Using Thermography to Study Audience Engagement during Theatre Performance

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Abstract

Previous investigators have suggested studying spectator engagement by examining physical reactions during performance. We compared one such objective measure, thermographic response (body temperature), to subjective audience ratings of engagement, during a theatrical performance of *Zoo Story*. Twenty-two people attended a performance of the play. Thermal photographs of participants were taken during the play; they were also asked to complete a series of questionnaires before and after the performance to record their own perceptions of engagement. Final results with n=16 participants suggest a strong connection between events that occurred on stage, audience facial temperature, as well as self-report of engagement. In addition to reviewing the results, this paper provides researchers with practical guidelines for using thermography in theatre audience engagement research, such as the selection of play, the best location of the camera, the relation between room temperature and audience members, and how to collect and manage thermographic data. Implications for using this tool are explored in the context of assessing and validating the impact of theatre arts in our lives.

Key words: Thermography, audience response, and engagement.

Introduction and Literature Review

It has been said that there is no theatre without an audience since there would be no spectator to receive the message of the play (Eversmann, 2004; Lora, 1955; McConahie, 2008). As Sauter stated, the theatrical experience includes "the presentation of a performance and the attention of an audience"(Sauter, 2002, p. 127). Likewise Reason (2010) claimed that "any work of art is only completed through the engagement and within the experience of an audience" (Reason, 2010, p. 15). However, measuring audience reception of a theatrical performance is one of the most challenging areas to study in arts administration. Although some research has been conducted, it is still unclear what is the best approach. This paper explores a new technique, thermographic photography, as a means to understand and measure the impact of theatre in audience engagement. By understanding what happens during theatrical experiences, we hope that art administrators will gain insight into what audiences value and responding to.

In general, the purpose of reception studies is to analyze "ways in which spectators experience performances" (Sauter, 2002, p. 116). Moreover, according to Sedgman (2017), there are three different waves of audience studies. While the first wave asks what culture does to audiences and the second one asks what audiences do with culture, recently, third wave studies focus on how culture matters to audiences. In order to respond to how culture matters to audiences, we argue that we need to first better understand the experience itself. For example, White and Hede (2008) suggested that investigators examine what researchers believe the experience is, what an audience member believes their experience is, and, how audience members reflect and externalize their experience. Thus, researchers must better understand how to quantify the gap between what spectators experience during the performance, and, what they think and express about their experience when the performance is over. One wonders if even the fact of surveying audience members after the show influences them and their responses (Sauter, 2002). In short and as White and Hede (2008) stated, "[t]he impact of art is a complex and multilayered concept that is experienced and understood in a variety of ways

contingent on each individual's experience and perspective" (White & Hede, 2008, p. 32). Thus, we need to understand theatrical experience as a concept to differentiate the layers inherent in such analysis.

According to Sauter, a theatrical experience is the act of playing "through the mutual contact between performer and spectator within the theatrical event" (Sauter, 2002, p. 129). Eversmann (2004), on the other hand, defined the concept of *theatrical experience* by applying the concept of a*esthetic experience* from Csíkszentmihályi and Robinson (1990) to theatrical reception. From this work, Eversmann (2004) adapted four dimensions: perceptual, cognitive, emotional and communicative. The combination of these four dimensions goes beyond the contact between performer and spectator. As Eversmann (2004) stated, the perceptual dimension reaches the audience by use of the five senses. The spectator perceives different shapes, colors, changes of sets, smells, different sound effects, and so forth. The cognitive dimension studies the intellectual involvement of the spectator or, in other words, their understanding of the performance. Eversmann (2004) also considered other variables that play a part in this dimension, such as the expectations of the audience before the performance, their identification with the play, and their capacity to relate to characters. In the emotional dimension, the spectator perceives, interprets, and contemplates the emotions of the actors. Eversmann (2004) suggested that the emotional dimension should be measured during the play since its presence is much more intense during these moments. He established a difference between the emotion that overcomes the audience because of the plot and the social emotion that takes place when one interacts in a social context. Last, the communicative dimension studies the social experience implied for spectators to be involved and to interact with other people besides themselves, and the necessity of sharing this experience with others. The social dimension includes the entire experience of attending a theatrical performance and what happens after it. Consequently, these four dimensions, when taken together, suggest that an experience includes what happens to the mind and body of an audience member during and after the performance (Reason, 2010, p. 24).

Engagement can be defined in different ways. Higgins & Scholer (2009) defined consumer engagement theory as "a state of being involved, occupied, fully absorbed, or engrossed in something (i.e., sustained attention)" (Higgins & Scholer 2009, p. 112). Engagement can also be defined as "the intensity of an individual's participation and connection with an organization's offerings and/or organizational activities" (Vivek, Beatty, Dalela, & Morgan, 2014, p. 133). All types of engagement likely relate to the psychological concept of flow: the idea of a mental state in which a person is fully absorbed or involved in an activity, loses track of time and feels a sense of energized focus (Csikszentmihalyi, 1990). In other words, engagement can be a multidimensional concept that encompasses different elements such as "attention, dialog, emotions, interactions, sensorial pleasure and immediate activation aimed at creating a total brand experience with customers" (Gambetti, Graffigna, & Biraghi, 2012). Thus, analyzing audiences' reception by only examining surveys after a show is probably too unidimensional. It would be better to include objective measurements in order to understand the complexity and reliability of the data. To do this would require investigators to find additional ways to understand audience reaction during the performance.

Authors such as Eversmann (2004), Sauter (2002), Pavis (2001), or McConahie (2008), have all pointed out the possibility of studying engagement in spectators during a performance through the use of physiological recordings. In his article, Sauter (2002) presented different techniques that have been used for the purpose of studying the emotional and communicative processes such as by measuring the spectator's heartbeat, respiration, perspiration, or eye tracking during a performance. Unfortunately, these techniques can be invasive for the subject and possibly alter their experience during the performance; hence, it could alter the objectivity of the results. Herein this paper presents a novel technique to measure physical reactions through the use of thermography. Thermography (also referred to as "thermo") detects the body's natural emitted thermal irradiations recording the temperature of skin.

Thermography has been traditionally used in other fields, especially in the psychological sciences, to objectively study emotions and stress. Nakanishi and Imai-Matsumura (2008) suggested that a joyful emotion in infants could be associated with a decrease in their facial skin temperature. Nhan and Chau's study (2010) explained that facial thermal data can provide information about people's affective state, and moreover Salazar et. al's (2015) article concluded that thermal facial changes (temperature of the nose) can help detect when people lie ('pinocchio effect') or experience the presence or absence of feelings. Merla & Romani (2007) studied the facial thermal signatures of stress, fear and pleasure arousal. Their findings suggested that in some cases, such as sexual arousal, the facial temperature increases, especially in the periorbital forehead and the lips region. Jang and colleagues reported that skin temperature drops with boredom, stress and fear and increases during relaxation and sleep (Jang, Park, Park, Kim, & Sohn, 2015). They reported significant changes in temperature under emotional stress, with rapid decreases and rapid returns to baseline levels. In conclusion, these articles show that thermography can be used as a marker of changes in emotional states, that there are different facial areas where those changes can be better detected, and, that some of these changes occur quite rapidly. Moreover, the direction of the temperature changes, i.e., whether it increases or decreases, has not always been consistent. For example, investigators have noted decreases and increases with both positive and negative emotions and different arousal levels.

Therefore, thermography could be used as an objective indicator of the audiences' internal "lived" experience during a performance. Using thermography as an objective indicator with multiple people, or an entire audience, presents unique challenges. Most of the thermography studies have measured the temperature of each person independently, and, for a short amount of time. Studying thermography in an audience would involve multiple people over an extended time period. Moreover, in previous studies, investigators have typically identified discrete stimuli (e.g., fear, happiness, etc.) in advance and then shown that specific image or video clip to people in an experimental setting, with only that precise emotion. In fact, in many of the cases, investigators even used mechanisms to hold the participant's face still to avoid any movement that could alter the data collection. This made us question how we could best study a small audience during a one-hour show with a multitude of different emotions and stimuli happening at the same time, with no movement control. As a team, we decided not to concentrate on specific distinct emotions, but to instead analyze audience *engagement* as a group.

As noted by Sauter (2002), it is problematic to exclusively analyze physiological responses in isolation of the participant's verbal experience. Most of the studies carried out in theatre reception are based on subjective data, questionnaires or interviews and, consequently, on the subjective response of the audience. One might ask if there is any correlation between audience objective physical responses and subjective responses. Our study explored *both* the objective physical reactions of audience members in conjunction with their subjective, self-report survey.

To develop the engagement questions, we relied on Sukalla and colleagues definition that engagement is the individual's experience of processing a narrative through cognitive and emotional immersion with the experience (Sukalla, Bilandzic, Bolls, & Busselle, 2016). We also incorporated four different dimensions of *narrative* engagement (Busselle & Bilandzic, 2009): attentional focus (attending to the story plot and characters), narrative understanding (making sense of the story), emotional engagement (emoting with and for the characters), and narrative presence (losing awareness of the actual world and feeling present in the story world). We asked audience members about key moments during the play where they felt most engaged. As such, our engagement measures allowed us to understand audience members' overall absorption or flow during the play.

The overall purpose of this study was to examine the potential use of thermography as a tool to analyze audience engagement during a 1-hour play to understand the impact of theatre performance on audience engagement. We speculated that there would be a strong association between physical engagement, as measured by thermographic temperature patterns, and subjective engagement, as measured by a survey. By doing so, we hope to be evaluate the effectiveness of thermography as a potential tool for audience reception.

Methodology

Study Overview

To fulfill the purpose of the study the selection of the production was very important. One of the biggest issues we encountered in our mid-sized Southwestern town was that of finding professional actors in a community that had only community or university theatre. We wanted professional actors so as to control the performance variables as much as possible. For example, if participants attended an amateur performance, their level of engagement could potentially vary due to the quality of the production instead of what was occurring during the play. Moreover, participants that attend community or amateur theatre often do so to support family and friends in the cast; this could also affect their level of engagement. The researchers did find two professional actors that had recently produced Albee's *Zoo Story* and asked them to provide one additional performance for the purposes of this study. It was a small production and ideal for the research and the space that was available. *Zoo story* is a one-act play written in 1958 where two men encounter each other in New York City's Central Park. During the story, Jerry approaches Peter and asks him personal questions and then tells him about his life, where he lives and his bizarre landlady who has a dog. Jerry then tells Peter how we tried to poison the dog and the outcomes of his intent. Peter grows increasingly agitated by the encounter while Jerry becomes more and more abusive provoking a fight. Jerry tosses Peter a knife and then impales himself on the knife.

This study included mixed methods of data collection. Before the performance, participants completed a background questionnaire and a pre-show measure of wellbeing. During the performance, thermographic images that measured body temperature variations in the audience were taken. After the performance, participants completed a post-show self-report survey and we collected data one week after the performance. However, for the purpose of this article, we only review relevant demographic characteristics, thermographic photographs, and the post-show self-report survey.

Participants

A total of 22 participants took part in this study by attending a specially-offered, free performance of *Zoo Story*. Recruitment for the participants took place through fliers and a pre-screening telephone conversation to determine eligibility. To be eligible, participants had to be 18 years or older, fluent in English, report no major psychiatric disturbance during the prior year and willing to avoid ingesting cigarettes, caffeine, or alcohol as well as avoid exercising during the 2 hours before the performance. According to previous studies (Ioannou et al. 2013; Jarlier et al. 2011; Merla &Romani, 2007), the latter behaviors could alter the images on the heat-sensing camera. This study was approved by the Institutional Review Board at our university and all procedures were followed.

For a summary of the sample characteristics, please see Table 1. The average age of the entire sample was 37 years (range 19 to 79); the majority were female, and a large percentage regularly attended theatrical cultural events. Many of the participants had acting experience and backstage technical experience. Most participants reported greater than average emotional and physical wellbeing. Out of the 22 participants, only 16 people were included in the thermographic analysis due to technical errors and missing data.

Table 1. Demographics for Both Entire Sample and Thermographic Sample

Characteristic	**Means (*SD;* range) or Percentage**	
	Entire Sample	**Final Thermographic Sample**
	n=22	**n=16**
Age	37.14 (19.79)	38.83 (20.93)
Gender	Male = 23% Female = 77%	Male = 25% Female = 75%
Ethnicity	Caucasian = 86% Hispanic = 18% Native American = 5%	Caucasian = 83% Hispanic = 17% Native American = 8%
Depression/Anxiety	1.88 (0.54)	2.04 (0.58)
Subjective Well-Being	0.21 (1.83)	0.18 (2.0)
Overall Health	3.68 (0.72)	3.83 (0.83)
Regular attendance at theatrical cultural events	68.2%	66.7%
Experience (professional or community) with theatre	Actor = 27.3% Technical = 36.4%	Actor = 8.3% Technical = 16.7%
Pre-Show Subjective Well Being	63.01 (10.26)	63.85 (8.20)
Narrative Engagement Scale	3.40 (0.46)	3.24 (0.52)
Script Engagement – Overall	3.85 (0.48)	3.91 (0.49)

Questionnaires

Demographics. Participants were asked about their gender, age, and health status and whether they participated in community or professional theatre as an actor or in another capacity (e.g., costumes, lighting, etc.).

Post-show Questionnaire. Participants were asked to rate their engagement during specific moments during the show to determine their involvement at key intervals

of the play by specifically indicating which parts of the performance they thought were noteworthy or engaged them the most. For this section, we included a list of 19 moments that occurred during the play (in chronological order according to the representation) and participants were asked to rate how engaged they were using a Likert-type scale, where 1 = not engaged at all, 3 = somewhat engaged, and 5 = extremely engaged. To determine this list of moments, we interviewed one of the two main actors and three other theatre scholars. Between all of them, we identified the "most significant moments of the play," and we also included non-relevant moments to the list to be able to compare. Additionally, we shared and evaluated the final list with the same actor to guarantee that all moments were recognizable and easy to remember. To analyze the data from the survey questions, we used SPSS.

Thermography Technique

This technique is based on the reception and quantification of the emission and reflection of thermal radiation and its transformation into digital pictures. It is a non-invasive technique since it can be carried out at a relatively long distance. Through these digital images, the changes in facial temperature can be recorded and related to the time of the scene, thus establishing a correspondence.

Image 1. Thermography technique from real photo to thermography. Photo by Elena SV Flys in 2012. Used by permission.

For this study, a FLIR A6750 longwave infrared thermal camera was used. The thermographic camera was placed on stage in the front right section of the theatre. The camera operator and camera were covered by a black panel, which had a hole in the center for the camera's lens. The bench used for the scene was located to the right of the black panel. Participants were seated in a specific section of the theatre where the camera could capture all participants at once. Each seat was identified with a number for data collection processes. Thus, each image collected the data for all participants at once.

To collect data, we used Research IR software and programmed the camera to take pictures every 5s (96 minutes). A total of 1152 images were taken. Pictures were taken continuously while participants were completing the pre-show self-report survey, during the show, and while they were completing the post-show self-report survey. Each

image was then paired with the specific time of the whole experience. To accurately do this, the researchers kept time frames for each part of the experience (before, during, and after the show). For the final analysis, we decided to study images of every 10s (66 minutes), a total of 660 images with the 22 participants, giving us a total of 13860 records. In addition, for each image, the temperature of the room was collected to identify how this temperature may have influenced our participants. For accuracy purposes, the temperature data for each individual was specifically taken from the nose area of each participant using a 9-pixel range cursor. This area was pointed out as one of the most significant ones according to Tanaka et al. (1998), Salazar et Al. (2015), Hahn et al. (2012), and Ioannou et al. (2013). Moreover, it was the only common area for all participants, considering that some of them had glasses or facial hair, both of which can alter the temperature of those facial areas.

When analyzing the data of each individual, the researcher categorized the images in terms of quality, producing 10 categories: good, good-hand, guessing, guessing-hand, bad-down, bad-hand, bad-down hand, bad-profile , bad-profile hand, and not valid. The category of good described a perfect state of image where the nose area was perfectly visible while the guessing category was given to those images that were blurry but the nose area was still able to be identified. The bad categories were related to those images where the participant was looking down (bad down) or looking away (bad profile) but the nose area was still visible to be measured. Categories that include the word "hand" describe those images where the hand was in contact with the facial area. The category of not valid was given to those images where the nose area was covered or the participant was completely in profile not being able to reach the specific area of analysis. Not valid, good-hand, guessing-hand, bad-down hand, bad-hand and bad-profile hand inputs were taken out of the study since previous research shows that the contact of the hand with the face may alter the temperature of that specific area (Memarian, Venetsanopoulos, & Chau, 2009; Sanchez-Vizcaino Flys 2013). The rest of the images were kept in the analysis. However, if while screening the data, temperature record increased or decreased drastically and unrealistically[1], then the researcher went back to the photograph to determine if the error was a consequence of the computer cursor location. If this was the case, then the data was corrected by taking the correct reading of the data (new location of the cursor). If the data was correct but still unrealistic, potentially due to technological error, then the researcher softened the data by averaging the temperatures from 10s before and 10s after.

Thermographic data analysis and processing. We divided the results into three different subsections: global temperature evolution, individual temperature pre-processing and comparison, and individual and group short period temperature behaviors. The first section provides an overview in the thermographic data for each participant. The second section explains the techniques utilized to standardized the temperature data of all participants into the range of [-1, 1], the use of Piecewise Aggregate Approximation (PAA) to reduce the number of data points and to smooth temperature fluctuations, and the comparison analysis between room temperature and

[1] Concretely, we considered a drastically decreased temperature value when it places out of the boundary of the mean value plus/minus 3 times the standard deviation of the previous 10 temperature values recorded.

participants temperature. The last section explores the use of a clustering algorithm to classify temperature behaviors, the comparison between self-reported engagement level and temperature behaviors in short time periods, and the exploration of subgroup behaviors in relation to temperature and engagement.

Data collection and cleansing. Along the entire experience, we collected a total of 660 IR pictures, i.e. 660 time steps: from t=1 to t=29, before the play; from t=30 to t=433, the play; and from t=434 to t=660, after the play. Thus, each participant had a time series with all their thermos data reports, collecting a total of collected 23 time series of temperature values T_i, one per each participant (i=1,2,…,22) and one for room temperature T_0. Data analyses were carried out with MATLAB 2017b software. Due to long periods of missing data, some participants were removed from this analysis (participants in analyses will vary from n=11 or n=16).

Individual temperature pre-processing and data comparison techniques. Participants had very different temperature fluctuations over the course of the play within themselves and compared to each other. For example, while the average temperature of one participant could range from 37 ºC – 39 °C another participant could have a very different range from 36.5-38 °C. Thus, to be able to analyze and compare each participant, the data was standardized into the range of [-1, 1], associating the maximum value of temperature to 1 and the minimum to -1. In addition, to deal with temperature fluctuations we used Piecewise Aggregate Approximation (PAA) to reduce the number of data points and to smooth temperature fluctuations in order to make the plot more readable.

To compare two time series, we used Cross-Correlation (x-correlation). The result of the evaluation of a x-correlation between two time series is a new series where, in the case of working with time series bounded into [-1,1], y-axis values close to 1 shows a high similitude between both lines, and x-axis shows the displacements (if x equals to 0 represent no time lag). This analysis was used to evaluate the influence of room temperature in each participant and then to compare individuals one to each other in order to find similar temperature behaviors along the play.

Individual and group short period temperature behaviors data processing techniques. To study shorter time period temperature behavior patterns and engagement level, two analysis were studied.

For the first analysis, two variables were considered at any time *t*. First the current value of temperature at a time t (standardized between -1 and 1), which represent the intensity of the body temperature; and second the slope of trend line between the last 5 temperature values (T(*t*-5), T(*t*-4),…,T(*t*)), which represent an instantly temperature decreasing (negative slope) or increasing (positive slope). After collecting both variables per individual along the time series, the *k-means* algorithm was used to cluster all instants into 9 types of behavior. Cluster type 1 represents stable temperature (neither high nor low) and no drastic changes either way. Cluster type 2 represents slightly high temperature and a drastic increase of temperature changes. Cluster type 3 represents higher temperature and no drastic changes. Cluster type 4 represents slightly lower temperature and a small increase in temperature. Cluster type 5 represents slightly high

temperature and a slight decrease in temperature. Cluster type 6 represents high temperature but with no drastic change. Cluster type 7 is the opposite of 6, low temperature and no changes. Cluster type 8 represents lower temperature and a decrease in temperature. Last, cluster type 9 represents lower temperature and a drastic increase in temperature.

To analyze more concisely this clustering approach, the list of moments developed for the survey and the data collected from the 11 participants for each moment was studied. The goal was to determine if specific patterns of temperature behavior were shown in relation to short moments of the play. Alternatively, in a second analysis, we smoothed every time series by using the mean moving average for time windows of *n=5*, *10* and *25*. The result of a moving average is a new time series. So, three time series (for n=5, n=10, and n=25) with information of 16 participants were created. In the case of n=5 for the participant i=1, the new time series is computed, for each *t*, through the mean value of T(*t*-5), T(*t*-4),…, T(t). We used these series to compute the slope of the trend line as above mentioned. The goal was to study each of the moments using the average temperature for each of the time slopes included and determine whether the tendency was for the average temperature to increase or to decrease.

Table 2. Moments of the play listed in the surveys, initial and final time slopes and number of slopes.

	Moment of the Play listed in surveys[2]	Initial Time	Final Time	Number of time steps
1	Do you mind if we talk?	29	33	5
2	Where do you live?	56	60	5
3	Jerry asks Peter who his favorite writers are	70	74	5
4	Jerry explains Peter where he lives	77	90	14
5	Jerry talks about his family (mother, father, aunt)	98	114	17
6	Description about the landlady	136	144	9
7	"And I made up my mind. I decided first to kill the dog kindly"	183	187	5
8	"So, I decided to kill the dog"	206	210	5
9	"The beast was deathly ill" **	221	225	5
10	Jerry explains that the dog and he have found a compromise. "The story of Jerry and the Dog, the end"	289	309	21
11	Peter says he doesn´t understand and doesn´t want to hear anymore	311	320	10
12	Jerry tickles Peter	326	337	12
13	Jerry keeps trying to push Peter off the bench	338	351	14
14	"Long enough"	351	355	5
15	Peter stands on bench and calls the police	360	364	5
16	(takes out the knife)	382	386	5
17	"So be it "Jerry impales himself on the knife	397	401	5
18	Jerry thanks Peter	405	409	5
19	Peter grabs the book	427	431	5

The next step was to analyze the temperature of each individual to determine whether there were moments/scenes where the temperature fluctuation of all participants was closer to each other or not. To do so, the value for each moment given by *n*=5; *n*=10; *n*=25 and for each individual was taken. Since each moment/section had different amounts of time steps, we collected the average data for each moment taking into consideration the amount of slopes and the median point for them. For example, for section #1 “Do you mind if we talk?” we collected the data from the database *n*=5 and selected the median point from time slopes 29-33. For moment/section #11, we collected the data from the *n*=10 database since the time slopes were more than 5 and less than 20.

Table 3. Moments of the play listed in the surveys, number of slopes, *n* database selected for each moment, and specific time slope selected.

[2] Times were codified into time steps. The beginning of the play 18:33:24pm was codified to time step #1 and the end of the play 19:30:39pm as time slope #510. Each 10s has a time step number that corresponds to each image. Thus, each of these moments/sections of the play will have (x) amount of time steps depending on the duration of the moment/section.

	Moment of the Play listed in surveys	Number of time steps	N Database	#Time Slope Selected for each participant
1	Do you mind if we talk?	5	5	31
2	Where do you live?	5	5	59
3	Jerry asks Peter who his favorite writers are	5	5	73
4	Jerry explains Peter where he lives	14	10	81
5	Jerry talks about his family (mother, father, aunt)	17	10	104
6	Description about the landlady	9	10	140
7	"And I made up my mind. I decided first to kill the dog kindly"	5	5	185
8	"So, I decided to kill the dog"	5	5	208
9	"The beast was deathly ill" **	5	5	223
10	Jerry explains that the dog and he have found a compromise. "The story of Jerry and the Dog, the end"	21	25	298
11	Peter says he doesn´t understand and doesn´t want to hear anymore	10	10	315
12	Jerry tickles Peter	12	10	330
13	Jerry keeps trying to push Peter off the bench	14	10	343
14	"Long enough"	5	5	353
15	Peter stands on bench and calls the police	5	5	362
16	(takes out the knife)	5	5	384
17	"So be it "Jerry impales himself on the knife	5	5	399
18	Jerry thanks Peter	5	5	407
19	Peter grabs the book	5	5	429

With each participant's time slope temperature collected, the range of the data was calculated by taking the minimum and the maximum values. The smaller the range value, the closer the temperature fluctuation was among participants.

To find individual and group patterns among participants according to their thermography data, individuals were grouped depending on their level of engagement with the play, their previous relation with theatre (regular theatre attendees or not), and/or the location in which they were seated at the theatre[3]. The goal of this analysis was to determine if there were any temperature behavior patterns among participants in relation with the other three variables. This was calculated by using range values.

Results

The overall goal of this paper was to analyze the use of thermography for audience reception research. As such, we review our strategic approach to evaluating the data.

[3] Location was determined in two different ways. The first was the row where participants were seated (closer to the stage or further away) and the second was the distance between participants.

Global Temperature Evolution First, we examined the overall data, i.e., the average temperature of all audience members along the entire experience, before, during, and after the show.

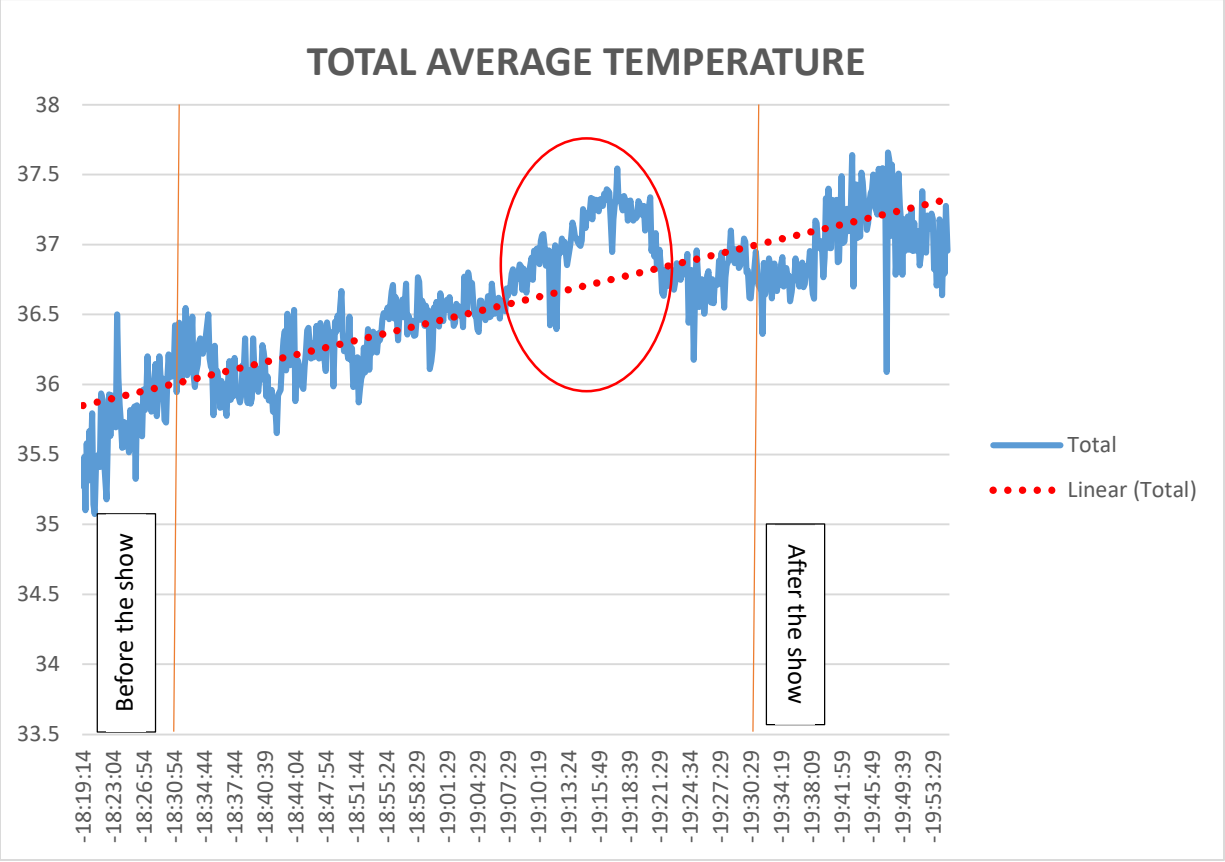


Figure 1. Figure shows in the x-axis the temperature and a timeline in the y-axis. The blue line represents the average temperature of the 22 participants and the dotted red line the trendline. The red circle indicates the specific moment where there is a temperature peak.

As shown in Figure 1, the overall temperature values *increased* gradually over time. Additionally, this plot shows long periods with different temperature fluctuations. For instance, between 19:07 to 19:21, a relevant increment of temperature values was observed and between 19:30 to 19:38, when audience started the post-surveys, a normalization in temperature was seen. These results revealed an overall pattern of increasing temperatures from the beginning to the end of the play, which was especially pronounced by the end of the play (marked in the graphic), in most audience members.

Second, in order to specifically link the thermographic data to the events that actually occurred during the performance (minutes 18:32:44 to19:29:49), and to know what was occurring during the designated time period, we created Figure 2, aligning the averaged thermographic data of all participants with specific narratives that occurred during the play. This closer look showed different peaks and fluctuations that, in relation to the time axis, allowed the researchers to link the fluctuations to specific parts of the play.

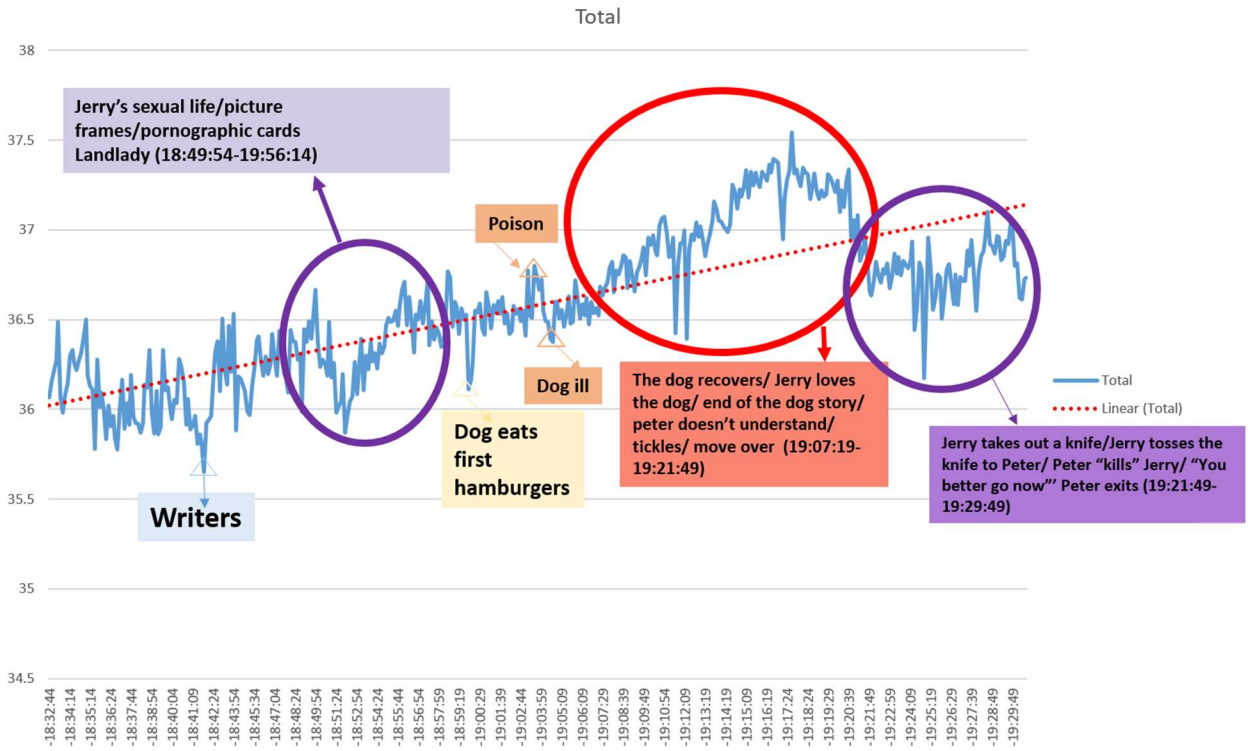
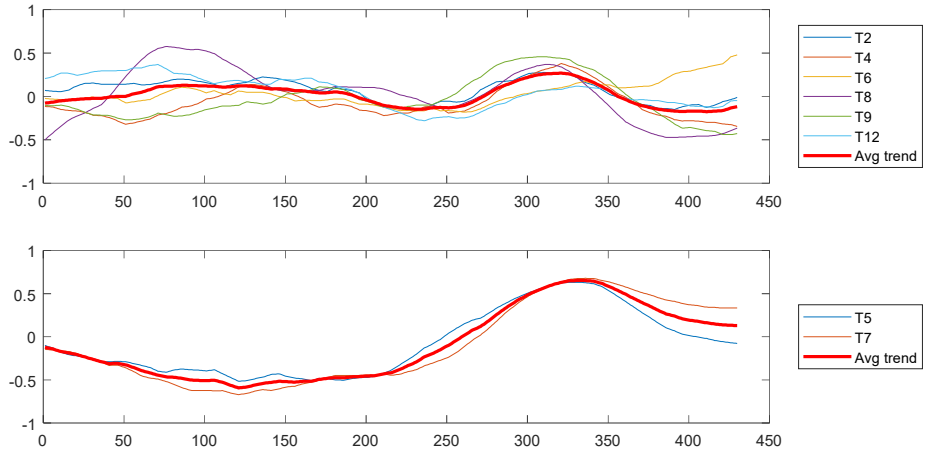


Figure 2. Figure shows in the x-axis the temperature and the play's timeline in the y-axis. The boxes include the information about what was on stage at that moment. The section marked with a red circle is the peak highlighted in the previous figure. Each arrow points to the moments of the play described in the boxes below or next to the areas of the figure.

In this analysis, different sections of the play were marked as well as the temperature fluctuations within them. Figure 2 clearly demonstrates the potential temperature fluctuations in relation to specific moments of the play. It also indicates the specific moment during which all audience members had an *increase in their temperature, followed by a decrease*; these align with the end of the dog story and the beginning of the fight between both characters. However, because the average temperature of all participants was taken into consideration, we needed to look at the specifics of each individual to see their overall data and how was the temperature of each individual affecting the general average.

Individual Temperature Preprocessing and Comparison Third, according to Merla & Romani (2007), Nhan & Chau (2010), Jarlier et al. (2011), Salazar et al (2015), and Ioannaou et al. (2013), room temperature can affect individual thermographic data. Most of these studies were held in temperature-controlled rooms. Although, we did not have control of the room temperature, we did monitor it and were able to see that the room stayed between 26.9-29.7 C. Results from the cross correlation analysis showed that since only four participants demonstrated a strong correlation with room temperature. As such, the room temperature did not appear to impact the majority of participants, when examined globally and individually. Therefore, it was not necessary to use room temperature as a covariate, i.e., remove it from individual data.

For the first analysis of this section, only eleven participants were chosen. These eleven participants appeared to have the strongest thermographic data and no missing data[4](participants A, B, D, E, F, H, I, J, K, M and T). The objective was to compare individuals by using their average temperature during the entire play as shown in figures 3 and 4.



Figures 3 and 4. The x-axis of these figures shows the standardized temperature reports of participants and the y-axis the time range.

The results of this analysis showed us, once again, what was seen in the first figure. It seemed as if most individuals (participants: B (T2), E (T4), H (T6), J (T8), K (T9) T (T12)) had similar temperature patterns, especially towards the end of the play (time range 250-400) as shown in figure 3. Due to lower temperature at the beginning of the experience, individuals F (T5) and I (T7) were separated from the rest (figure 4), noticing that both their temperature variation was almost identical during the entire experience and similar to the rest from time range 250 until the end of the show. Three participants out of this pool were not included in the figures. Participant A (T1) had a completely different temperature pattern compared to the rest of the audience members. Participant D (T3) had the same temperature pattern as the rest at the end of the play (around time 250) but not during the beginning. Participant M (T10) had a similar temperature pattern at the end of the play as well but really high temperatures during the beginning of the play (maybe due to a small fever).

Results indicated that, indeed, there was a potential trend in terms of temperature variations (as shown in figures 1-2), and it also suggested that an analysis of specific moments could be developed to learn more about temperature behaviors in specific moments.

Individual and Group Short Period Temperature Behaviors Results from shorter time period temperature behavior patterns and engagement are discussed in this section.

[4] As mentioned in the methodology section, due to the selection process of images there were several images categorized as not valid or good-hand that were taken out of the study leaving some of the participants with some gaps/missing data during the entire experience.

The first analysis was developed to review temperature behavior patterns among participants. To try this new technique we only utilized the data collected from the 11 participants that had no gaps in their temperature data. Nine clusters of temperature behavior patterns were created and studied among the participants. The following figure shows the distribution of temperature behaviors among the different clusters for the 11 participants during the play.

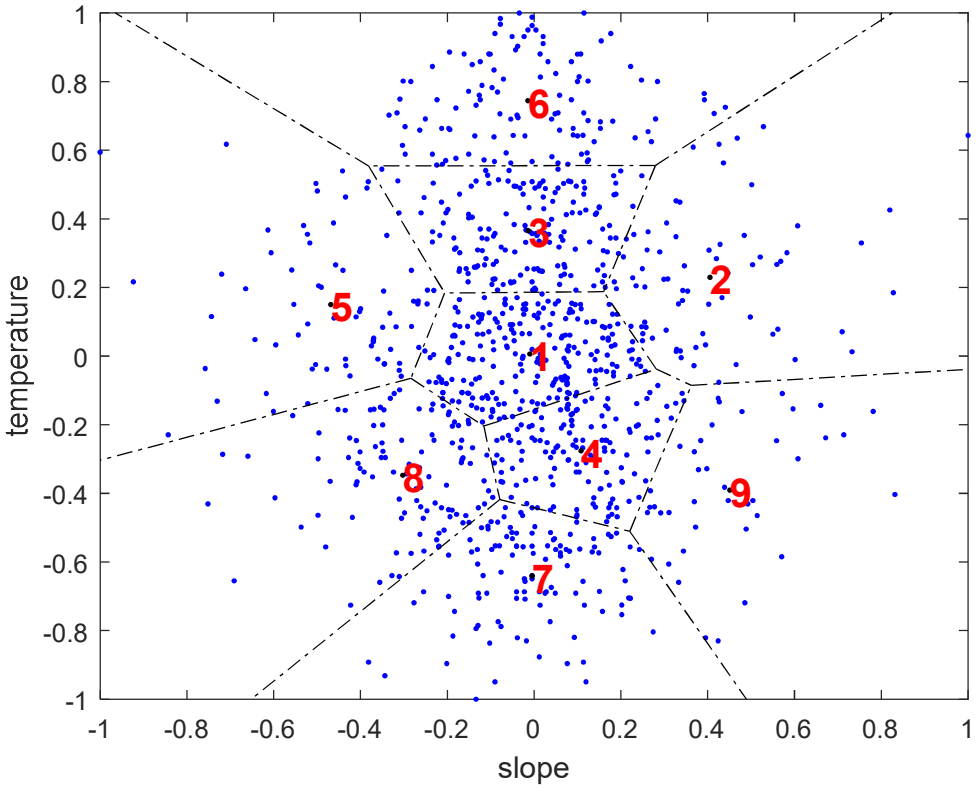


Figure 5. Figure shows the distribution of temperature behaviors among the different clusters for the 11 participants during the play. The description of each cluster is included in page 9.

A table for the results of the 11 participants was also designed and analyzed to search for each cluster's frequency in relation to the moments of the play. To keep the results noteworthy, only those with 50% or above, meaning that out of 11 participants the temperature variation of six or more of them fell into a specific cluster, were considered. Results showed only two specific time periods (T296-300 and T301-305) where that occurred. During the first time period, the temperature variation of six participants fell into cluster 1, and during the second time period the temperature variation of six participants fell into that same cluster. Thus, towards the end of the dog story when Jerry explains that the dog and he had found a compromise, the temperature of 50% of the analyzed participants was neither high nor low and with no drastic changes. This section corresponded with the top of the peak of temperature increase that we have seen all along in the study.

However, no more time periods had notable results which meant that even though the data had been standardized, the small variances between each individual

temperature report did not allow a clear view of a pattern (the changes were to small but still too different to be able to see any type of temperature pattern).

With the second analysis and using the three new time series with the smother data (n=5, n=10, n=25), each of the moments listed in the surveys was analyzed. By including moments/sections from the play and maintaining them in chronological order, we could also use these results as an overall view of temperature patterns during the entire performance. Although this approach was similar to the clustering algorithm, the intention was to reduce the categories/clusters and study whether there was a correlation between moment average temperature behavior and engagement[5] reported by participants through self-reported surveys. The following table shows results of engagement and thermography tendencies. For this section, data for 16 of the participants for each time period was collected[6].

Table 4. Moments of the play listed in the surveys, thermography patterns and tendencies, and results of engagement for the thermographic sample and the entire sample.

Characteristic	**Means (*SD;* range) or Percentage**		
	Thermo Tendencies	**Thermographic Sample (n=16)**	**Entire Sample (n=22)**
Jerry asks Peter if they can talk	Increase	3.07 (0.96)	2.95 (0.94)
Jerry asks Peter about favorite writers	Decrease	2.53 (0.74)	2.45 (0.83)
Jerry asks Peter where he lives	Decrease	3.20 (0.94)	3.20 (0.89)
Jerry explains to Peter where he lives	Increase	3.33 (0.98)	3.40 (0.99)
Jerry talks about his family	Increase	3.73 (0.80)	3.70 (0.80)
Jerry describes landlady	Decrease	4.07 (0.70) 7	4.00 (0.79)
Jerry tells Peter about plans to kill dog	Decrease	4.20 (0.68) 5 (t)	4.25 (0.72) 4
Jerry realizes dog is ill	Increase	4.13 (0.64) 6 (t)	4.20 (0.70) 6
Jerry talks about compromise with dog	Decrease	4.13 (0.64) 6 (t)	4.15 (0.88) 7
Peter says he doesn't want to hear any more	Increase	4.00 (0.65) 8 (t)	3.90 (0.79)
Jerry tickles Peter	Decrease	3.87 (0.99)	3.65 (0.99)
Jerry tries to push Peter off bench	Increase (trendline doesn't show the down at the end)	4.20 (0.86) 5 (t)	4.00 (0.92)

[5] Engagement was measured with a 0 to 5 point scale where "0" means lower engagement and "5" means higher engagement. Numbers next to engagement data show the ranking patrons gave to each moment. Those with a (t) corresponding to those moments indicate there was a tie in ranking.

[6] In this part of the study, we had 16 instead of 21 people because participants with more than four consecutive time-slots without data were removed. Participants who had less than four consecutive time-slots without data were kept. To successfully analyze the temperature in those participants with gaps, we calculated the average temperature of that specific time slot by taking into consideration the data from the previous and the following time slots.

Peter says he has put up with Jerry long enough	Decrease	4.13 (0.83) 6	4.05 (0.83) 8
Peter stands on bench and calls for police	Decrease	4.00 (0.85) 8 (t)	3.95 (0.94)
Jerry takes out knife	Stable tendency drop	4.67 (0.49) 2	4.55 (0.60) 2
Peter kills Jerry	Decrease	4.80 (0.41) 1	4.65 (0.49) 1
Jerry thanks Peter	Decrease	4.60 (0.83) 3	4.50 (0.83) 3
Peter grabs the book	Stable/ Decrease	4.50 (0.65) 4	4.22 (0.88) 5

Results showed that out of all of the moments/scenes that participants scored between 4-5 on engagement level (12 in total for the thermographic sample and 10 for the entire sample), nine (72%) in the thermographic sample and 8 (80%) in the entire sample had a tendency of temperature decrease and three (25%) in the thermographic sample and two (20%) in the entire sample had a tendency to temperature increase. Moreover, the three most relevant/engaging moments (according to self-reported surveys) had a temperature decrease fluctuation.

The second step of this second analysis was to determine whether there were moments/scenes where the temperature fluctuation of all participants was closer to each other or not. Results of the range analysis for all of the moments varied from a minimum of 0.014 to a maximum difference of 0.053. This shows that during specific moments the temperature behavior of all participants was very similar. Thus, during moments #10 and #11 (“Jerry explains that the dog and he have found a compromise: the end of the dog story” “Peter says he doesn’t understand and doesn’t want to hear anymore) the temperature pattern behavior for all spectators was almost the same, which correlates with the results shown in the clustering analysis and those shown in the overall figures. However, when comparing the data with the engagement level reported in the surveys, no similar pattern was observed. The hypothesis was that in the moments where participants reported higher engagement, their temperatures would be similar to each other. The results of this analysis show that this hypothesis was incorrect.

More explorations were developed to examine individual and group patterns among participants according to their thermography data. Non-strong patterns that would relate any of the groups with their thermography data were found in the results to determine which audience members had the closest temperature behaviors and if those were related to either their level of engagement, previous experience with theatre, and/or the location in which they were seated. Nonetheless, each participant was compared individually with each of the other participants. Results showed that the differences were minimal amongst most of the participants, having minimum data entries such as 0.103 and maximum entries such as 0.33. In addition, from this analysis, two other observations should be highlighted. First, participants E and L and participants I and F showed practically the same temperature patterns because their range difference was less than 0.137 for the first and was 0.103 for the second. The second, interestingly seven participants (44%) showed their temperature fluctuations were closest to participant I. This could be because participant I’s temperature was closest to the average temperature

of all participants and one who rated probably the highest overall engagement in the self-reported survey. In addition, six participants (38%) shared their biggest difference in temperature fluctuation with person T who had also reported an overall high engagement, but had the furthest relation to the overall average temperature.

Discussion

Overall, the results of this study suggest that there was a consistent temperature pattern that all audience members followed. We found that temperature fluctuations were linked to different parts of the performance, creating almost a similar but inverted[7] graphic to the one used by theatre scholars to analyze the dramatic structure of a play. Where previous studies, such as Devlin et al.'s (see UCL 2017) showed that audience members watching a live theatre performance could synchronize their heartbeat with other people in the audience without knowing each other, we also found that patrons shared similar temperature behavior: there was a decrease in body temperature during highly engaging moments/scenes of the play in the majority of participants. .

Thus, inspection of the data suggested that the peak temperature *change* matched the "rising action" in the play, as well as audience engagement. When compared, the thermographic data was consistent with the self-report of engagement, showing that those moments/scenes where participants scored their highest level of engagement, the average temperature of participants decreased. In other words, the audience appeared to be in synchrony with the production and therefore engaged with it. This would explain the increase in temperature of all participants at the end of the show, as well as the temperature fluctuations in relationship to the plot. To more fully support this finding, we would need to develop more studies with greater sample sizes and across different types of plays, e.g., comedies, romance, etc. From this analysis, it can be concluded that, besides the temperature pattern found in the overall average temperature, each of the moments/scenes had a traceable temperature pattern that tended to decrease or increase. Overall, we did find support for the idea that there is a relationship between high audience engagement and temperature *decrease*. Previous thermography studies have shown that temperature decreases and increases were related to specific emotions; we did not examine specific emotions. However, it is a reasonable conjecture that we would find thermographic changes in accordance with specific emotions. For example, the moment where Jerry tickles Peter can provoke laughter and maybe that may be why the temperature tendency decreased, based on Salazar et al. (2015). More data and a larger sample would be needed in order to support this conclusion. In addition, it would be interesting to analyze how much of the results are due to the audience empathizing with the feelings of the characters and not necessarily to what they are personally feeling[8]. Hence, more research in this area needs to be done in order to analyze whether self-reported responses and physical responses always match. Although temperature decreases were predominantly

[7] Inverted because in dramatic structure analysis, the climax is at the top of the peak; in this thermography analysis, the climax was reflected as a temperature decrease.

[8] "In regard to the contagiousness of laughter and of pain, it is interesting to note that despite dealing with emotions of opposite valence, nasal temp decreased in both cases and that the change in temperature is associated to participant's empathy level" (Salazar et al. 2015, 57)

associated with engagement, it could also have been due to the experience of specific emotions provoked by each scene. The latter would corroborate the idea suggested before regarding the relationship with the dramatic structure of a play and that engagement is the overall fluctuation and not a specific pattern of increase or decrease.

Results of this study suggest that there is no relationship between temperature pattern and seat location in the theatre as well as no relationship with previous leisure activities. Eversmann stated that the more often you go to the theatre the more critical[9] you become (2004). Thus, one could have predicted that thermographic data from more "seasoned" theatre attendees would be different than those of novices. We found no such relationship between theatre attendance and thermographic behavior.

As part of this discussion, we include all the learned lessons for future research in audience reception with thermography.

Lessons Learned

1. Selection of the play. Our primary goal was to have professionals on stage and we picked a previously performed play by two known actors to facilitate this process. We now also realize the importance of the play selection. The production of Albee's *Zoo Story* has its own difficulty as a play. Many have argued about Albee's use of techniques and ideas from the 'absurdist" plays for this play (Kolin, 2005). Thus, this could explain why the structure, and especially the themes of the play, such as miscommunication, isolation and loneliness, can be interpreted by audience members in many different ways, making it difficult for the researchers to identify specific themes, moments and areas and relate them to an explicit emotion or temperature behavior. This is something that would probably not happen in other plays, for example, in a Greek tragedy or a realism play where the dramatic structure, themes and plot tend to be very clear and common to all participants. Perhaps, the use of another play would have facilitated the identification of different temperature behaviors. Certainly, a less ambiguous play would lend itself to analysis more easily. Moreover, we also wondered about the role of gender in engagement; unfortunately, our sample size was too small to evaluate this. It is of note that our professional actors were both male and most of our participants were female; engagement may be different based on gender, as well as the interactivity between audience and cast and audience to audience.

2. Camera location and data collection. Another component to consider for future projects is the perfect location for the thermographic camera as this played an important role in the way we collected data. For example, although our, camera location allowed us to observe all 21 participants we encountered several problems. In order to centralize the camera's location, part of the action of the play was moved to a specific side of the stage (to avoid actors being in front of the camera making it impossible to collect data). Consequently, patrons would follow the action not only with their eyes but also with their heads positioning themselves in profile to the thermographic data at many key moments during the play. Thus, some of the data collected could not be used and was categorized as "not valid" due to the lack of access to the front area of the nose. As

[9] Critical referred to staging, acting, plot and everything related to the artistic design of the play.

such, we would recommend a camera that is in an elevated position, above the stage, so as to observe the audience members' faces and not interfere with actor location. In addition, most thermographic studies concentrate in specific areas of the face. We conclude that for future audience data collection (more than one participant being studied), the average temperature of the *entire face* should be considered. This will facilitate not only the work of the researcher but also the accuracy of the recorded temperature. If we consider the entire facial area, we will be able to analyze more of the data independently if they move.

3. Room temperature and seasonality. Our results indicate that room temperature did not have a great impact on participants. Although it is important to keep measuring room temperature to ensure that there is no drastic change at any given moment, this study shows that the room temperature was minimally important.Another question that was brought up was seasonality and month of the year. For example, this play occurred in December when it was snowing outside; this could have impacted the room temperature as well as the attire worn by audience attendees. Although this could be an issue, most theatrical environments (including this one) are temperature controlled. Moreover, we did measure participants' temperature before the play to calculate their baseline temperature. As a result, some of the participants had to be disqualified (as explained in methodology) due to high temperatures indicating a potential sickness or fever. We did not note any participants with decreased body temperatures.

4. Thermography data treatment. In this article, we have described different ways to approach and treat thermographic data. Due to body temperature's small variation, we conclude that the best way to continue this work is by standardizing the data and smooth the time series by using a mean moving average. It is worth noting that most previous thermographic studies collected data from one individual at a time and for shorter time periods, providing data with potentially fewer variables or fluctuations. Thus, the data treatment method described above is what we recommend for longer time periods and more than one participant studies.

5. Cost and future use. The cost of renting a thermographic camera is more affordable each year (definitely more affordable and less invasive than collecting other physiological data, such as saliva). We were able to rent the camera for one week for $1600.

There is a variety of ways in which these data could be utilized in the future. For example, the benefits of understanding the impact that theatre has during the actual representation can provide insight information to arts administrators in terms of which productions engage more audience members. It could also be combined with other techniques to measure audience's wellbeing and serve as a useful assessment to explain the benefits of the arts. Due to its noninvasive approach this technique could also be used to measure the engagement of audience members with cognitive disabilities that might not be able to express verbally or by written means their feedback (e.g. Memarian et al.'s research 2009). As Brown & Novak-Leonard (2013) state measuring the arts impact and how individuals benefit from the arts will play a growing role in arts policy in future years. Therefore, we need to continue researching tools that will allow us to understand how art works on audience members.

Conclusion

Thermography is an interesting and promising tool to measure objective engagement from audience members, but it may be limited when used by itself. The results of this study showed that there is a connection between audience temperature behavior and what is happening on stage as well as temperature and self-reported engagement. Although previous investigators have examined temperature patterns and emotions, we are the first investigators to examine audience engagement and temperature patterns in theatre audience members. This seems like a useful approach for future studies since it gives us the opportunity to study and join audience members during the performance. As McConahie (2008)[10] states, the theatre is something alive that takes place in an immediate space and time. Therefore, the reactions of the audience are spontaneous and unrepeatable. Thus, by collecting surveys and thermography data we were able to analyze a broader experience and combine objective temperature patterns with subjective beliefs about the experience. While we agree that any production is more than the text and actors, we only measured the impact of the entire experience on the audience; this was not broken down into smaller components. Last, this paper provides future researchers with practical guidelines for the use of thermography in theatre audience engagement research such as the selection of play, the best location of the camera, the relation between room temperature and audience members, and how to collect and treat data obtained.

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[10] McConahie (2008), pp. 7.

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