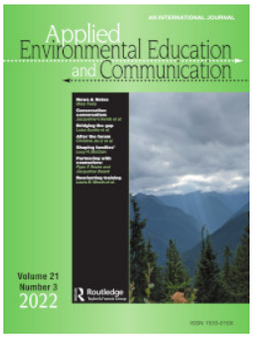

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Can a science café and a concert communicate global change concepts?

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ABSTRACT

A science café and a concert with a panel discussion were held with public audiences to communicate information about global change and ecosystem soundscapes. Both events were evaluated through: (i) post-event surveys to measure global change perceptions, awareness, and attitudes; (ii) skin biosensors to measure the engagement levels of a sub-group of attendees; and (iii) post-event interviews with the same sub-group to better understand their reflections on and their own enjoyment and engagement at each event. Results indicate both events were beneficial to attendees, but the combined concert and panel discussion event was more engaging and enjoyable for attendees.

Introduction

Despite evidence suggesting the knowledge deficit model is an oversimplified understanding of the best practices in science communication, it is still used by many scientists as they communicate their science with the general public for several reasons (Simis et al., 2016). Although the actual scientific facts are important, audience attitudes toward science are just as important and can even be confounding factors in science communication (Sturgis & Allum, 2004; Allum et al., 2008). This is especially true in cases where the science has become politicized, such as for anthropogenic climate change. Furthermore, providing scientific information is not enough to change minds or to inspire action (Priest, 2016).

To overcome these obstacles, science communicators can draw from the wisdom of the broader communication field in order to effectively communicate important scientific findings. For starters, scientists would benefit from knowing and utilizing the key elements of communication. Moser (2010) outlines the key elements of communication as: the scope and purpose of the message; the audience; the framing of the message; the message itself; the messenger; the modes and channels of communication; and an

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evaluation of the effectiveness of the communication. Keeping these in mind, the present work explores how art - in this case, symphony music performed live at a concert - can be used as the message framing for the communication of global change concepts to the general public and then evaluates the effectiveness of this communication strategy by comparing the results from the concert to those from a more traditional science lecture.

Communication of science through art

Art, in the form of plays, music, origami, dance, photography, comics, and gardens, has been used to communicate scientific ideas including ecological and environmental science and the carbon cycle (Schwartz, 2014; Stolberg, 2006; Frankel, 2001; Tatalovic, 2009; Wolfe & Russell, 2010). Additionally, climate and global change concepts have been communicated through various art forms (Miles, 2010) including music (Wodak, 2018; St. George et al., 2017) and photography (Lam & Tegelberg, 2019). Art has the ability to invoke emotions and engage the imaginations of audience members and thus to promote changes in actions and behaviors, making it particularly beneficial for climate change communication (Lesen et al., 2016). Although the use of art to communicate scientific ideas is becoming more ubiquitous, there is a gap in the existing literature on the evaluation of these efforts. Without evaluation, the efficacy of art as a means for science communication remains unknown.

Evaluation

Evaluation is the process by which we can determine whether our communication strategies help us accomplish our goals and purposes for communication. It "involves establishing the value or worth of something" (Candy & Ferguson, 2014, p. 4). Evaluation can help us answer questions such as: "Is art … more authentic than a press report of scientific data? Does it engage in more emotive and human terms?" (Miles, 2010, p. 32). Additionally, the purpose of evaluation is to make sense of something observable with the aim of identifying factors to improve it in the future (Candy, 2014). Evaluation methods and measures include: using multimedia formats; implementing pre- and post-surveys as well as audience interviews; determining changes in the understanding, knowledge, attitudes, awareness, interest, and appreciation of the project topics; and measuring the emotional and aesthetic responses of the audience to the art (Lesen et al., 2016).

Despite the gap in the existing literature on the evaluation of science communication through art, science communication efficacy has been evaluated in other informal education settings such as museums (Boisvert & Slez, 1995, Phelan et al., 2017), planetariums (Plummer 2008, Türk & Kalkan, 2015), and alternate reality games (Gilliam et al., 2017).

Skin biosensors

One way to measure the audience's emotional response to the art is through skin biosensors. This technology measures skin conductance, a proxy for engagement level (Di Lascio et al., 2018; Villanueva et al., 2018, Soltis et al., 2020), where engagement is defined in this study as participant interest in and positive emotional response to stimuli, through electrodermal activity (EDA). EDA is a reliable way to measure physiological arousal and is commonly used "due to its ease of use and minimal intrusiveness" (Tan & Ferguson, 2014, p. 144). As described in McNeal et al. (2020), EDA varies due to changes in palm sweat, which is controlled by the sympathetic nervous system. The more engaged a person is, the more active the sympathetic nervous system becomes, the more sweat the body produces, and the higher the EDA values become. In addition to engagement, the sympathetic nervous system can lead to increased palm sweat production if/when a person is stressed, anxious, angry, etc., so caution and additional data collection (e.g. surveys and interviews) should be used in conjunction with EDA to discern whether the response is truly from engagement.

Skin biosensors have been used in undergraduate lecture and laboratory settings (McNeal et al., 2014; Di Lascio et al., 2018, Soltis et al., 2020; McNeal et al., 2020; Morrison et al., 2020) to measure emotional responses to various stimuli (Gatti et al., 2018), detect pain in infants and post-operative patients (Eriksson et al., 2007; Ledowski et al., 2007), evaluate mental workload (Shimomura et al., 2008), and measure emotional response to music (Khalfa et al., 2002; Rickard, 2004; Dillman Carpentier & Potter, 2007; Lundqvist et al., 2008). The use of skin biosensors to measure emotional response to music is of particular interest to this study. Relatively higher EDA values are linked to emotional responses to music such as fear and happiness but not sadness or peacefulness (Khalfa et al., 2002). Similarly, Lundqvist et al. (2008) found stronger EDA values were associated with happy music. Rickard (2004) found higher EDA values were associated with emotionally powerful music as opposed to relaxing music or emotionally powerful film scenes. Dillman Carpentier and Potter (2007) found all music tempos elicited higher EDA values compared to silence, but music with faster tempos elicited the highest EDA values.

Research aims

This study specifically examines how attendance at a science café and/or a concert about global change impacts attendees' engagement with, perspectives of, and attitudes toward global change. Results from this study can be used to assess whether art-focused events (e.g. concerts) succeed in changing the general public's awareness of, attitudes toward, and engagement with climate and global change as compared to more traditional informal education events (e.g. science cafés). To this end, this work specifically aims to answer the following questions:

1. Do both events, a science café and a concert, lead to increased learning gains and/or positive changes in attitudes and behaviors of the attendees toward climate change?
2. Is one event more impactful than the other?
3. How do attendee engagement levels differ between the two events?

Methods

The events

Two informal education events, a science café and a concert followed by a panel discussion, were held and open to the general public with the aim of increasing the attendees' overall global change knowledge and motivation to take action. For the purpose of this study, global change is defined as large-scale changes in the Earth system. The events were coordinated and focused on *The Great Animal Orchestra Symphony*, a symphony written by Richard Blackford and inspired by the bio-acoustic recordings made by Bernie Krause of a variety of species from around the world. The science café is a recurring and informal science lecture held in the café area of the local science museum, the North Carolina Museum of Natural Sciences, that encourages audience questions and interactions with scientists. This particular event introduced the audience to ecosystem soundscapes - the collection of biological, geophysical and anthropogenic sounds that emanate from a landscape and which vary over space and time reflecting important ecosystem processes and human activities" (Pijanowski et al., 2011, p. 1214) - the local scientists who study them, and the story behind the symphony. The concert was held on North Carolina State University's campus three days later and included a performance of the symphony by the Raleigh Civic Orchestra and a panel of global change scientists who answered audience questions after the performance. Although the events were coordinated and both focused on the same symphony and on ecosystem soundscapes in general, the science café and the panel discussion after the

concert were not identical as the scientists and the audience questions were different.

Study design

All audience members were recruited verbally through announcements which followed a series of protocols with Institutional Review Board approval (North Carolina State University Protocol #6526 and Auburn University Protocol #18-348), and those who were willing to participate completed post-event surveys (N = 58 for the science café and N = 258 for the concert). A subset of participants (n = 13) attended both events, completed post-event surveys, and answered interview questions within the two weeks following both events, and a smaller group (n = 10) within the subset wore skin biosensors throughout the science café and the concert events. Participants in the subset were recruited verbally as they entered the science café venue, and those who agreed to participate were compensated with $40 Amazon gift cards.

Basic demographic information was collected (Table 1) using post-event surveys. These surveys also measured attendees' engagement with, perspectives of, and attitudes toward global change through a series of questions at the

Table 1. A summary of the demographic information from participants at the science café, at the concert, and the subset from both.

Demographics	Science café	Concert	Subset
Age	*N = 54*	*N = 190*	*N = 13*
Average	40	38	36
Range	18–84	18–86	18–70
Gender	*N = 57*	*N = 228*	*N = 13*
Male	30	95	8
Female	27	132	5
Nonbinary	0	1	0
Race/ethnicity	*N = 58**	*N = 231!*	*N = 13○*
American Indian/Native American/Alaskan	1	3	1
Asian/Asian American	2	11	1
Black/African/African American	0	11	0
Latino(a)/Hispanic	1	10	0
Native Hawaiian/Pacific Islander	0	1	0
White/Caucasian	53	197	12
Other	3	4	0
Education	*N = 58*	*N = 231*	*N = 13*
High school/GED	6	11	2
Some college	12	56	6
Vocational/Trade training or Associate degree	1	7	0
Bachelor's degree	25	73	4
Graduate or Professional degree	14	84	1
Political affiliation	*N = 57*	*N = 225*	*N = 13*
Democratic	27	101	5
Independent	15	70	3
Republican	6	30	3
Other	3	8	1
None/Not interested	6	14	1

Under the Race/Ethnicity question, two participants selected two options at the science café (denoted by *), six participants selected two options at the concert (denoted by !), and one participant in the subset group selected two options (denoted by ^).

Table 2. Compiled survey data from the science café.

Science café	Responses
How important is global change to you?	*N = 57*
Very important	44
Somewhat important	12
Not important	1
How worried about global change are you?	*N = 58*
Very worried	35
Somewhat worried	20
Not worried	3
How sure are you that global change is happening?	*N = 57*
Extremely sure	46
Somewhat sure	7
Not sure	4
How well informed do you feel you are about global change?	*N = 57*
Extremely informed	22
Somewhat informed	33
Not informed	2
Which comes closest to your own view?	*N = 58*
Most scientists think global change is occurring.	53
Most scientists think global change is not occurring.	0
Scientists generally disagree about whether global change is occurring.	4
I do not know.	1
Soundscapes can provide information about global change.	*N = 53*
True	48
False	5
How has the amount of carbon dioxide in the atmosphere changed since the start of the Industrial Revolution 150 years ago?	*N = 58*
The amount of carbon dioxide has remained the same.	0
The amount of carbon dioxide has decreased.	0
The amount of carbon dioxide has increased.	54
I do not know.	4
The Science Café made me more aware of global change.	*N = 56*
Strongly agree	4
Agree	20
Neutral	26
Disagree	4
Strongly disagree	2
The Science Café helped me understand global change better.	*N = 54*
Strongly agree	2
Agree	20
Neutral	24
Disagree	6
Strongly disagree	2
The Science Café has convinced me to alter my behavior in order to reduce my personal impact on global change.	*N = 56*
Strongly agree	2
Agree	16
Neutral	28
Disagree	7
Strongly disagree	3

science café (Table 2) and concert (Table 3). The skin biosensors (Affectiva Q Sensor, 8 Hz) were worn on the hand to measure skin conductance (Table 4). The interview portion of the study included open-ended questions and Likert scale statements (Table 5, Appendix). Questions and statements used in the survey and interview portions of the study (Tables 2, 3, 5, Appendix) were written based on existing instruments examining climate content knowledge (McNeal et al., 2014; Aksit et al., 2017; Libarkin et al., 2018) and on feedback from the planning team for both events. This study utilized a mixed-methods

Table 3. Compiled survey data from the concert and panel discussion.

Concert	Responses
How important is global change to you?	*N = 253*
A. Very important	201
B. Somewhat important	47
C. Not important	5
How well informed do you feel you are about global change?	*N = 250*
A. Extremely informed	88
B. Somewhat informed	154
C. Not informed	8
Which comes closest to your own view?	*N = 258*
A. Most scientists think global change is occurring.	217
B. Most scientists think global change is not occurring.	3
C. Scientists generally disagree about global change.	33
D. I do not know.	5
Soundscapes can provide information about global change.	*N = 245*
A. Strongly agree	80
B. Agree	113
C. Neutral	43
D. Disagree	5
E. Strongly disagree	4
The concert helped me better understand the link between the natural sciences and music.	*N = 243*
A. Strongly agree	71
B. Agree	121
C. Neutral	41
D. Disagree	8
E. Strongly disagree	2
I relate more to music than I do to science.	*N = 252*
A. Strongly agree	24
B. Agree	43
C. Neutral	115
D. Disagree	27
E. Strongly disagree	43
Music better connects me to nature than science does.	*N = 250*
A. Strongly agree	12
B. Agree	42
C. Neutral	113
D. Disagree	58
E. Strongly disagree	25
The science behind soundscapes is more interesting than the music is.	*N = 244*
A. Strongly agree	15
B. Agree	39
C. Neutral	120
D. Disagree	60
E. Strongly disagree	10
The panel made me more aware of global change.	*N = 169*
A. Strongly agree	13
B. Agree	56
C. Neutral	80
D. Disagree	16
E. Strongly disagree	4
The panel made me more aware of human influences on the environment.	*N = 169*
A. Strongly agree	25
B. Agree	62
C. Neutral	65
D. Disagree	13
E. Strongly disagree	4
Did you also attend Thursday night's Science Café at the NC Museum of Natural Sciences?	*N = 223*
Yes	22
No	201
If yes, please answer the following: The combination of Thursday's Science Café and tonight's concert provided the appropriate balance between the natural sciences and music in order to better my understanding of soundscapes.	*N = 22*

(*continued*)

Table 3. Continued.

Concert	Responses
A. Strongly agree	8
B. Agree	11
C. Neutral	2
D. Disagree	0
E. Strongly disagree	1
As a result of your attendance, are you inspired to learn more about any of these topics? Please check all that apply.	*N* = 185*
A. Soundscapes	148
B. Global Change	86
C. Biodiversity	88
D. Sustainability	85
E. Natural Sciences	87
F. Music	101
G. Other	7

*signifies that some participants may have chosen more than one response.

approach for the following reasons: surveys were used because they could most easily reach the largest number of attendees and therefore produce a large sample size; skin conductance, although limited by the small sample size, allowed for the collection of quantitative data that could not be influenced or swayed by attendee perceptions, thus producing an unbiased measure of engagement; and interviews provided elaborations on the findings from and provided a context for the skin conductance data.

Analysis

Survey data from both events were compared between the events and for the subgroup of participants who attended both events and completed additional research activities (Tables 1–3).

Skin conductance data, reported as EDA in micro-Siemens (μS), were smoothed using a Savitzky-Golay filter (across 30 seconds of measurements). Basic statistics (mean, standard deviation) were calculated for the science café, concert, panel discussion, and combined concert and panel discussion events, and a one-tailed Wilcoxon signed-rank test was used to compare skin conductance data between events (Table 4).

Interview data consisted of open-ended questions and Likert scale numeric responses with open-ended elaborations, and they were used to explain the quantitative data, following a mixed-methods explanatory sequential design. The open-ended responses and elaborations were coded thematically, and the Likert scale responses were compiled and averaged (Table 5).

Results

Participants

Demographic data demonstrate a relatively homogeneous audience attended the events (Table 1). Attendees at the science café and the concert were

Table 4. A comparison of the minimum (Min), maximum (Max), mean (Avg), and standard deviation (SD) skin conductance values for the science café (Café), concert (Con), and panel discussion (Pan), and the entire concert and panel discussion (C/P).

Sensor	Café Min	Café Max	Café Avg	Café SD	Con Min	Con Max	Con Avg	Con SD	Pan Min	Pan Max	Pan Avg	Pan SD	C/P Min	C/P Max	C/P Avg	C/P SD	C/P – Café **	Con – Café **	Pan – Café *	Con – Pan
00XL	0.07	0.26	*0.16*	0.05	0.20	1.56	*0.34*	0.26	0.28	0.52	*0.36*	0.06	0.20	1.56	*0.35*	0.20	0.19	0.19	0.20	−0.01
00XU	0.19	0.40	*0.26*	0.05	0.24	2.16	*0.42*	0.41	0.36	3.37	*0.76*	0.62	0.24	3.38	*0.58*	0.54	0.32	0.16	0.50	−0.34
00ZH	0.21	0.61	*0.34*	0.10	0.29	1.34	*0.52*	0.19	0.31	1.78	*0.48*	0.23	0.26	1.78	*0.51*	0.21	0.17	0.18	0.15	0.04
01AC	0.13	0.68	*0.25*	0.15	0.16	0.98	*0.31*	0.12	0.58	1.65	*1.02*	0.23	0.16	1.65	*0.61*	0.40	0.36	0.06	0.78	−0.72
014N	0.84	1.96	*1.11*	0.23	0.33	4.59	*1.45*	1.29	0.24	0.42	*0.30*	0.05	0.23	4.59	*0.96*	1.13	−0.15	0.35	−0.81	1.16
017J	0.48	0.62	*0.54*	0.03	0.52	1.15	*0.66*	0.13	0.55	1.36	*0.77*	0.18	0.52	1.37	*0.70*	0.16	0.16	0.11	0.22	−0.11
0117	0.01	0.05	*0.04*	0.01	0.33	1.57	*0.42*	0.21	0.27	0.34	*0.31*	0.01	0.27	1.58	*0.37*	0.17	0.33	0.38	0.26	0.12
0122	0.07	0.21	*0.12*	0.03	8.32	17.04	*10.77*	1.08	4.34	7.44	*5.94*	0.65	4.28	17.16	*8.72*	2.55	8.59	10.64	5.81	4.83
0132	0.71	1.03	*0.89*	0.09	0.89	1.66	*1.11*	0.13	1.10	3.77	*1.82*	0.76	0.89	3.78	*1.41*	0.61	0.51	0.22	0.92	−0.71
0175	0.97	2.98	*1.22*	0.30	0.63	2.20	*1.11*	0.27	0.71	2.54	*1.33*	0.19	0.63	2.53	*1.20*	0.26	−0.01	−0.10	0.11	−0.21

Units are μS. Additionally, the differences between means across events are provided as follows: concert and panel discussion minus café (C/P – Café); concert minus café (Con – Café); panel discussion minus café (Pan – Café); and concert minus panel discussion (Con – Pan). Statistical significance is denoted with asterisks: '**' represents significance at $\alpha = 0.01$ for a one-tailed Wilcoxon signed-rank test, and '*' represents significance at $\alpha = 0.05$ for a one-tailed Wilcoxon signed-rank test.
The columns associated with averages are italicized.

Table 5. Summarized results from select portions of the interview.

Open-ended			
Was one event more engaging than the other?			Responses:
NA			6
Café			2
Concert			5
Was one event more informative than the other?			Responses:
NA			4
Café			5
Concert			3
Panel			1
Which event did you enjoy more overall?			Responses:
NA			1
Café			1
Concert			11
Likert Scale			
I often feel a sense of oneness with the natural world around me.			
Mean:	4.31	SD:	0.91
I think of the natural world as a community to which I belong.			
Mean:	4.46	SD:	0.50
I recognize and appreciate the intelligence of other living organisms.			
Mean:	4.54	SD:	0.50
I often feel disconnected from nature.			
Mean:	2.54	SD:	1.34
When I think of my life, I imagine myself to be part of a larger cyclical process of living.			
Mean:	4.38	SD:	0.84
I often feel a kinship with animals and plants.			
Mean:	4.00	SD:	0.88
I feel as though I belong to the Earth as equally as it belongs to me.			
Mean:	4.04	SD:	1.28
I have a deep understanding of how my actions affect the natural world.			
Mean:	4.08	SD:	1.00
I often feel part of the web of life.			
Mean:	4.23	SD:	0.70
I feel that all inhabitants of Earth, human and nonhuman, share a common 'life force.'			
Mean:	4.23	SD:	0.89
Like a tree can be part of a forest, I feel embedded within the broader natural world.			
Mean:	4.38	SD:	0.74
When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature.			
Mean:	3.08	SD:	1.27
I often feel like I am only a small part of the natural world around me, and that I am no more important that the grass on the ground or the birds in the trees.			
Mean:	2.77	SD:	1.42
My personal welfare is independent of the welfare of the natural world.			
Mean:	1.92	SD:	0.92

The total number of responses to each question/statement is 13. The open-ended questions are coded into four categories based on participant responses: 'NA' for those who said both events were engaging, informative, or more enjoyable; 'Café' for those who identified the science café event; 'Concert' for those who identified the concert event; and 'Panel' for those who identified the panel discussion portion of the concert event. The Likert scale statements were rated from 1 to 5, where 1 is 'Strongly disagree' and 5 is 'Strongly agree.'

similar in average age (40 and 38, respectively) and in the range of ages represented (18 to 84 and 18 to 86, respectively). A higher percentage of the attendees at the science café were male (53%) compared to the concert (42%). The majority of attendees at both events identified as White/Caucasian (science café: 91%, concert: 85%) and as Democrats or Independents (science café: 74%, concert: 76%). Additionally, roughly two-thirds of the attendees at both events had a Bachelor's or graduate/professional degree. Demographic data are also provided specifically for the subset

of participants who attended both events, completed post-event surveys, and answered interview questions within the two weeks following both events (Table 1), of which the smaller subgroup of participants (n = 10) who wore skin biosensors is a part.

Survey data

Compiled survey data for the science café and the concert are provided (Tables 2 and 3, respectively). When asked, "How important is global change to you?" the majority of attendees at both events said global change was "Very important" (science café: 77%, concert: 79%), and when asked, "How well informed do you feel you are about global change?" the majority said "Extremely informed" or "Somewhat informed" (science café: 96%, concert: 97%). Overall, both audiences felt informed on global change and viewed it as important. These findings suggest the two events might be "preaching to the choir," especially given the attendees' education levels and political affiliations, a potential limitation of this study; however, 43% of the science café attendees (41% of the concert attendees) agreed or strongly agreed that the event made them more aware of global change while only 11% (12% of the concert attendees) disagreed or strongly disagreed, suggesting the "choir" can still learn from new "preaching."

About 41% of the science café attendees agreed or strongly agreed that the event helped them better understand global change, and 32% agreed or strongly agreed that the event helped convince them to alter their behavior in order to reduce their personal impact on global change. More than three-fourths of the concert attendees agreed or strongly agreed the concert helped them better understand the link between the natural sciences and music, and the panel portion of the concert event helped make the audience more aware of human influences on the environment (34% agreed or strongly agreed v. 10% disagreed or strongly disagreed). A majority of the concert attendees (73%) said the event inspired them to learn more about scientific topics discussed during the event. When asked to rate the statement, "The science behind soundscapes is more interesting than the music is," more participants disagreed or strongly disagreed (29%) than those who agreed or strongly agreed (22%), suggesting more attendees found the music just as or more interesting than the science. This finding highlights that some attendees are more science-minded and others are more music-minded. An event with a coordinated concert and panel discussion meets the interests of both extremes.

For those who attended both events (N = 22), roughly 86% agreed or strongly agreed the events together provided enough balance between the natural sciences and music in order to better their understandings of soundscapes (Table 3). This result demonstrates that a coordinated pair of events -

a science café and a concert - can be useful for informing the audience while still engaging them at a higher level than they would be otherwise.

Skin conductance

Comparisons of the smoothed skin conductance measurements for all ten participants at the science café (Figure 1) and at the concert with the panel discussion (Figure 2) are provided. In general, EDA values were highest at the beginning of the science café and dropped off over time (Figure 1). During the concert and panel discussion event, EDA values were much more variable. There are marked moments of higher EDA values, in general, at the start of both parts - the concert and the panel discussion - and instances of higher EDA values at other points throughout (Figure 2). EDA values vary from person to person, throughout a single event, and between events. To better observe the differences in EDA values between the events, comparisons of the skin conductance data for the science café, concert, and panel discussion portions are provided (Table 4). Average values were highest for either the concert or the panel discussion but never for the science café. For eight out of ten participants, the EDA values for the concert and panel discussion event were higher than those for the science café. For nine out of ten participants, the EDA values for the concert portion or the panel discussion portion were higher than those for the science café. This finding suggests participants were, on average, more engaged during the concert or the panel discussion.

Instances of higher EDA values during the concert portion could be the result of emotional responses to the music itself, as well as a physiological response to the tempo of the music. The higher EDA values on average

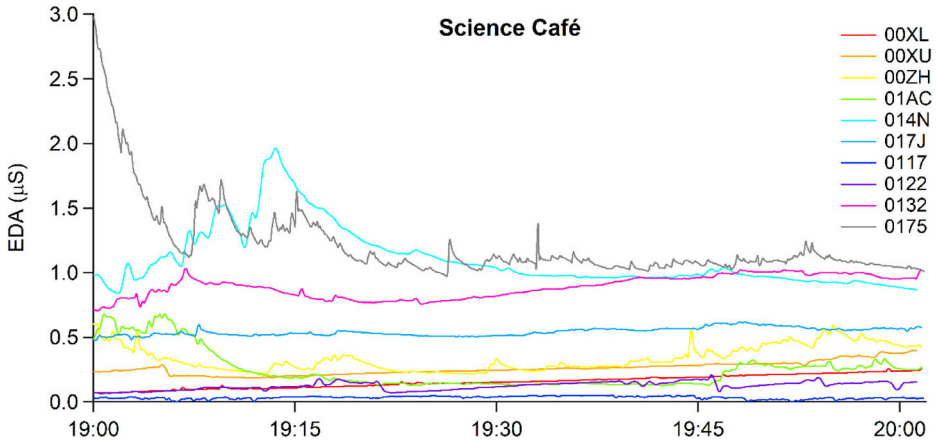

Figure 1. A comparison of the smoothed skin conductance measurements for all ten participants at the science café. Participants are represented by the specific sensor (e.g. 00XL, 00XU, etc.) they wore during both events. Higher EDA values represent higher levels of engagement.

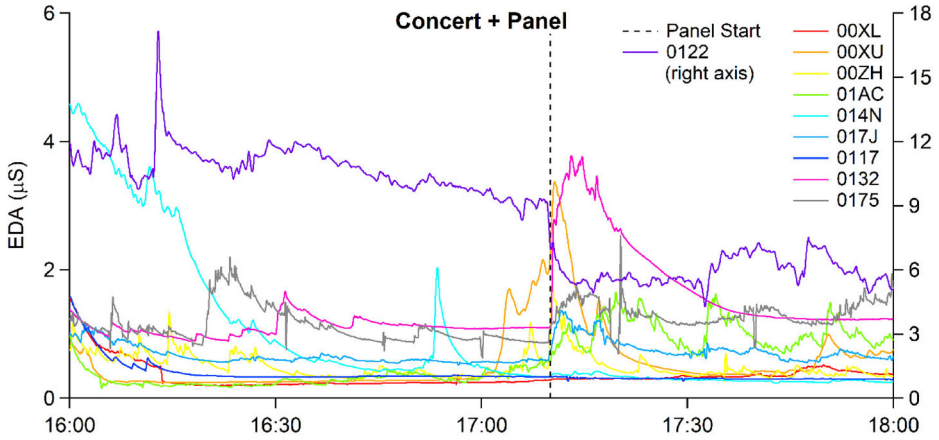

Figure 2. A comparison of the smoothed skin conductance measurements for all ten participants at the concert with the panel discussion. Participants are represented by the specific sensor (e.g. 00XL, 00XU, etc.) they wore during both events and match Figure 1 in color and name. The vertical dashed line separates the concert from the panel discussion.

during the concert and panel discussion event relative to the science café event are likely the result of the music eliciting a strong and positive emotional response that the science café was unable to do.

Interviews

When asked if one event was more engaging than the other, six participants indicated neither was more engaging, two indicated the science café was more engaging, and five indicated the concert was more engaging (Table 5). For many, these responses contradict their EDA values, which suggest the concert and panel discussion event was more engaging than the science café. One possible explanation for this contradiction is found in their responses when asked if one event was more enjoyable than the other. For this prompt, one participant indicated neither was more enjoyable, one indicated the science café was more enjoyable, and eleven indicated the concert was more enjoyable (Table 5). Overall enjoyment and engagement were likely confused by a few of the participants in the subset. When asked which event was more informative, four participants indicated neither, five indicated the science café, three indicated the concert, and one indicated the panel discussion separate from the concert (Table 5).

Responses to the Likert scale questions indicate the subset of participants, in general, feel a sense of oneness with nature, consider themselves part of the natural world community, imagine themselves to be part of a cyclical life process, and recognize and appreciate the intelligence of other living things (Table 5). These findings suggest the subset of participants was

potentially motivated to attend the science café (and then the concert) out of an interest in and appreciation for the natural world.

Examples

Four participants from the subgroup, along with their data, are examined in greater detail below. These four were selected based on their representativeness of the group as a whole. Names are changed for anonymity purposes.

Sara (00XL in Figures 1 and 2 and Table 4) is a 20-year-old female, undergraduate student. She considers herself White/Caucasian and a Democrat. When asked if one event was more engaging than the other, she explained how the science café "appealed to [her] science side," but the concert was "good too." Sara found the science café to be more informative because it included "explanations, more details, and methods," but she enjoyed the concert more overall because it was "more entertainment-focused." Sara's average skin conductance values were slightly higher during the concert and panel discussion event than during the science café (0.35 v. 0.16 μS), demonstrating how even those who consider themselves more science-minded can be more engaged at an event where the focus is more on the art.

Joey (017J) is a 19-year-old, White/Caucasian male. He is an undergraduate student and a registered Democrat. He found the science café to be more engaging, informative, and enjoyable overall, yet his skin conductance values were higher during the concert and panel discussion event than during the science café (0.70 v. 0.54 μS). Joey's data highlight the disconnect between what a person may think is engaging and how they emotionally engage with an experience. When asked whether either event changed his view on the connectedness of the natural sciences and music, he explained how he became more aware of the combination of science and music and how he "wouldn't have drawn the same conclusions" without both events. Given the timing of the events - the science café was held three days before the concert event - Joey attended the concert with a deeper understanding of ecosystem soundscapes and the science behind them, perhaps leading to the higher levels of engagement during the concert and the panel discussion.

Ben (0122) is a 22-year-old, White/Caucasian, male, undergraduate student and a Democrat. His skin conductance values stand out from those of his peers - he has the highest values out of the entire subset for the concert event, and his average value for the concert event is much higher than for the science café (8.72 v. 0.13 μS). These results are consistent with his interview responses. Although the science café presented "the facts," Ben

felt the concert event was more informative because it "opened doors of thought" and provided "time for thought." He found the concert event to be more enjoyable overall because it left him feeling "more inspired." The room for thought and additional inspiration are likely explanations for his higher levels of engagement during the concert event.

Jane (0175) is a 70-year-old, White/Caucasian retiree with a college degree, and she considers herself an Independent. Jane felt both events were equal in terms of being engaging and informative, but she enjoyed the concert event more overall because of the symphony and the instrumentalists. Furthermore, she felt her attendance at both events "reinforced" and "validated" her view on the connectedness of science and music. Interestingly, Jane was slightly less engaged during the concert event than during the science café (1.20 v. 1.22 μS). Jane acknowledged she thought the "panel [discussion] added depth" to the concert event, and her average skin conductance values were highest during the panel discussion portion of the concert event (1.33 μS).

Discussion

Event impacts

For the majority of attendees at both events, global change is important and they feel informed about it. Despite those responses, the survey results showed that more than 40% of them felt the events made them more aware of global change. The science café helped several attendees better understand global change and convinced many to change their behaviors in order to reduce their impacts on global change. The concert event helped attendees better understand the human impacts on the environment and inspired many to learn more about other related topics. These findings suggest both events led to increased learning gains and/or positive changes in attitudes and behaviors toward climate change of the attendees, but neither event appeared to be more impactful.

Engagement

Although both events were similarly impactful according to the survey results, the skin conductance data widely show a higher level of engagement at the concert and panel discussion event than at the science café. Furthermore, the interview data revealed that, of the subgroup, 38% felt the concert was more engaging and 85% felt the concert was more enjoyable. These findings suggest the concert and panel discussion event was overall more engaging than the science café for the entire subgroup.

Limitations

One potential limitation of this study is whether the survey respondents at either of the events are representative of the broader general public. Some might argue that events such as a science café or an orchestral concert would attract only a small portion of the general public. Although there is a risk of "preaching to the choir," this study focuses on measuring attendee engagement and impacts from attending either of the events - not on an attendee's attitudes or beliefs about global change prior to attending either event - and thus any engagement or impacts from their attendance would build on their baseline understanding or awareness from before the events. Additional limitations related to the subset of study participants who wore the skin biosensors are: the small sample size ($n = 10$), determined by the limited availability of skin biosensors; the lack of baselines in the EDA data prior to the start of the events due to logistical constraints; and the lack of data on medications, health conditions, or stress levels of the study participants that could have impacted the EDA data only minimally because of the short period of time between the two events (three days). Lastly, the order of the events (the science café before the concert and panel discussion event) could have an impact on attendee engagements levels at the concert, either more or less engaged because of the information gleaned from the science café.

Conclusion

A science café and a concert with a panel discussion, both focused on the impacts of global change on ecosystem soundscapes, were held a few days apart and evaluated using a mixed-methods approach. Post-event survey data suggest both events were effective at impacting audience awareness and attitudes regarding global change. Analyses of the EDA data from a subset of attendees at both events suggest the concert and panel discussion event was more engaging than the science café. Altogether, the findings reported here suggest both types of events are equally beneficial to attendees, but a combined concert and panel discussion event is more engaging and enjoyable for attendees.

For future research, we suggest bridging science and music as a strategy to engage a greater swath of the general public in global change-related content. We encourage collaborations between scientists and artists in order to implement global change communication and outreach events. Such events should be carefully evaluated using a mixed-methods approach including pre- and post-surveys, interviews, and biometric data to determine if attendees continue to be more engaged in art-focused events and if specific learning goals are met at both types of events. Additionally, we recommend more evaluations to assess the effectiveness of communication

efforts of climate and global change concepts to the public through art, especially since such activities have gained traction while the rigorous evaluation of them remains limited.

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No potential conflict of interest was reported by the authors.

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References

Aksit, O., McNeal, K. S., Libarkin, J. L., Gold, A. U., & Harris, S. (2017). The influence of instruction, prior knowledge, and values on climate change risk perception among undergraduates. *Journal of Research in Science Teaching*, *55*(4), 550–572. https://doi.org/10.1002/tea.21430

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: A meta-analysis. *Public Understanding of Science*, *17*(1), 35–54. https://doi.org/10.1077/0963662506070159

Boisvert, D. L., & Slez, B. J. (1995). The relationship between exhibit characteristics and learning-associated behaviors in a science museum discovery space. *Science Education*, *79*(5), 503–518. https://doi.org/10.1002/sce.3730790503

Candy, L. (2014). Evaluation and experience in art. In L. Candy & S. Ferguson (Eds.), *Interactive experience in the digital age: Evaluating new art practice* (pp. 25–48). Springer.

Candy, L., & Ferguson, S. (2014). Interactive experience, art and evaluation. In L. Candy & S. Ferguson (Eds.), *Interactive experience in the digital age: Evaluating new art practice* (pp. 1–10). Springer.

Di Lascio, E., Gashi, S., & Santini, S. (2018). Unobtrusive assessment of students' emotional engagement during lectures using electrodermal activity sensors. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, *2*(3), 21. https://doi.org/10.1145/3264913

Dillman Carpentier, F. R., & Potter, R. F. (2007). Effects of music on physiological arousal: Explorations into tempo and genre. *Media Psychology*, *10*(3), 339–363. https://doi.org/10.1080/15213260701533045

Eriksson, M., Storm, H., Fremming, A., & Schollin, J. (2007). Skin conductance compared to a combined behavioural and physiological pain measure in newborn infants. *Acta Paediatrica (Oslo, Norway : 1992)*, *97*(1), 27–30. https://doi.org/10.1111/j.1651-2227.2007.00586.x

Frankel, F. (2001). Communicating science through photography. *Journal of Chemical Education*, *78*(10), 1312–1314. https://doi.org/10.1021/ed078p1312

Gatti, E., Calzolari, E., Maggioni, E., & Obrist, M. (2018). Emotional ratings and skin conductance response to visual, auditory and haptic stimuli. *Scientific Data*, *5*. https://doi.org/10.1038/sdata.2018.120

Gilliam, M., Jagoda, P., Fabiyi, C., Lyman, P., Wilson, C., Hill, B., & Bouris, A. (2017). Alternate reality games as an informal learning tool for generating STEM engagement among underrepresented youth: A qualitative evaluation of the source. *Journal of Science Education and Technology*, *26*(3), 295–308. https://doi.org/10.1007/s10956-016-9679-4

Khalfa, S., Isabelle, P., Jean-Pierre, B., & Manon, R. (2002). Event-related skin conductance responses to musical emotions in humans. *Neuroscience Letters*, *328*(2), 145–149. https://doi.org/10.1016/S0304-3940(02)00462-7

Lam, A., & Tegelberg, M. (2019). Witnessing glaciers melt: Climate change and transmedia storytelling. *Journal of Science Communication*, *18*, 1–17. https://doi.org/10.22323/2.18020205

Ledowski, T., Bromilow, J., Wu, J., Paech, M. J., Storm, H., & Schug, S. A. (2007). The assessment of postoperative pain by monitoring skin conductance: Results of a prospective study. *Anaesthesia*, *62*(10), 989–993. https://doi.org/10.1111/j.1365-2044.2007.05191.x

Lesen, A. E., Rogan, A., & Blum, M. J. (2016). Science communication through art: Objectives, challenges, and outcomes. *Trends in Ecology & Evolution*, *31*(9), 657–666. https://doi.org/10.1016/j.tree.2016.06.004

Libarkin, J. L., Gold, A. E., Harris, S., McNeal, K. S., & Bowles, R. (2018). A new, valid measure of climate change understanding: Associations with risk perception. *Climatic Change*, *150*(3-4), 403–416. https://doi.org/10.1007/s10584-018-2279-y

Lundqvist, L.-O., Carlsson, F., Hilmersson, P., & Juslin, P. N. (2008). Emotional responses to music: Experience, expression, and physiology. *Psychology of Music*, *37*(1), 61–90. https://doi.org/10.1177/0305735607086048

McNeal, K. S., Walker, S. L., & Rutherford, D. (2014). Assessment of 6- to 20-Grade educators' climate knowledge and perceptions: Results from the Climate Stewardship Survey. *Journal of Geoscience Education*, *62*(4), 645–654. https://doi.org/10.5408/13-098.1

McNeal, K. S., Zhong, M., Soltis, N., Doukopoulos, L., Johnson, E. T., Courtney, S., Alwan, A., & Porch, M. (2020). Biosensors show promise as a measure of student engagement in a large introductory biology course. *CBE–Life Sciences Education*, *19*, 1–10.

Miles, M. (2010). Representing nature: Art and climate change. *Cultural Geographies*, *17*(1), 19–35. https://doi.org/10.1177/1474474009349997

Morrison, A. L., Rozak, S., Gold, A. U., & Kay, J. E. (2020). Quantifying student engagement in learning about climate change using galvanic hand sensors in a controlled educational setting. *Climatic Change*, *159*(1), 17–36. https://doi.org/10.1007/s10584-019-02576-6

Moser, S. C. (2010). Communicating climate change: History, challenges, process and future directions. *WIREs Climate Change*, *1*(1), 31–53. https://doi.org/10.1002/wcc.11

Phelan, S., Specht, I., Schnotz, W., & Lewalter, D. (2017). Attitude change when presenting science museum visitors with risk–benefit information. *Science Education*, *101*(6), 873–886. https://doi.org/10.1002/sce.21296

Pijanowski, B. C., Farina, A., Gage, S. H., Dumyahn, S. L., & Krause, B. L. (2011). What is soundscape ecology? An introduction and overview of an emerging new science. *Landscape Ecology*, *26*(9), 1213–1232. https://doi.org/10.1007/s10980-011-9600-8

Plummer, J. D. (2008). Early elementary students' development of astronomy concepts in the planetarium. *Journal of Research in Science Teaching*, *46*(2), 192–209. https://doi.org/10.1002/tea.20280

Priest, S. (2016). *Communicating climate change: The path forward* (p. 177). Palgrave Macmillan. https://doi.org/10.1057/978-1-137-58579-0

Rickard, N. S. (2004). Intense emotional responses to music: A test of the physiological arousal hypothesis. *Psychology of Music*, *32*(4), 371–388. https://doi.org/10.1177/0305735604046096

Schwartz, B. (2014). Communicating Science through the Performing Arts. *Interdisciplinary Science Reviews*, *39*(3), 275–289. https://doi.org/10.1179/0308018814Z.00000000089

Shimomura, Y., Yoda, T., Sugiura, K., Horiguchi, A., Iwanaga, K., & Katsuura, T. (2008). Use of frequency domain analysis of skin conductance for evaluation of mental workload. *Journal of Physiological Anthropology*, *27*(4), 173–177. https://doi.org/10.2114/jpa2.27.173

Simis, M. J., Madden, H., Cacciatore, M. A., & Yeo, S. K. (2016). The lure of rationality: Why does the deficit model persist in science communication? *Public Understanding of Science (Bristol, England)*, *25*(4), 400–414. https://doi.org/10.1177/0963662516629749

Soltis, N. A., McNeal, K. S., Atkins, R. M., & Maudlin, L. C. (2020). A novel approach to measuring student engagement while using an augmented reality sandbox. *Journal of Geography in Higher Education*, *44*(4), 512-531. https://doi.org/10.1080/03098265.2020.1771547

St. George, S., Crawford, D., Reubold, T., & Giorgi, E. (2017). Making climate data sing: Using music-like sonifications to convey a key climate record. *Bulletin of the American Meteorological Society*, *98*(1), 23–27. https://doi.org/10.1175/BAMS-D-15-00223.1

Stolberg, T. L. (2006). Communicating science through the language of dance: A journey of education and reflection. *Leonardo*, *39*(5), 426–432. https://doi.org/10.1162/leon.2006.39.5.426

Sturgis, P., & Allum, N. (2004). Science in society: Re-evaluating the deficit model of public attitudes. *Public Understanding of Science*, *13*(1), 55–74. https://doi.org/10.1177/0963662504042690

Tan, C. T., & Ferguson, S. (2014). The role of emotions in art evaluation. In L. Candy & S. Ferguson (Eds.), *Interactive experience in the digital age: Evaluating new art practice* (pp. 139–152). Springer.

Tatalovic, M. (2009). Science comics as tools for science education and communication: A brief, exploratory study. *Journal of Science Communication*, *8*, 1–17. https://doi.org/10.22323/2.08040202

Türk, C., & Kalkan, H. (2015). The effect of planetariums on teaching specific astronomy concepts. *Journal of Science Education and Technology*, *24*(1), 1–15. https://doi.org/10.1007/s10956-014-9516-6

Villanueva, I., Campbell, B. D., Raikes, A. C., Jones, S. H., & Putney, L. G. (2018). A multimodal exploration of engineering students' emotions and electrodermal activity in design activities. *Journal of Engineering Education*, *107*(3), 414–441. https://doi.org/10.1002/jee.20225

Wodak, J. (2018). Shifting baselines: Conveying climate change in popular music. *Environmental Communication*, *12*(1), 58–70. https://doi.org/10.1080/17524032.2017.1371051

Wolfe, D., & Russell, K. (2010). Garden/Art: The nature-based sculpture program of the South Carolina Botanical Garden. *Environmental Communication*, *4*(2), 237–249. https://doi.org/10.1080/17524031003755341

Appendix

Interview Questions:

1. What were the main ideas of the concert?
2. What were the main ideas of the science cafe?
3. Did attending either event change your perspective on global change?
4. Did attending either event change your view on the connectedness of the natural sciences and music?
5. After attending these events, do you feel more connected, less connected, or equally connected to nature as compared to before? Why?
6. Was one event more engaging than the other? If yes, which? Why?
7. Was one event more informative than the other? If yes, which? Why?
8. Which event did you enjoy more overall? Why?
9. Would you attend another combination of a concert and a science cafe to learn more about a science topic? Why or why not?
10. If you could change either event, what would you change? Why?
11. Do you think that events such as these could help communicate science to the public, on topics such as global change? Why or why not?
12. Why were you interested in attending these events? How frequently do you attend such events?
13. Is there any other information you wish you knew about soundscapes, global change, biodiversity, sustainability, the natural sciences, music, or something else?