR (Goodie et al., 2000). The heart rate monitor was placed around the participant’s chest and transmitted data to the Polar Beat application that they were asked to download on their smartphone at the beginning of the session.

*Self-report measures.* The 6-item awe subscale of the Dispositional Positive Emotion Scale (DPES, α = .78; Shiota et al., 2006) was used to measure levels of dispositional awe. The awe subscale asks participants to respond to statements such as “I often feel awe” on a 7-point response scale from “Strongly agree” to “Strongly disagree.”

*Emotion ratings.* Participants rated how happy, relaxed, excited, aroused, in awe, and dominant they were feeling on a scale from 0 to 100 in intervals of 5. These emotion adjectives are a part of Bradley and Lang's (1994) Self-Assessment Manikin (SAM). They are categorized under pleasure (happy, relaxed), arousal (excited, aroused), and dominance (awe, dominance), which Bradley and Lang argue can accurately capture an individual's affective response to stimuli (Bradley & Lang, 1994).

*Emotion Induction.* The current study used videos previously demonstrated in our lab to elicit specific emotions. These two videos were neutral and awe. In pilot testing, participants rated how much awe they were experiencing on a scale from 1 to 7, with higher numbers indicating higher state-level awe. The neutral video had a mean awe rating of 2.46 out of 7, and
the awe video had a mean rating of 5.44 out of 7. Participants watched the YouTube videos that the researchers showed them via the share feature on a Zoom video call (Zoom Video Communications, 2016) without any audio. Participants first watched the neutral video, which was approximately three minutes long, and provided a demonstration for tying a necktie (https://www.youtube.com/watch?v=HXJx8j7JpKY). They next watched the awe video, which was two minutes and 29 seconds long and depicted Earth from space (https://www.youtube.com/watch?v=FG0fTKAqZ5g).

**Experimental Design**

A quasi-experimental design was used. The within-subjects factor was the type of video shown, either neutral or awe. Age was the independent variable in that early mid-life adults and late mid-life adults were compared. Dependent variables included self-reported levels of emotions (measured before, immediately after, and two minutes after watching each video) and HR.

**Procedure**

To minimize exposure to the COVID-19 virus, participants completed the study over a video call with the researcher. Full details of the protocol are presented in Appendix A. Participants were mailed a Polar HR monitor, copies of the informed consent form, and copies of the rating scales before completion of the study and were allowed to keep the monitor as their honorarium. They downloaded the Polar Beat smartphone app to their cell phone. Previous studies in our lab used the Polar Beat app with earlier versions of the Polar HR monitor and were successfully able to calculate levels of HRV. Researchers provided each participant with a unique username and password to log in to their Polar account used for data collection. The researcher pre-registered the HR monitor used by each participant to correspond with their
respective account. The researcher briefly described the study procedure, risks, and benefits and obtained informed consent. The researcher asked the participant each question as an interview and recorded their responses in Qualtrics.

They first responded to the awe subscale of the DPES. They then provided baseline emotion ratings on the six emotion adjectives from the SAM.

Next, the researcher asked the participant to attach the Polar heart rate monitor and to press Start in the Polar Beat app to begin recording HR data. The participant was asked to sit quietly for five minutes to collect a baseline HR level. All participants first watched the neutral video, followed by the awe-inducing video. Participants provided emotion-adjective ratings immediately before and immediately after each video. As a manipulation check, after each video participants were asked to briefly describe the contents of each video to ensure they watched it. After a three-minute rest period following each video, participants provided emotion ratings again. They then sat quietly for an additional five minutes in between the videos.

Participants were asked to stop recording their HR within the Polar Beat app following both videos. The researcher then ensured that the participant's HR data were recorded correctly and uploaded to their Polar account, which the researcher accessed on their computer. Participants were then instructed to remove their HR monitor and asked a series of demographic questions that inquired about: age, race, financial status, spirituality, and gender identity. The researcher thanked the participant for their time (For full study protocol, see Appendix A). For details about how protocol shifted from original proposal, see Appendix B.

Variables

Awe. At multiple points throughout the study, participants provided self-reported levels of awe. In total, there were seven times of measurement of self-reported awe: at the very
beginning (Awe_Baseline), immediately before the neutral video (Awe_V1_T1), immediately following the neutral video (Awe_V1_T2), three minutes following the neutral video (Awe_V1_T3), immediately before the awe video (Awe_V2_T1), immediately following the awe video (Awe_V2_T2), and three minutes following the awe video (Awe_V2_T3). See Appendix D for a timeline of the protocol and awe times of measurement.

**Average HR.** The Polar Beat app on participants’ phones provided a running timer of their HR session. Participants provided the time shown on the Polar timer at multiple points throughout the protocol before and after each rest period and video. Researchers later divided each participant’s HR session into minute- and second-based intervals. There were twelve different intervals throughout the study: first five-minute rest period (HR_Rest1), time during self-report measures before the neutral video (HR_V1_T1), time during the neutral video (HR_V1_T2), time during self-report measures immediately following neutral video (HR_V1_T3), time during the three-minute recovery period following neutral video (HR_V1_T4), time during self-report measures three minutes following the neutral video (HR_V1_T5), the time during second five-minute rest period between videos (HR_Rest2), the time during self-report measures before awe video (HR_V2_T1), the time during awe video (HR_V2_T2), the time during self-report measures immediately following awe video (HR_V2_T3), the time during the three-minute recovery period following awe video (HR_V2_T4), the time during self-report measures three minutes following the awe video (HR_V2_T5). Average HR in each of the twelve intervals was calculated for each participant. See Appendix D for a timeline of HR intervals and how they match up with awe times of measurement.
Results

Dispositional and Baseline Awe

The awe subscale of the DPES had six items, each with a response scale of 1-7. The awe subscale displayed good internal consistency with a Cronbach's alpha of 0.73. There were zero cases of missing data. There also were not any univariate outliers. Dispositional awe was normally distributed and did not violate the assumptions of skewness or kurtosis. Dispositional awe had a mean score of 5.97 (SD = .57; range = 4.67 – 6.67). Baseline awe had a response scale of 0 – 100 in intervals of 5. Baseline awe had a mean score of 44.25 (SD = 33.73; range = 0 – 95).

Awe and HR During Neutral Video

Before comparing awe and average HR across the two conditions, we first examined how the mean of both outcome variables changed throughout each video (neutral and awe). We calculated mean and standard deviation values for both awe and average HR at each time of measurement during both the neutral and awe videos.

Awe. Immediately before watching the neutral video, the mean of self-reported awe was 44.25 (SD = 33.73). The mean of self-reported awe immediately following the neutral video was 44.25 (SD = 31.26). The mean of self-reported awe three minutes following the neutral video was 38.25 (SD = 28.94). Full descriptive information is provided in Table 2 of Appendix F. To assess whether self-reported awe differed significantly as a function of time throughout the neutral video, we conducted a repeated-measures ANOVA with a Greenhouse-Geisser correction. The ANOVA determined that average awe did not significantly differ from each time of measurement ($F(1.65, 31.82) = 2.46, p = .11$). See Figure 1 in Appendix I.
Given the large standard deviation of self-reported awe scores, we calculated a person-centered, change-from-baseline awe score for each time of measurement. This was done by subtracting the self-reported awe score from the participants' baseline awe score for each video to create a change-from-baseline score for each measurement time. For analyses run to assess how change-from-baseline awe changed throughout the neutral video, see Appendix L. To see how change-from-baseline awe scores change over the course of the neutral video, refer to Figure 7 of Appendix L.

**HR.** Average HR during the first rest period was 72.89 bpm (SD = 11.35). Immediately before watching the neutral video, the average HR was 73.26 bpm (SD = 11.94). Average HR while watching the neutral video was 70.70 bpm (SD = 12.06). Immediately following the neutral video, the average HR was 73.56 bpm (SD = 12.36). During the three-minute recovery period following the neutral video, the average HR was 71.83 (SD = 11.67). Three minutes following the neutral video, the average HR was 72.89 (SD = 12.44). Average HR during the second rest period was 70.52 bpm (SD = 11.04). Full descriptive information is provided in Table 3 of Appendix F. A related-samples Wilcoxon signed-rank test was conducted to assess whether participants returned to their initial HR during the second rest period. Average HR was significantly higher during the first rest period ($M = 72.89$, SD = 11.35) than during the second rest period ($M = 70.52$, SD = 11.04; $Z = 37.00$, $p = .01$).

To assess whether mean, average HR differed as a function of time during the neutral video, a repeated-measures ANOVA with Greenhouse-Geisser correction was conducted. The ANOVA determined that mean average HR did differ significantly as a function of time ($F(2.92, 55.50) = 7.26$, $p < .01$). Post hoc analysis with a Bonferroni adjustment revealed that average HR significantly decreased from immediately before the neutral video to the time during
the neutral video (-2.56 (95% CI 0.78 to 4.35) bpm, \(p < .001\)) and significantly increased from the time during the neutral video to the time immediately following the neutral video (2.86 (95% CI 1.29 to 4.43) bpm, \(p < .01\)). See Figure 2 of Appendix I.

**Awe and HR During Awe Video**

**Awe.** Immediately before watching the awe video, the mean of self-reported awe was 38.25 (SD = 30.87). This was the same mean value as 3 minutes following the neutral video. The mean of self-reported awe immediately following the awe video was 62.00 (SD = 32.62). Three minutes following the awe video, the mean of self-reported awe was 50.25 (SD = 34.43). Full descriptive information is provided in Table 2 of Appendix F.

To assess how self-reported awe changed throughout the neutral video, a repeated-measures ANOVA with Greenhouse-Geisser correction was conducted. The ANOVA determined that average awe differed significantly between times of measurement \((F(1.55, 29.53) = 16.05, p < .01)\). Post hoc analysis with a Bonferroni adjustment revealed that mean levels of awe increased significantly from immediately before the awe video to immediately after the awe video (23.75 (95% CI 5.62 to 41.89), \(p < .01\)) and decreased significantly from immediately after to three minutes following the video (-11.75 (95% CI -21.70 to -1.80, \(p = .02\)). To see how awe changed over the course of the awe video, see Figure 3 of Appendix J. To see how awe changed over the course of the entire protocol, see Figure 5 of Appendix K. To see how change-from-baseline awe scores change over the course of the awe video, refer to Figure 8 of Appendix L.

In addition to the repeated-measures ANOVA using change-from-baseline awe outlined in Appendix L, we also plotted each participants' trajectory of both awe and change-from-baseline throughout the awe video. Given the large standard deviation in self-reported awe, we
were interested to see how each participant’s level of awe changed throughout the awe video. See Appendix M for these graphs.

**HR.** Immediately before watching the awe video, the average HR was 71.99 bp (SD = 12.14). The average HR while watching the awe video was 68.83 bpm (SD = 12.00). Immediately following the awe video, the average HR was 71.66 bpm (SD = 12.10). During the three-minute recovery period following the awe video, the average HR was 69.76 bpm (SD = 11.27). Three minutes following the awe video, the average HR was 71.15 bpm (SD = 12.19). Full descriptive information is provided in Table 3 of Appendix F.

To assess how the average HR changed throughout the awe video, a repeated-measures ANOVA with Greenhouse-Geisser correction was conducted. The ANOVA determined that average HR differed significantly between time intervals ($F(2.60, 56.23) = 5.99, p < .01$). Post hoc analysis with a Bonferroni adjustment revealed that average HR significantly decreased from the time immediately before the awe video to the time during the awe video ($-3.16 (95\% CI -5.80 to -0.53) \text{ bpm, } p < .01$) and significantly increased from the time during the awe video to the time immediately following the awe video ($2.83 (95\% CI 0.66 to 4.99) \text{ bpm, } p < .01$). To see how average HR changed over the course of the awe video, see Figure 4 of Appendix J. To see how average HR changed over the course of the entire protocol, see Figure 6 in Appendix K.

**Effect of Condition on Awe**

Given the small sample size of the present study, non-parametric tests were used to test the hypotheses and for exploratory analyses. A related-samples Wilcoxon signed-rank test was conducted to compare the immediate post-video effects of each condition (neutral versus awe) on self-reported awe. This was done to assess whether there was a significant difference in self-reported awe immediately following the neutral and awe videos. Self-reported awe immediately...
following the awe video ($M = 62.00, SD = 32.62$) was significantly higher than awe following the neutral video ($M = 44.25, SD = 32.29 ; Z = 177.50, p < .01$).

An additional related-samples Wilcoxon signed-rank test was conducted to assess whether there was a significant difference in awe at baseline and immediately following the awe video. Self-reported awe was significantly higher immediately following the awe video ($M = 62.00$ bpm, $SD = 32.62$) than at baseline ($M = 44.25$ bpm, $SD = 33.73$); $Z = 143.0, p = .01$.

**Effect of Condition on HR**

To compare the effect of each condition (neutral versus awe) on average HR while watching each video, a related-samples Wilcoxon signed-rank test was conducted. Specifically, this was to assess whether there was a significant difference in average HR during the neutral video and the awe video. HR during the awe video ($M = 68.83$ bpm, $SD = 12.00$) was significantly lower than that during the neutral video ($M = 70.70$ bpm, $SD = 12.06; Z = 175.0, p < .01$). Another related-samples Wilcoxon signed-rank test was conducted to assess whether this difference in average HR was also present following each video. Specifically, this was done to assess whether there was a significant difference between average HR immediately following the neutral video and average HR immediately following the awe video. The test did not reveal a significant difference in average HR following each video ($Z = 15.00, p = .110$).

An additional related-samples Wilcoxon signed-rank test was used to assess whether there was a significant difference in average HR between the second rest period and during the awe video. Average HR during the awe video ($M = 68.83$ bpm, $SD = 12.00$) was significantly lower than average HR during the second rest period ($M = 70.52$ bpm, $SD = 11.04; Z = 43.00, p = .02$).

**Associations Among Subjective Reports of Awe and HR (Hypothesis 1)**
Awe Induction. To assess whether subjective reports of awe were associated with average HR during and after the awe-inducing video, Spearman’s rho coefficients were calculated between the following variables awe immediately following the awe video: average HR during the awe video, and average HR immediately following the awe video. There was a significant correlation between self-reported awe immediately after the awe video and HR during the awe video ($\rho = -.447, p = .024$). Higher levels of self-reported awe were associated with lower average HR while watching the awe-inducing video. This supports the first hypothesis of the present study. There was no significant correlation between awe immediately following the awe video and average HR immediately following the awe video ($\rho = -.277, p = .119$), suggesting that the association between felt awe and lower heart rate did not persist long past the viewing. Spearman’s rho correlations between all measures of awe and intervals of HR are provided in Table 4 of Appendix G.

To control for baseline levels of awe, we decided to calculate partial Pearson’s correlations between self-reported awe immediately following the awe video and HR during and immediately after the awe video, controlling for baseline awe. Given that we are unable to calculate partial Spearman’s rho correlations, we opted to calculate partial Pearson’s correlations. However, first we calculated bivariate Pearson’s correlations without controlling for baseline awe. There was a significant correlation between awe immediately following the awe video and HR during the awe video ($r = -.43, p = .03$). The correlation between awe immediately following the awe video and HR immediately following the awe video was not significant ($r = -.32, p = .09$). Once we controlled for baseline awe, the correlation between self-reported awe immediately following the awe video and HR during the awe video was no longer significant ($r = -.12, p = .62$). The correlation between self-reported awe immediately following the awe video
and HR immediately following the awe video remained non-significant once we controlled for baseline awe \((r = .001, p = .99)\).

**Other Emotions.** To assess how the correlation between self-reported awe and HR during the awe video compared to other emotions, Spearman’s rho correlations were calculated between average HR and the following self-reported emotions following the awe video: happiness, relaxation, arousal, dominance, and excitement. A significant correlation was found between average HR during the awe video and happiness following the awe video \((\rho = -.38, p = .05)\). Lower HR while watching the awe video was associated with higher self-reported happiness following the awe video. A significant correlation was found between average HR during the awe video and arousal following the awe video \((\rho = -.48, p = .02)\). Lower HR levels while watching the awe video were associated with higher levels of arousal following the awe video. No significant correlations were found between average HR while watching the awe video and excitement \((\rho = -.33, p = .08)\), dominance \((\rho = -.36, p = .06)\), or relaxation \((\rho = -.14, p = .29)\) following the awe emotions.

We wanted to understand how the self-reported emotions significantly correlated with average HR were distinct from awe. We conducted two related-samples Wilcoxon signed-rank tests to assess how these self-reported emotions (happiness and arousal) compared to self-reported awe following the awe video. These tests assessed whether there was a significant difference between awe and happiness and awe and arousal. Mean levels of awe following the awe video \((M = 62.00 \text{ bpm}, SD = 32.62)\) were significantly higher than mean levels of arousal following the awe video \((M = 41.50 \text{ bpm}, SD = 36.46; Z = 23.5, p = .01)\). There was no significant difference between mean levels of awe and happiness after the awe video \((Z = 104.00, p = .06)\).
Baseline and Dispositional Awe. Additionally, Spearman’s rho correlations were calculated between levels of baseline awe and HR at each time of measurement and dispositional awe and HR at each time of measurement. There were significant correlations between baseline state awe and average HR immediately before the neutral video ($\rho = -.48, p = .02$), during the neutral video ($\rho = -.46, p = .02$), immediately following the neutral video ($\rho = -.48, p = .02$), during the three-minute rest period following the neutral video ($\rho = -.47, p = .02$), following the three-minute rest period after the neutral video ($\rho = -.54, p = .01$). Baseline state awe was also significantly correlated with average HR during the second baseline period ($\rho = -.56, p = .01$), immediately before the awe video ($\rho = -.60, p = .01$), during the awe video ($\rho = -.59, p = .01$), immediately following the awe video ($\rho = -.53, p = .01$), and following the three-minute rest period after the awe video ($\rho = -.49, p = .02$).

There were no significant correlations between dispositional awe and average HR at any time of measurement. We note that some rho coefficients exceeded the absolute value of .30 but failed to reach statistical significance, given our small sample size. Specifically, these notable correlations are between dispositional awe and average HR immediately before the neutral video ($\rho = -.31, p = .10$), during the neutral video ($\rho = -.34, p = .07$), immediately following the neutral video ($\rho = -.34, p = .07$) and following the three-minute rest period after the neutral video ($\rho = -.37, p = .052$). Notable, but not significant correlations, were also found between dispositional awe and average HR immediately before the awe video ($\rho = -.35, p = .07$), and immediately following the awe video ($\rho = -.33, p = .08$). Spearman’s rho correlations between all measures of awe and intervals of HR are provided in Table 4 of Appendix G.

Age Differences in Awe and HR (Hypothesis 2)
Awe. We hypothesized that self-reported levels of awe following the awe video would be higher in late mid-life adults than in early mid-life adults. To examine age differences within the mid-life sample, we used Mann-Whitney U Tests. Mann-Whitney U Tests are similar to the parametric independent samples t-test but use data ranks rather than absolute mean values. Multiple independent-samples Mann-Whitney U Tests were conducted to assess whether there were significant differences between age groups in self-reported dispositional or baseline awe or awe following each video. These tests revealed no significant age differences in dispositional awe ($U = 74.50, p = .06$), baseline awe ($U = 64.00, p = .30$), awe following the neutral video ($U = 62.00, p = .37$), or awe following the awe video ($U = 63.50, p = .30$). For full details of analyses see Table 5 of Appendix H.

We then decided to assess how self-reported awe differed as a function of age, treating age as a continuous rather than dichotomous variable. We ran Spearman’s rho correlations between age and dispositional awe, baseline awe, and self-reported awe following both the neutral and awe video. There were significant correlations between age and dispositional awe ($\rho = .44, p = .03$), baseline awe ($\rho = .39, p = .05$), awe immediately following the neutral video ($\rho = .48, p = .02$), and awe immediately following the awe video ($\rho = .41, p = .04$).

HR. Multiple independent-samples Mann-Whitney U Tests were conducted to assess whether there were significant differences between age groups in levels of average HR during rest, during, or following each video. These tests revealed no significant age differences in HR during the first 5 minute rest period ($U = 34.00, p = .26$), during the neutral video ($U = 29.00, p = .13$), following the neutral video ($U = 31.00, p = .18$), the second 5 minute rest period ($U = 30.00, p = .15$), during the awe video ($U = 27.00, p = .10$), and following the awe video ($U = 31.00, p = .18$). For full details of analyses see Table 6 of Appendix H.
We then decided to assess how average HR differed as a function of age, treating age as a continuous rather than dichotomous variable. We ran Spearman’s rho correlations between age and HR during the initial five-minute rest period, during the neutral video, immediately following the neutral video, during the second five-minute rest period, during the awe video, and immediately following the awe video. The correlation between age and HR during the first rest period was not significant ($\rho = -.35, p = .07$). There were significant correlations between age and HR during the neutral video ($\rho = -.42, p = .03$), following the neutral video ($\rho = -.43, p = .03$), during the second rest period ($\rho = -.41, p = .04$), during the awe video ($\rho = -.46, p = .02$), and following the awe video ($\rho = -.43, p = .03$).
Discussion

We know that positive emotions and physical health influence one another such that more frequent positive emotions are associated with a lower risk of illnesses (Cohen et al., 2003). However, much of the work examining the interactions between positivity and health has focused on positive affect rather than specific positive emotions (Pressman & Cohen, 2005). Fredrickson (1998) argues that positive emotions can help build physical, intellectual, and social resources. We know that positive emotions can "undo" the cardiovascular effects of negative emotions, which are associated with an increased risk of heart disease (Blascovich & Katkin, 1993). We also know that different emotions have distinct influences on cardiovascular activity (Jang et al., 2015).

Awe, one such positive emotion, operates uniquely in that it is also described as a "self-transcendent experience" (Yaden et al., 2017). Awe elicits experiences of perceived vastness of the world around oneself and the need to accommodate existing schemas to account for such vastness (Keltner & Haidt, 2003). Inducing awe is associated with lengthened pre-ejection periods and increased respiration, indicating greater parasympathetic nervous system activity (Shiota et al., 2011). To our knowledge, however, no work has yet examined how physiological markers, specifically HR, correlate with self-reported measures of awe. Preliminary work suggests age differences in awe, such that as individuals age, they are more likely to experience awe (Ebert, 2021). However, how awe operates in middle-adulthood, a significant transitional period, is understudied and requires more attention.

As adults age, both their autonomic activity and emotional preferences change. Individuals tend to show less cardiovascular reactivity in response to emotional stimuli as they get older (Blanchard-Fields, 2007). Such decreased levels of HR change may provide additional
evidence that older adults are more successful in regulating their emotions (Charles & Carstensen, 2014). Older adults are more likely to subjectively report positive emotions, referred to as the "positivity effect," and can influence how they recall information (Mather & Carstensen, 2003). However, work investigating age differences in emotions often does not closely examine midlife (e.g., Charles & Carstensen, 2008). HR tends to decrease with age (Antelmi et al., 2004; Umetani et al., 1998) and is lower in women (Koenig & Thayer, 2016).

The present study was interested in further understanding how positive emotions, specifically awe, influence physiological activity in a middle-aged sample. We were looking to build on the field's limited knowledge of awe in a non-college sample. Experiencing awe can offer a variety of benefits, such as enhanced feelings of generosity (Piff et al., 2015), improved well-being (Gordon et al., 2017), increased humility (Stellar et al., 2018), and openness to new ideas (Danvers & Shiota, 2017). Much of the current work examining awe has either used samples of younger adults or has not examined how age might influence awe. Studying awe in a middle-aged sample allows researchers to understand further how this unique positive emotion manifests itself at various points throughout the lifespan, which improves the likelihood of adults of all ages reaping the benefits.

Additionally, both lower resting HR and lower cardiovascular reactivity are associated with improved health outcomes, such as a reduced risk of hypertension and coronary heart disease and longevity (Levine, 1997; Manuck, 1994; Whittaker et al., 2021). Given that there is evidence of successful awe interventions (Sturm et al., 2020), if awe is linked to specific cardiovascular activity, that is one avenue that might help promote improved cardiovascular health. Suppose researchers can induce feelings of awe both in the context of lab studies and in naturalistic settings. In that case, understanding how this emotion is linked to heart rate might
provide initial evidence to allow the use of awe to improve cardiovascular activity, which has positive implications for individuals' health.

**Associations of Awe and HR**

The first hypothesis of our study predicted that there would be an association between subjective reports of awe and HR. This hypothesis was supported such that higher levels of self-reported awe following the awe-inducing video were associated with lower levels of average HR during the awe-inducing video. Additionally, average HR was lower during the awe video than in the neutral video.

Pilot testing done with both the neutral and awe video suggested that the awe video would elicit significantly higher levels of self-reported awe. This was confirmed in the present study with a significant difference in self-reported awe following each video. The average level of awe was about 18 points higher than that following the neutral video. Given that the present study was conducted remotely over a video conferencing platform, it was reassuring that the materials used to induce discrete emotions were still successful, especially with a small sample size. Additionally, levels of self-reported awe were significantly higher following the awe-inducing video than their levels of awe at the beginning of the study. This suggests that the awe-inducing video elicited a higher level of awe than the neutral video. Still, it also successfully induced a state of awe higher than the participant’s entry level awe.

Average HR was significantly lower while watching the awe video than while watching the neutral video and during the five-minute rest period before the awe video. Average HR was also significantly lower while watching the awe video than the five-minute rest period between the neutral and awe video. Additionally, there was a significant decrease in average HR from the time immediately before watching the awe video to the time the participant watched the awe
video, along with a significant increase in average HR from the time spent watching the awe video to the time following the video.

We do note that a similar pattern of average HR was found for the neutral video, with a significant decrease in average HR followed by a significant increase. This suggests that it may be the act of watching a video, not interacting with researchers, and not having to listen to directions that may contribute to some of the decreases in HR. Additionally, it is known that activities that require attentive observation of one’s environment (i.e. watching a video) are associated with a decrease in HR (Libby et al., 1973). Given that the awe and neutral video were not counterbalanced, it is difficult to tell whether it was in fact the experience of awe that contributed to a lower HR or the fact that the awe video came second.

After controlling for baseline awe, we found that the associations between self-reported awe and HR after the awe video were no longer significant. We do note that we did conduct partial Pearson’s correlations as we are unable to conduct partial Spearman’s rho correlations. Given the small sample size, Spearman’s rho correlations were used in the initial correlation analyses. However, given these Pearson’s correlations were not significant once controlling for baseline awe, it may be the case that the amount of awe and individual was experiencing at the beginning of the study impacted how they responded to the awe video. More work should be done with larger sample sizes, normally distributed data sets, and parametric analyses to tease out the effect of baseline awe.

Previous work has found that the experience of awe is associated with a lengthened pre-ejection period (PEP), which suggests an increased influence of the parasympathetic nervous system as opposed to the sympathetic (Shiota et al., 2011). However, this same study found that awe increased respiration rate, which suggests an increased role of the sympathetic as opposed to
the parasympathetic nervous system. Reduced HR levels are associated with an increase in the activity of the parasympathetic nervous system and a decrease in the activity of the sympathetic nervous system (Gordan et al., 2015; Glick et al., 1965). The decreased HR associated with the experience of awe in the present study suggests that awe might activate the parasympathetic nervous system (Shiota et al., 2011). However, more work is needed to assess how exactly the autonomic nervous system is responding to awe and whether different metrics of autonomic activity respond differently to awe.

In addition to understanding how self-reported awe was associated with HR, we were interested in whether that association was distinct from other emotions. Some literature suggests that awe is a distinct positive emotion. It leads to an experience of self-transcendence (Yaden et al., 2017) and encourages us to process new information about our environment (Allen, 2018; Shiota et al., 2007). Our data found that there was not a significant difference between happiness and awe following the awe induction. We also found that happiness was correlated with reduced HR, similarly to awe. This might suggest a high level of overlap between the experiences of awe and happiness. Given that Fredrickson does not distinguish between the impacts of positive emotions in her initial broaden and build theory (Fredrickson, 2013), it may be the case that some positive emotions overlap in their physiological effects. Future work might disentangle the specific elements of awe that are distinct from happiness.

State vs. Trait Awe

Our findings suggest that the type of awe examined (state versus trait) might differentially impact HR. Higher baseline levels of awe predicted lower HR levels throughout the study, except for the first five-minute rest period and the 3-minute recovery period following the awe video. This suggests that those who entered the study experiencing higher levels of awe
before participating in the protocol have lower HR levels. Interestingly, levels of dispositional awe were not associated with average HR levels at any point in the study. This might indicate that the awe an individual is feeling in a given moment or on a given day is more predictive of their physiological activity, specifically their average HR, rather than their trait-level awe. This has implications for intervention work. Studies interested in promoting lower cardiovascular reactivity or average HR through awe may want to focus their efforts on more frequent state-like experiences rather than increasing levels of dispositional awe. Future studies interested in such intervention work should explore how exactly both dispositional and state-like awe are distinctly associated with more consistent cardiovascular measures, such as resting HR.

Previous work has found that both state and trait levels of awe are associated with lower stress levels, inducing a state-like feeling of awe is associated with lower sympathetic arousal when stressed (Bai et al., 2021). There is also evidence distinct types of awe (threat-based versus positive) elicit distinct amounts of sympathetic reactivity (Gordon et al., 2017). Therefore, the finding that state and trait-based awe do not have the same predictive value of average HR throughout the protocol furthers our understanding of distinct types of awe.

**Duration of Awe**

To understand how awe might influence HR and how those associations might inform health promotion, researchers must also understand the amount of awe necessary to impact HR and how long that impact lasts. We did not find a significant association between self-reported awe immediately following the awe video and average HR while providing that self-report measure (average HR immediately following the awe video). It may be the case that the period during which awe impacts physiological measures, such as HR, is limited. During the awe video, HR decreased significantly from baseline but returned to a near-baseline level once the video
was over, suggesting the impacts of awe on HR are short-lived. Levels of self-reported awe did increase significantly from baseline following the awe-inducing video and did decrease three minutes later. The decrease here was not back down to baseline, as was the case with average HR.

Additionally, while there was a significant difference in HR while watching each video, the effect of the awe video on HR was no longer present in the period immediately following each video. There was no longer a significant difference in HR between the neutral and awe video immediately following the videos. However, there was a significant difference in self-reported awe immediately following the video. With the limited data from the present study, it may be the case that awe-induction influences individuals' subjective reports of awe and their immediate average HR. Thus, the effect of awe-inductions on HR may be indirect through self-reported awe. Future studies similar to the present study, with increased sample size, should be conducted to disentangle the relations among awe induction, self-reported awe, and average HR. Additional work could be done to assess whether longer exposures of awe or how many short-term exposures are necessary for a longer duration of state-like awe.

**Age Differences**

The present study was also interested in examining how the association between self-reported awe and HR differed as a function of age. Given the age differences in physiological reactivity to emotional stimuli (Labouvie-Vief et al., 2003; Tsai et al., 2000), it was expected that early mid-life adults might experience awe differently than late mid-life adults. We designed our between-groups study to assess age differences in two groups of middle-age adults. When we examined age differences with age as a dichotomous variable, we did not find any significant age differences in self-reports of awe at baseline, immediately following the neutral video, or
immediately following the awe video. There were also no age differences in dispositional awe. However, when we treated age as a continuous variable, we did find significant positive correlations between age and dispositional awe, baseline awe, and awe following both the neutral and awe videos. Levels of awe were higher in older participants. This is consistent with previous work suggesting that older adults are more likely to experience positive emotions (Mroczek & Kolarz, 1998) and awe specifically (Ebert et al., 2020)

When comparing average HR between early and later mid-life adults, we did not find significant age differences in in the five-minute rest periods during the neutral and awe video or immediately following both the neutral and awe video. However, when we ran correlations between average HR and age, with age as a continuous variable, age did play a role in average HR. There were significant inverse correlations between age and average HR during both the neutral and awe videos, immediately following both videos, and during the second five-minute rest period. Average HR was lower in older participants. HR does tend to decrease slightly with age (Umetani et al., 1998) so these findings are consistent with previous literature.

Despite that we could not detect age differences when comparing between groups, we were able to see that when treated as a continuous variable, age does influence both awe and HR. We also better understood better the ways awe impacts HR in a midlife sample. Much of the work examining awe has used a college-aged sample, and studies about emotional aging have compared younger and older adult groups only (i.e., Carstensen et al., 2003), so there was a need to understand these constructs in middle-aged adults. The present study detected an association between awe and HR in a middle-aged sample. This contributes to our understanding of the interactions between positive emotions and health in an understudied but important transitional age group.
Implications for Health Promotion

These findings may also provide promising implications for health promotion. Awe is an emotion that can be elicited by various stimuli such as nature scenes, spiritual or religious experiences, or viewing images of space (Allen, 2018). For most individuals, experiences of nature are easily accessible, and our findings suggest that even viewing images of space on a computer can elicit feelings of awe. Therefore, individuals might be able to experience awe regularly without many barriers. This suggests that the use of awe as an intervention to influence cardiovascular activity and potentially improve health outcomes may be accessible for many and may be an avenue for health promotion that requires few resources.

Such interventions might incorporate elements of mindfulness and meditation. A large body of literature links meditation to physical health and cardiovascular health (Kok et al., 2013b). Meditation is associated with lower heart rate levels (Jevning et al., 1992) and lower blood pressure (Ospina et al., 2007). Additionally, mindfulness meditation is associated with better emotion regulation and decreased emotional reactivity to negative stimuli (Davis & Hayes, 2011). Meditation was cited as a spiritual experience that induced feelings of awe and the “small self” (Preston & Shin, 2017), suggesting an overlap in the experiences of awe, meditation, and mindfulness. Given that both meditation and the experience of awe are associated with lower HR levels and that the two have been experienced simultaneously (Preston & Shin, 2017), future studies might examine precisely how the two are related. Awe might partially explain some of the physiological benefits of meditation, or it may be the case that incorporating awe induction into meditation may offer additional benefits.

These findings provide a better understanding of the overlap between objective and subjective markers of health and well-being. We now know that self-reported measures of awe
are associated with patterns of lower HR. Work looking at self-rated health suggests that individuals have a good sense of the current state of their body and provide reliable ratings of their own health and quality of life (Jylhä, 2009). Even though self-reported measures of awe are not measures of physical health, their correlation with the objective measure of HR suggests that they might provide some insight into one's current physical state. Future work examining how awe influences cardiovascular reactivity can provide more insight into how awe-related interventions might promote health. The insight into the subjective and objective measures of awe that the present study provides allows for a more holistic understanding of the impact of positive emotions.

**Limitations and Future Directions**

The small sample size (N = 20) is one main limitation of the present study. The present study does offer some initial evidence for the association between awe and HR, and the use of non-parametric analyses does provide some sound statistical backing for the conclusions discussed. Future studies can build off these findings with larger and more diverse sample size. An increased sample size may also highlight age differences that we could not detect in the present study. These future studies might also use more advanced statistical models that are possible with increased power. Additionally, future studies might detect gender differences in awe and HR by comparing across genders. Given that the present study included only women participants, we can only apply conclusions to women.

When designing the study, we opted to have each participant watch the neutral video first followed by the awe video. This was done to allow participants to “practice” the study protocol of wearing the HR monitor and provide self-reported awe before watching the awe video. However, this lack of counterbalancing does not allow us to eliminate order effects. We cannot
conclude whether it is the awe video leading to lower levels of HR or the fact that participants were more acclimated to the study conditions and therefore experiencing lower autonomic arousal. Future studies should counterbalance awe and neutral conditions across participants.

While the use of average HR as a variable of interest does provide some insight into cardiovascular activity, understanding how awe is associated with different heart rate variability metrics is ideal. Average HR was only one outcome variable initially proposed. Additional studies in our lab are currently exploring how high and low-frequency HRV, root mean square of successive differences R-R intervals (RMSSD), and respiratory sinus arrhythmia (RSA) are associated with self-reported measures of awe. These additional outcome variables may also highlight age differences that are not present in average HR alone. The Kubios software will also allow us to calculate heart rate recovery, highlighting additional physiological responses to awe.

Conclusions

Despite the limited sample size and physiological outcome variables, the present study provides initial evidence of an association between self-reported awe and average HR. Additionally, while the limited sample size does not allow us to make conclusions regarding age differences, the use of a middle-aged female sample allows for an understanding of how awe exists in a more age-diverse sample than is typical of previous awe studies. The present study also provides insight into which type of awe (state versus trait) may predict physiological activity, which can help inform intervention work. It also paves the way for future studies to discover the mechanisms through which awe inductions, self-reports of awe, and HR influence one another, along with understanding the dosage of awe necessary to impact physiology.

Given that awe is associated with increased levels of connectedness (Krause & Hayward, 2015), positive mood (Joye & Bolderdijk, 2015), and greater well-being (Gordon et al., 2017),
understanding its physiological correlates is essential. Positive emotions can be used as a mechanism to promote health, so understanding exactly how the body reacts to specific emotions can improve the efficacy of relevant health interventions. Additionally, using positive emotions, which individuals tend to experience more often as they age, to promote health in middle and older adults may be especially effective later in the lifespan. Therefore, understanding how the body reacts and how this reaction might look different as people age has informed our understanding of both awe and health across the lifespan.
AWE AND HEART RATE VARIABILITY

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Appendix A. Study Protocol

Instructions for the researcher are found within brackets and a script for the researcher is in quotation marks.

“Thank you for your help with this project. In this study, we will ask you a variety of questions about how you feel in general, as well as thoughts and feelings that you have during the study. We will ask you to view several immersive videos using the screen share option. Before we begin, let's make sure you have all of the necessary items. Do you have 1) your Polar heart rate monitor 2) a wet wipe or moist paper towel, 3) your smart phone 4) the two rating scales that were mailed to you 5) a copy of the informed consent form that was mailed to you? Great, let's get started.”

Enter ID number here: Interviewer's Initials_next_number (e.g., LEB_001)

“Please pull out the informed consent form that you were mailed. You may keep one copy and will sign and mail back the other. I am going to review the consent form with you now.” [Walk them through the consent form, have them sign it, and put it in the pre-stamped envelope and ask them to put it in the mail to send back to us]

“Great, thank you. Do you have your Polar heart rate monitor with you? Ok, now I am going to ask you to download the Polar Beat app from the App Store on your smartphone. It is a free app available from the Apple or Google Play store.”

“Okay, now you are going to sign in with the following username and password.” [Provide them with the username and password unique to that participant]

“On the screen, you should see an option labeled ‘Connect My Sensor’. Click on that option. Your heart rate monitor should already be paired to your account. Can you confirm that there is an image of a heart rate monitor on your phone?”

“The following questions ask about how often or how strongly you feel certain ways. Using response card #1 please answer how much you agree or disagree with each question.”

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<th>I often feel awe. Would you say that you:</th>
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I feel wonder almost every day. Would you say that you:

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I often look for patterns in the objects around me. Would you say that you:

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I have many opportunities to see the beauty of nature. Would you say that you:

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I seek out experiences that challenge my understanding of the world. Would you say that you:

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[ask participant to pull out response card #2]

“Thank you for answering those items. In this study, you will be asked to watch a few brief videos. After each video, I will ask you to rate how much you are feeling different ways on a scale from ZERO to 100. Let's practice that now”

Baseline Measures. “On a scale of 0 to 100%, please tell me how _____ you are feeling right now:”

|                | 0 | 5 | 10 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|----------------|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Happy          |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Aroused        |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| In Awe         |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Excited        |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Dominant       |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Relaxed        |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
“Great. Now that we have practiced using the response scale, I am going to show you how we will measure your body's reaction to the different videos you will see. The Polar heart rate monitor fits around your ribs with this elastic belt. Please moisten the back of the black plastic portion of the belt and then I will ask you to reach under your shirt and position the belt. Please be sure to fit it snugly around your upper ribs, with the monitor in the center and front. Great, now click on the + (plus) button on the bottom of your screen. Now, click on the "Open HRV Reading". I am going to ask you a few questions before we begin collecting heart rate data. Can you show me your phone screen so I can ensure the app is collecting your heart rate data? [Have them show you their screen]. Okay, now we will sit for 5 minutes while a baseline is being established.

[Wait 5 minutes while a baseline is being established. You can time this yourself using your phone/your own stopwatch.]

“Okay, now I am going to ask you some more questions about how you are feeling. We will ask you before, immediately after, and 3 minutes following both videos that you watch.”

“Can you tell me approximately what time is displayed on the Polar app?” [Enter the time here]

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V1 Pre. “On a scale of 0 to 100%, please tell me how ____ you are feeling right now:”

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“Okay, now I will pull up the first video and share my screen with you.”
[Open https://www.youtube.com/watch?v=HXJx8j7JpKY and share your screen and have them watch the video. Be sure the sound is muted]

“Can you please tell me approximately what time is displayed on the Polar app?” [Enter the time here]
“I am going to ask you again how you are feeling.”

Video 1 Post: “On a scale of 0 to 100%, please tell me how ____ you are feeling right now:”

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“Okay, now we will have a 3 minute rest period and then I will ask you how you are feeling again.” [Wait 3 minutes]

“Can you please tell me approximately what time is displayed on your Polar phone app?” [Enter time here]

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Video 1 Post 2 “On a scale of 0 to 100%, please tell me how ____ you are feeling right now:”

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</table>
AWE AND HEART RATE VARIABILITY

Relaxed

“In a few words, can you describe what was in the video you just watched:”

___________________________

“Great, thank you. Now we will have another 5 minute rest period.”

“Can you please tell me approximately what time is displayed on the Polar app?” [Enter time here]

___________________________

“I am going to ask you some more questions about how you are feeling.”

Video 2 Pre: “On a scale of 0 to 100%, please tell me how ____ you are feeling right now:”

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“Okay, now I will pull up the second video and share my screen with you.”
[Open https://www.youtube.com/watch?v=FG0fTKAqZ5g and share your screen and have them watch the video. Be sure the sound is muted. Once video is over, stop sharing]

“Can you please tell me approximately what time is displayed on the Polar app?” [Enter the time here]

___________________________
“I am going to ask you again how you are feeling.”

Video 2 Post 1. “On a scale of 0 to 100%, please tell me how ____ you are feeling right now:”

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“In a few words, can you describe what was in the video you just watched?”

______________________________

“Okay, now we will have a 3 minute rest period and then I will ask you how you are feeling again.” [Wait 3 minutes]

“Can you please tell me approximately what time is displayed on your Polar phone app?” [Enter time here]

______________________________

Video 2 Post 2. “On a scale of 0 to 100%, please tell me how ____ you are feeling right now:”

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“Please press the red pause button at the bottom of your phone screen. Now press stop and then "Done" in the top left corner. I am going to check to ensure that the data has been uploaded.”
[Log in at flow.polar.com using their username and password. You should see a running icon on the current date in the calendar.]

“You may take off the heart rate monitor.”

“I am going to finish by asking you some questions about yourself.”

“Do you consider yourself to be Hispanic?”
  o Yes
  o No

“With which ONE racial group do you most identify or which do you consider yourself to be:”
  o White
  o Black or African American
  o Asian/East Asian
  o Native Hawaiian or other Pacific Islander
  o American Indian or Alaska Native
  o Other

“How much difficulty do you have meeting your bills, would you say:”
  o None, at all
  o A little
  o Some
  o A great deal

“How spiritual are you? Would you say:”
  o Not at all
  o Slightly
  o Somewhat
o Very
o Extremely

“[In terms of gender identity are you:]”
  o Female/woman
  o Male/man
  o Gender non-binary

“The study is now complete. Thank you! I appreciate your help.”
Appendix B. Data Analysis Adjustment

The proposed plan for the present study was to analyze metrics of HRV using the *Kubios* software. We had proposed to use the *Polar Beat* smartphone application to collect continuous HR data and transfer that data to Kubios to calculate HRV. At the beginning of the data collection process, I reached out to the graduate student recommended by Dr. Larkin to ask which software was used to convert data from *Polar* to *Kubios*. She explained that she used a different application than *Polar Beat* that was able to convert the data to a .txt file, which is what was necessary to upload to *Kubios*. Given that we already had an application (*Polar Beat*) that was used in our lab previously and was able to convert data to a .txt file, we figured that this was difference in preference. However, in retrospect, it seems the *Polar Beat* application is the issue (which likely is due to a recent update associated with the newer H10 Polar monitors).

Once the data collection process was complete, I met with this graduate student to get training for analyzing heart rate data in the *Kubios* software. I was working through analyzing my data and noticed that the total length of session time in *Kubios* was not matching up with the actual length of the session (for example, the length of a particular session was showing up as 33 minutes on the Polar website, but once it was uploaded it to *Kubios* it was only displaying as 28 minutes long).

I reached out to this graduate student again, but she was not familiar with the issue. I reached out to the *Kubios* support team and they informed me that the *Polar Beat* app, which is what was used to collect HR data only collects R-R interval data, which cannot be used for HRV analysis. It instead only provides average HR per second. They informed me that I must use a Polar watch to assist in data collection to get the proper type of data. I also reached out to the Polar support team to see if there was any way to retroactively run previously collected data.
through a watch or similar device, but they informed me I wasn’t able to. Unfortunately, this meant that the 20 sessions of data would not be able to be analyzed for HRV. Given that the protocol of the present study (using the *Polar Beat* app) was modeled after previous protocols from our lab, we realized that this incompatibility between the *Polar Beat* app and the Polar heart rate monitor must be a feature of the new H10 Polar heart rate monitor that we purchased, as this was not an issue in the past.

Unfortunately, we were not able to calculate the following variables as originally proposed: root mean square of successive differences R-R intervals (RMSSD), low-frequency HRV (LF HRV), high-frequency HRV (HF HRV), respiratory sinus arrhythmia (RSA) or ECG derived respiratory frequency (EDR). Our lab plans to continue collecting data to calculate these measures of HRV in the future.
Appendix C. Heart Rate Variability Literature

HRV is an objective measure of physical health mediated by the autonomic nervous system (ANS) and is defined by variation in heart rhythm. The parasympathetic branch of the ANS influences HRV through the vagus nerve (Dexter et al., 1992). HRV is a measure of health in that it assesses neurocardiac function and the regulatory activity of the autonomic nervous system (McCraty & Shaffer, 2015). Additionally, HRV is a measure of the cardiovascular system’s response to environmental stimuli in that it indexes the body’s ability to return to homeostasis following cardiovascular reactivity (Krygier et al., 2013; McCraty & Shaffer, 2015; Shaffer & Ginsberg, 2017; Thayer & Friedman, 2002). Individuals tend to have higher levels of HRV while completing tasks that require high, as opposed to low, levels of self-regulatory effort, which suggests that HRV is an index of self-regulation (Segerstrom & Nes, 2007).

Not only does HRV give insight into individuals’ physical health, there are pronounced age differences. While levels of HRV tend to decline with age (Umetani et al., 1998; Zulfiquar, et al., 2010), there are increases in the HRV-parasympathetic function in the later years of life. Time domain measures of the parasympathetic function of HRV, levels of the root mean square of the successive normal sinus RR interval difference (rMSSD) and percentage of successive normal sinus RR interval > 50ms (pNN50), tend to show increases in the eighth decade of life, which is consistent of HRV patterns in younger individuals. These increases indicate a positive association between levels of HRV and longevity (Zulfiquar, Jurivich, Gao, & Singer, 2010). Data from four years of The Framingham Heart Study indicated that older adults (mean age = 72.0) with significant decreases in low-frequency power of HRV were at higher risk of all-cause mortality (Tsuji et al., 1994). HRV can be used as a measure of overall health and well-being, but may also highlight age differences in the reaction to emotional stimuli.
Heart Rate Variability (HRV). We planned to calculate multiple measures of HRV and reduce artifacts using Kubios HRV Premium software (Version 3.4; Niskanen et al., 2004). We planned to calculate the root mean square of successive differences R-R intervals (RMSSD), low-frequency HRV (LF HRV), high-frequency HRV (HF HRV), Respiratory Sinus Arrhythmia (RSA), and ECG derived respiratory frequency (EDR). RMSSD provides a time-domain measurement of short-term variability in HR (Niskanen et al., 2004). LF-HRV falls between .04 and .15 Hz and is influenced by activity from the sympathetic and parasympathetic nervous systems (Berntson et al., 1997; Niskanen et al., 2004; Shaffer & Ginsberg, 2017). HF-HRV between .15 and .40 Hz and is influenced by the activity of the parasympathetic nervous system (Berntson et al., 1997; Niskanen et al., 2004; Shaffer & Ginsberg, 2017). HF HRV is composed of the Respiratory Sinus Arrhythmia (RSA), which is how respiration influences HRV (Shaffer & Ginsberg, 2017). EDR is a measure of respiration (Niskanen et al., 2004), which is an indicator of focused attention (Lutz et al., 2008).
Appendix D. Timeline Figure

Figure 1. Timeline depicting order of study protocol including points that self-reported awe (SR awe) is provided, five-minute rest periods (Rest 1 and 2) and videos 1 (neutral) and 2 (awe) are shown to participants (line 1; bold). The seven awe times of measurement are indicated (line 2) along with the twelve intervals of average HR (line 3).
Appendix E. Demographic Information

Table 1. Demographic Characteristics of the Sample

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<td>45</td>
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<td>Older Middle-Aged Adults (50-70)</td>
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<td>Asian or East Asian</td>
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<td>A great deal</td>
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Appendix F. Descriptive Statistics

Table 2. Descriptive Statistics of self-reported awe (dispositional and state-level).

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<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<th>Max.</th>
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<td>Awe_V1_T1</td>
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<td>44.25</td>
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<td>32.62</td>
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<td>34.43</td>
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Table 3. Descriptive statistics of average HR (bpm)

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<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
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<td>11.94</td>
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<td>104.98</td>
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<td>55.41</td>
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<td>71.99</td>
<td>12.14</td>
<td>51.61</td>
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<tr>
<td>HR_V2_T2</td>
<td>20</td>
<td>68.83</td>
<td>12.00</td>
<td>49.92</td>
<td>100.83</td>
</tr>
<tr>
<td>HR_V2_T3</td>
<td>20</td>
<td>71.66</td>
<td>12.10</td>
<td>53.34</td>
<td>104.69</td>
</tr>
<tr>
<td>HR_V2_T4</td>
<td>20</td>
<td>69.76</td>
<td>11.27</td>
<td>53.02</td>
<td>102.38</td>
</tr>
<tr>
<td>HR_V2_T5</td>
<td>20</td>
<td>71.15</td>
<td>12.19</td>
<td>51.63</td>
<td>106.19</td>
</tr>
</tbody>
</table>

1 We do note one individual with a HR consistently over 100 bpm. While not an outlier, we did re-run our analyses excluding this participant. When excluded, our analyses did not differ greatly. Some correlation coefficients decreased in magnitude, but we attributed this to a lower sample size (given the already small sample size in the study).
### Appendix G. Hypothesis 1 Analyses

Table 4. Summary Table for Spearman’s Rho Correlations and Significance Levels Between Each Measure of Awe (Horizontal Axis) and All Measures of Average HR (Vertical Axis)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dispositional Awe</th>
<th>Baseline Awe</th>
<th>V1 T1</th>
<th>V1 T2</th>
<th>V1 T3</th>
<th>V2 T1</th>
<th>V2 T2</th>
<th>V2 T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR_Rest 1</td>
<td>-.25(.14)</td>
<td>-.35(.06)</td>
<td>-.39*.(05)</td>
<td>-.19.(21)</td>
<td>-.14(28)</td>
<td>-.16.(25)</td>
<td>-.25.(15)</td>
<td>-.24.(16)</td>
</tr>
<tr>
<td>HR_V1 T1</td>
<td>-.31(.10)</td>
<td>-.48*.(02)</td>
<td>-.56**(.01)</td>
<td>-.34(.06)</td>
<td>-.34(.07)</td>
<td>-.37(.06)</td>
<td>-.33(.08)</td>
<td>-.37(.06)</td>
</tr>
<tr>
<td>HR_V1 T2</td>
<td>-.34(.07)</td>
<td>-.46*.(02)</td>
<td>-.50*.(01)</td>
<td>-.29(.11)</td>
<td>-.27(.13)</td>
<td>-.29(.10)</td>
<td>-.34(.07)</td>
<td>-.37(.06)</td>
</tr>
<tr>
<td>HR_V1 T3</td>
<td>-.34(.07)</td>
<td>-.48*.(02)</td>
<td>-.54**(.01)</td>
<td>-.31(.09)</td>
<td>-.30(.10)</td>
<td>-.33(.08)</td>
<td>-.40*.(04)</td>
<td>-.40*.(04)</td>
</tr>
<tr>
<td>HR_V1 T4</td>
<td>-.28(.11)</td>
<td>-.47*.(02)</td>
<td>-.54**(.01)</td>
<td>-.31(.09)</td>
<td>-.31(.10)</td>
<td>-.33(.08)</td>
<td>-.29(.11)</td>
<td>-.35(.07)</td>
</tr>
<tr>
<td>HR_V1 T5</td>
<td>-.37(.05)</td>
<td>-.54**(.01)</td>
<td>-.62**(.01)</td>
<td>-.44*.(03)</td>
<td>-.40*.(04)</td>
<td>-.42*.(03)</td>
<td>-.45*.(02)</td>
<td>-.47*.(02)</td>
</tr>
<tr>
<td>HR_Rest 2</td>
<td>-.26(.14)</td>
<td>-.56**(.01)</td>
<td>-.59**(.01)</td>
<td>-.33(.08)</td>
<td>-.32(.08)</td>
<td>-.34(.07)</td>
<td>-.24(.15)</td>
<td>-.30(.10)</td>
</tr>
<tr>
<td>HR_V2 T1</td>
<td>-.35(.07)</td>
<td>-.60**(.01)</td>
<td>-.63**(.01)</td>
<td>-.47*.(02)</td>
<td>-.43*.(03)</td>
<td>-.46*.(02)</td>
<td>-.46*.(02)</td>
<td>-.48*.(02)</td>
</tr>
<tr>
<td>HR_V2 T2</td>
<td>-.33(.08)</td>
<td>-.59**(.01)</td>
<td>-.64**(.01)</td>
<td>-.46*.(02)</td>
<td>-.43*.(03)</td>
<td>-.45*.(02)</td>
<td>-.45*.(02)</td>
<td>-.49*.(02)</td>
</tr>
<tr>
<td>HR_V2 T3</td>
<td>-.23(.16)</td>
<td>-.53**(.01)</td>
<td>-.56**(.01)</td>
<td>-.37(.06)</td>
<td>-.35(.07)</td>
<td>-.37(.06)</td>
<td>-.28(.12)</td>
<td>-.35(.07)</td>
</tr>
<tr>
<td>HR_V2 T4</td>
<td>-.13(.30)</td>
<td>-.40*.(04)</td>
<td>-.47*.(02)</td>
<td>-.31(.09)</td>
<td>-.24(.15)</td>
<td>-.24(.16)</td>
<td>-.20(.19)</td>
<td>-.22(.17)</td>
</tr>
<tr>
<td>HR_V2 T5</td>
<td>-.24(.16)</td>
<td>-.49*.(02)</td>
<td>-.55**(.01)</td>
<td>-.36(.06)</td>
<td>-.34(.07)</td>
<td>-.37(.05)</td>
<td>-.31(.09)</td>
<td>-.38*.(05)</td>
</tr>
</tbody>
</table>

*Note. Values indicate Spearman’s rho correlations with significance levels within parentheses.

* indicates $p \leq .05$ (one-tailed). ** indicates $p \leq .01$ (one-tailed)
Appendix H. Hypothesis 2 Analyses

Table 5. Summary Table for Independent-Samples Mann-Whitney U Test Comparing Awe Scores Between Age Groups; Group 1 = Early Mid-Life Group 2 = Late Mid-Life

<table>
<thead>
<tr>
<th>Variable</th>
<th>X₁</th>
<th>X₂</th>
<th>n₁</th>
<th>n₂</th>
<th>U</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispositional awe</td>
<td>5.72</td>
<td>6.17</td>
<td>9</td>
<td>11</td>
<td>74.50</td>
<td>.06</td>
</tr>
<tr>
<td>Baseline awe</td>
<td>35.56</td>
<td>51.36</td>
<td>9</td>
<td>11</td>
<td>64.00</td>
<td>.30</td>
</tr>
<tr>
<td>Awe_V1_T2</td>
<td>38.89</td>
<td>48.64</td>
<td>9</td>
<td>11</td>
<td>62.00</td>
<td>.37</td>
</tr>
<tr>
<td>Awe_V2_T2</td>
<td>56.11</td>
<td>66.82</td>
<td>9</td>
<td>11</td>
<td>63.50</td>
<td>.30</td>
</tr>
</tbody>
</table>

Table 6. Summary Table for Independent-Samples Mann-Whitney U Test Comparing Average HR Between Age Groups; Group 1 = Early Mid-Life Group 2 = Late Mid-Life

<table>
<thead>
<tr>
<th>HR Period</th>
<th>X₁</th>
<th>X₂</th>
<th>n₁</th>
<th>n₂</th>
<th>U</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR_Rest 1</td>
<td>77.11</td>
<td>69.44</td>
<td>9</td>
<td>11</td>
<td>34.00</td>
<td>.26</td>
</tr>
<tr>
<td>HR_V1_T2</td>
<td>76.05</td>
<td>66.32</td>
<td>9</td>
<td>11</td>
<td>29.00</td>
<td>.13</td>
</tr>
<tr>
<td>HR_V1_T3</td>
<td>78.86</td>
<td>69.22</td>
<td>9</td>
<td>11</td>
<td>31.00</td>
<td>.18</td>
</tr>
<tr>
<td>HR_Rest 2</td>
<td>78.92</td>
<td>68.11</td>
<td>9</td>
<td>11</td>
<td>30.00</td>
<td>.15</td>
</tr>
<tr>
<td>HR_V2_T2</td>
<td>74.23</td>
<td>64.41</td>
<td>9</td>
<td>11</td>
<td>27.00</td>
<td>.10</td>
</tr>
<tr>
<td>HR_V2_T3</td>
<td>77.04</td>
<td>67.24</td>
<td>9</td>
<td>11</td>
<td>31.00</td>
<td>.18</td>
</tr>
</tbody>
</table>

Table 7. Summary Table for Spearman’s rho correlations between age as a continuous variable and awe and HR.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispositional awe</td>
<td>.44*(.03)</td>
</tr>
<tr>
<td>Baseline awe</td>
<td>.39*(.05)</td>
</tr>
<tr>
<td>Awe_V1_T2</td>
<td>.49*(.02)</td>
</tr>
<tr>
<td>Awe_V2_T2</td>
<td>.41*(.02)</td>
</tr>
<tr>
<td>HR_Rest1</td>
<td>-.35(.07)</td>
</tr>
<tr>
<td>HR_V1_T2</td>
<td>-.42*(.03)</td>
</tr>
<tr>
<td>HR_V1_T3</td>
<td>-.43*(.03)</td>
</tr>
<tr>
<td>HR_Rest2</td>
<td>-.41*(.04)</td>
</tr>
<tr>
<td>HR_V2_T2</td>
<td>-.46*(.02)</td>
</tr>
<tr>
<td>HR_V2_T3</td>
<td>-.43*(.03)</td>
</tr>
</tbody>
</table>

Note. Values indicate Spearman’s rho correlations with significance levels within parentheses. *indicates p ≤ .05 (one-tailed). **indicates p ≤ .01 (one-tailed)
Appendix I. Change in Awe and HR During Neutral Video

Figure 1. Change in self-reported awe (from 0-100) at three time points before, immediately after, and three minutes following the neutral video.

![Change in awe: Neutral Video](image)

Times of measurement
Error bars: 95% CI

Figure 2. Change in average HR (bpm) at six time intervals before, during, and after the neutral video.

![Change in average HR: Neutral Video](image)

Time Intervals
Error bars: 95% CI
Appendix J. Change in Awe and HR During Awe Video

Figure 3. Change in self-reported awe (0-100) at three time points before, immediately after, and three minutes following the awe video.

Figure 4. Change in average HR at six time intervals before, during, and after the awe video.
Appendix K. Change in Awe and HR Across Entire Protocol

Figure 5. Change in self-reported awe throughout the entire study.

![Change in Awe: Entire Study](image)

Figure 6. Change in average HR throughout the entire study.

![Change in HR: Entire Protocol](image)
Appendix L. Change-From-Baseline Awe Analyses

To account for the large standard deviation in self-reported awe scores, a person-centered variable was calculated. This was done by subtracting the self-reported awe score from the participants’ baseline awe score for each respective video to create a change- from-baseline score for each time of measurement. For example, if a participant reported an awe score of 20 at baseline and then a score of 40 at time 1, their change-from-baseline score for time 1 would be 20.

Neutral Video. To assess whether if this change-from- baseline person-centered score differed significantly as a function of time throughout the neutral video, an additional repeated measures ANOVA with a Greenhouse-Geisser correction was conducted. This ANOVA also revealed that average change-from-baseline awe did not significantly differ from each time of measurement during the neutral video ($F (1.96, 37.31) = 1.18., p = .32$).

Figure 7. Change-from-baseline awe (0-100) at four time points: baseline, before, immediately after, and three minutes following the neutral video.
Awe Video. To assess whether change-from-baseline awe scores differed significantly as a function of time throughout the awe video, a repeated-measures ANOVA with a Greenhouse-Geisser correction was conducted. This ANOVA revealed that average change-from-baseline awe did differ significantly from each time of measurement during the awe video ($F(1.87, 35.60) = 11.22, p < .01$). Post hoc analysis with a Bonferroni adjustment revealed that change-from-baseline awe significantly increased from the time immediately before the awe video to the time immediately after the awe video (23.75 (95% CI 4.41 to 43.09), $p = .01$ and significantly decreased from the time immediately following the awe video to the time three-minutes following the awe video (-11.75 (95% CI -22.91 to -.59) bpm, $p = .04$), $p = .04$.

Figure 8. Change-from-baseline awe (0-100) at four time points: three minutes following the neutral video, before, immediately after, and three minutes following the awe video.
Appendix M. Individual Awe Trajectories

Figure 9. Individual trajectories for self-reported awe throughout the awe video with 0 representing three-minutes following the neutral video, 1 representing immediately before the awe video, 2 representing immediately following the awe video, and 3 representing three-minutes following the awe video.
Figure 10. Individual trajectories for change-from-baseline awe throughout the awe video with 0 representing three-minutes following the neutral video, 1 representing immediately before the awe video, 2 representing immediately following the awe video, and 3 representing three-minutes following the awe video.