WASHINGTON STATE UNIVERSITY

School of Music

MUS 702

Masters Special Problems, Directed Study and Examination

THE HEATED TRUMPET STAND AND COMBATING EXTERNAL TEMPERATURE CHANGES: SOLVING INTONATION ISSUES FOR TRUMPET PLAYERS

Submitted by

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ABSTRACT

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This project began after spending many years sitting through frigid football games for marching band and performing in a variety of ensemble and orchestral settings with long breaks and *tacets*. My intonation would be negatively affected by the varying external temperatures, which in turn impacted the full ensembles in which I participated until my instrument returned to the approximate temperature of human breath, around 86-90 degrees Fahrenheit. I also witnessed marching band competitions in colder weather, where soloists would end up with frozen valves and could not perform. This project was the result of ruminating on this problem and aiming to find an accessible solution, that would create a more seamless transition from rest to performance.

Research has been conducted with the Washington State University trumpet professor, Dr. David Turnbull, and the Washington State University trumpet studio. The priority of the design was efficient airflow from the stand through the trumpet itself. The stand is switch operated and rechargeable for the most efficient usage as well as for ease of transportation.

While the focus of this project is based around the physical stand, there is an accompanying document that contains an introduction, the history of trumpet intonation, methods that have been attempted to remedy intonation issues, the design and construction

process, a collection of data showing the stands efficiency, surveys from study participants, and a bibliography.

With the invention of this product, I have brought an accessible method of reducing intonation issues that will allow trumpet players to maintain their intonation and match the ensemble more effectively. The result of this project is a trumpet stand that can easily replace traditional trumpet stands, while providing additional functions that aid in the instrument's intonation. This design can also serve as a template for heated stands to benefit other brass instruments.

ACKNOWLEDGEMENTS

I would like to thank Dr. David Turnbull for supporting me throughout my time at Washington State University. His encouragement, advice, and his service as my committee chair made this project possible. I will forever be thankful for our educational discussions.

Thank you to my family for supporting me through my degree and being my biggest cheerleaders. A special thanks to my father, Robert Swanson, for helping me learn the tools I needed to build my project. I would not be where I am now without your guidance. Thank you to my mother, Kimberley Swanson, for reminding me that I am worth more than I tell myself.

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INTRODUCTION

Intonation among trumpet players has been a consistent issue throughout the recorded history of the instrument, especially those faced with external temperatures in outdoor performance spaces, performance settings with different building temperatures, and in repertoire with lengthy *tacets*. Trumpet players have tried multiple methods to prevent intonation inconsistencies during performance such as blowing air through their instruments during rests, bending pitches through embouchure shifts, and constantly adjusting the third valve slide and tuning slides. The goal of this project is to eliminate the need for excessive measures to be taken regarding tuning during or prior to performances that occur within the realm of these factors.

For trumpet players dealing with intonation issues while performing can be incredibly frustrating and negatively impacts the sound of individuals and ensembles. The heated trumpet stand reduces additional adjustments and performer frustrations that are often caused by the negative impacts of the sound of individuals with cold trumpets and their respective ensembles.

BACKGROUND

Throughout my experience in marching bands and pep bands, I have dealt with a variety of external temperatures in practice and performance spaces. Within the trumpet section, I have personally experienced instruments becoming increasingly out of tune due to weather at pep events at football games. I have also witnessed soloists at marching competitions with frozen valves, which can negatively impact their ensembles' overall scores.

After dealing with these issues in a variety of instances, I wanted to find a solution that would increase the accuracy of the trumpet in these settings and create more consistency in intonation overall. I spent hours perusing for sources in the Washington State University libraries and on the internet, seeking to find any current inventions or solutions that would maintain trumpet intonation during breaks in performances or *tacets*. I could not find anything that would satisfactorily deal with this issue, and thus decided to attempt to invent my own solution.

SCOPE

This project will cover the design and creation of the heated trumpet stand, which is a switch operated, rechargeable heating alternative for trumpet players facing external temperature conflicts with intonation. This project will be limited solely to the assistance of trumpet players and focus only on usage in outdoor performance and select ensemble settings, such as *tacets,* long breaks between pieces or performances, and temperamental environments such as churches and concert halls. This project is also focused only on a heated stand's benefit for trumpet players, and not any other brass instruments. Within this document there will be sections dedicated to the history of intonation difficulties regarding trumpet players, the process of design for the stand, construction, testing trials, as well as future research goals and implications.

PART 2

HISTORY OF INTONATION ISSUES IN TRUMPET PLAYING

Throughout the history of the trumpet, the physical attributes and temperament of the instrument's construction has affected intonation on several notes, specifically the fifth and seventh partials within the harmonic overtone series of B-flat trumpets, circled in the figure below.

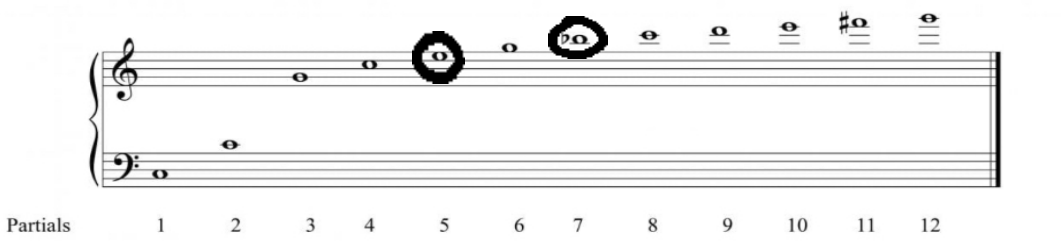

Figure 1: Harmonic Overtone Series

With the rise of natural trumpets in the Renaissance and Baroque periods in Europe, it became very clear that in regard to the harmonic overtone series the fifth and seventh partials were significantly out of tune.[1] These trumpets were often only able to be adjusted using tuning bits in five-cent movements.[2] As lip-reed aerophones, it was the performers responsibility to bend the pitches depending on how sharp or flat specific notes in the harmonic overtone series.[3]

When developing the modern trumpet, the addition of piston valves positively impacted the intonation of the instrument but did not fully solve those issues. Lengthening the trumpet

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[1] Erika L. Schafer, "Trumpet Tuning Tendencies Relating to the Overtone Series with Solutions," *UTC Trumpet Studio*, https://blog.utc.edu/erika-schafer/trumpet-tuning-tendencies-relating-to-the-overtone-series-with-solutions-2/.

[2] "Trumpet – Egger," *EGGER Historic Trumpets*, https://eggerinstruments.ch/en/historic/trumpets/.

[3] Edward H. Tarr, "The Trumpet before 1800," *The Cambridge Companion to Brass Instruments* (October 13, 1997): 84–102.

using the valves to lower pitches by a single semitone requires a change in length of 5.9%.[4] Taking this into context, the average length of a modern B-flat trumpet is 140 centimeters in length. This means that a single semitone would require a change in length by 8.3 centimeters. When depressed, the first valve of the instrument adds an additional 6% of length to the instrument. The second valve also has similar length in regard to these intonation changes, as both of these valves are made slightly longer than the third when used independently in order to combat as many of the tuning difficulties the instrument has as possible.[5]

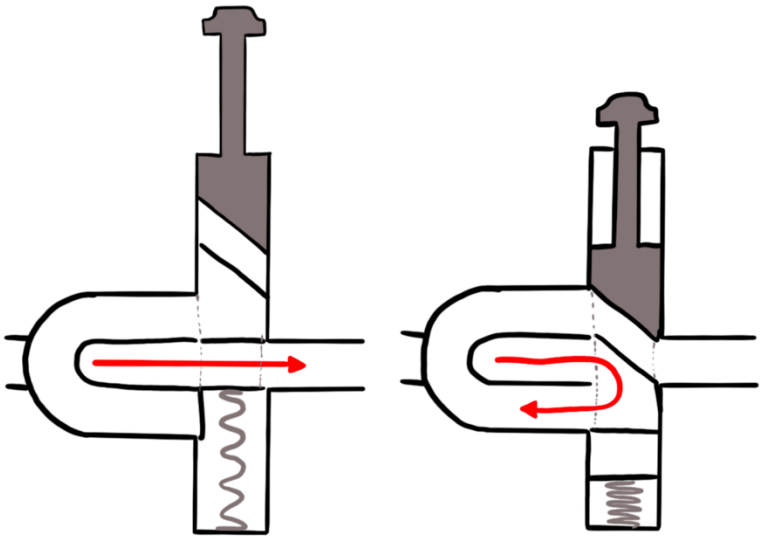

Figure 2: Difference Between Uncompressed and Decompressed Piston Valve

[4] Thomas J. Moore, "The Acoustics of Brass Musical Instruments," *Acoustics Today* (Winter 2016): 33, https://acousticstoday.org/wp-content/uploads/2016/12/Brass.pdf.

[5] Moore, "The Acoustics of Brass Musical Instruments," 34.

However, this does not fully resolve the intonation issues naturally laying on the instrument's harmonic overtone series. While the tubing is increased there is still a difference between the true sounding note and the notes intonation via tubing depression.[6]

External temperatures make intonation issues even more pronounced and difficult for musicians to correct. While they have been somewhat reduced using alternate fingerings, shifts in embouchure, tuning slide adjustments, and the addition of piston valves to the instrument, when faced with colder external temperatures these notes will still become exponentially out of tune because every note on the instrument becomes more out of tune at the same rate. This is because as external temperatures lower, the materials within the instrument shrink, causing the speed of the sound waves traveling inside to slow down slightly as the air molecules grow colder. The sensitivity of the human ear can pick up on these changes, which is how notes can be perceived as 'flat.' Moisture within the instrument's valves can freeze within the instrument as well, which can cause tuning slides and the valves themselves to become stuck. This negatively impacts the efficiency of valve decompression, and thus removes the ability to lengthen the tubing of the instrument.

[6] Moore, "The Acoustics of Brass Musical Instruments," 36.

PAST SOLUTIONS FOR TRUMPET INTONATION ISSUES

The only observed solutions for trumpet intonation issues that do not directly coincide with the evolution of the instrument itself is a mention of the desire for a heated stand, the use of space heaters, and an expired US Patent. An online blog post on the 'Trumpet Herald' contains two mentions of a stand from 2006, with one expressing interest in a potential heated stand being invented, and the other expressing interest in an idea called the "electric sock method."[7] There are no observed blog posts that date past this 2006 thread referring to a heated stand of any kind.

The 'Trumpet Herald' also contains a secondary thread from 2014 where a discussion about how to keep your trumpet warm during club and outdoor gigs was held.[8] There was not much back and forth within this thread, however there was the suggestion of using a space heater and keeping the trumpet nearby. The use of space heaters and heated fans to keep instruments warm has been a common solution to standing out in the cold with an instrument, however this is not necessarily a feasible option in many performance venues or event locations such as on stage at concerts and in stadiums for pep band gigs.

There is also a single expired US Patent (US4529865A) by Philip B. Oakes, Jr. for an electrically heated musical instrument stand from 1983, expiring in 2003 after the initial publication application was not renewed.[9] This stand has no record of being manufactured or sold.

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[7] Francois, "Horn Warmer, Anyone? - View Topic: Trumpet Herald Forum," *TrumpetHerald.Com*, January 4, 2006, https://www.trumpetherald.com/forum/viewtopic.php?t=47759&sid=5f321a6dfc04aa9c0f5d1f220921ad4f.

[8] "How Can I Keep the Cornet and/or Mouthpiece Warm? - View Topic: Trumpet Herald Forum." *TrumpetHerald.Com*, 2014, https://www.trumpetherald.com/forum/viewtopic.php?p=1392776&sid=7e6d28f7a44b2d6c37933fdb6f0b166b.

[9] Philip B. Oakes, "Electrically Heated Musical Instrument Stand," July 16, 1985.

While this stand contains a heating component, there is no specificity on whether this is for brass or wind instruments and does not have the necessary supports for the weight of a trumpet, as well as no portability or precautions for overheating. In addition to the support of instruments, this patent says that the stand could hold any number of instruments, however balancing issues could become a hazard, potentially leading to instrument damage. Regarding portability, according to the figure, the device needs to be plugged in for use which reduces the locations where the invention would be most useful.[10] Outdoor performances for marching bands, pep gigs, or other events would not permit a functioning stand unless outlets were available for use.

According to U.S. patent laws, when filing for a patent application there is no requirement for inventions to be built or prototyped.[11] This means that while this now expired patent could have been a viable solution for trumpet intonation in accordance with the technology available in 1983, the stand has not been proven as such.

[10] Philip B. Oakes, "Electrically Heated Musical Instrument Stand," July 16, 1985.

[11] Randall T. Erickson, "Should I Create a Prototype before Applying for a Patent on My Invention?" *Erickson Law Group, PC*, https://www.ericksonlawgroup.com/law/patents/patentfaq/create-prototype-before-applying-for-patent-on-my-invention/.

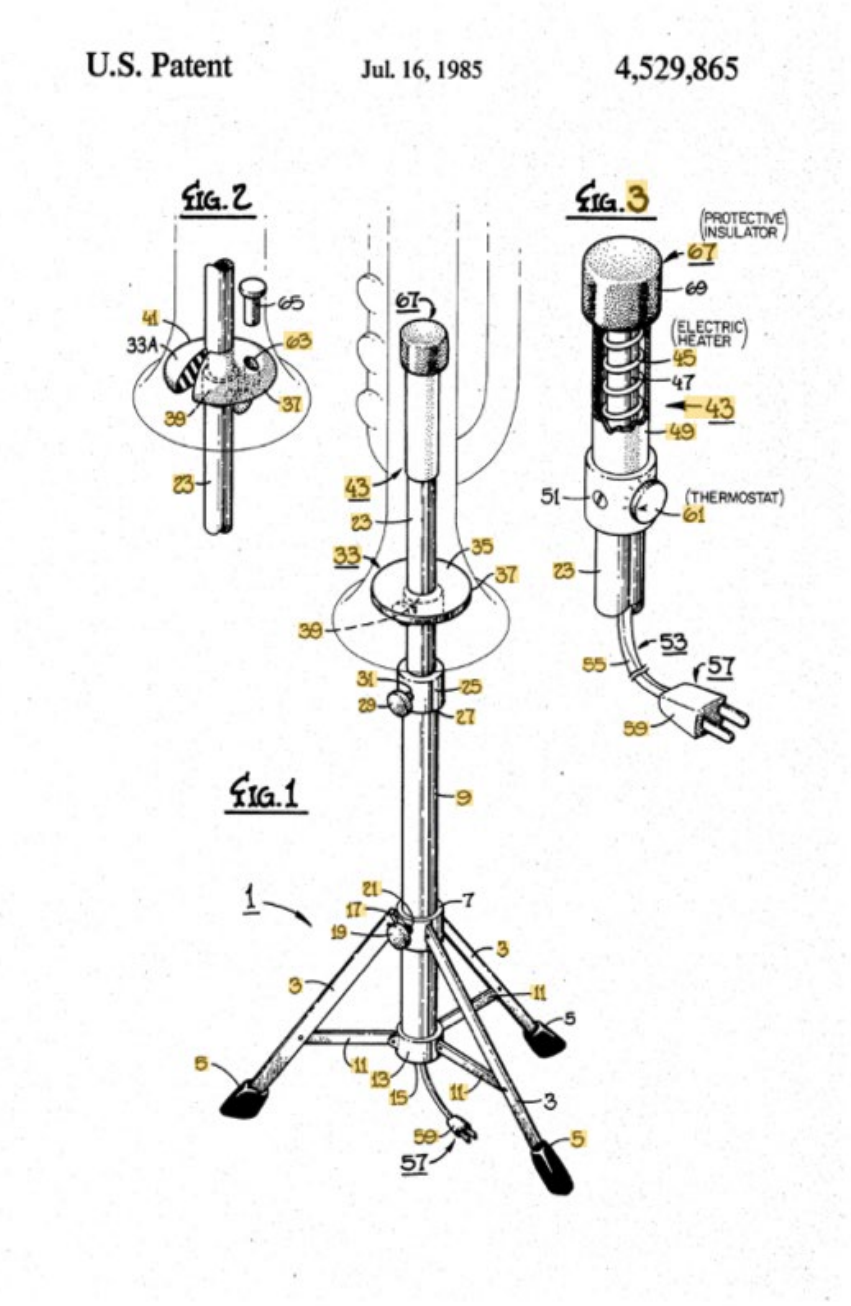

Figure 3: 1983 Electronic Heated Musical Instrument Stand

PART 3

CREATION TIMELINE, CONS˙ .UCTION, AND PROGRESS

From the idea of this stand, the collection of materials, and the construction of the stand itself, this project spanned approximately three months. I spent two weeks researching to find a heating mechanism that would be the most beneficial for this project. Finding the most effective heater that would not cause any damage was the most important step in the construction process. This project began with finding a main source of heat and flow that could be easily controlled and would not cause damage to instruments through prolonged use. These requirements led me to a 12V 100W Fdit PTC Car Fan Air Heater which would allow me to do this on a scale small enough to be utilized for the trumpet stand. This mechanism allows automatic heating regulations, with the mechanisms capping at approximately 26 degrees Celsius or 78.8 degrees Fahrenheit. The reason for choosing a PTC, or Positive Temperature Coefficient heater, instead of a resistive heater is because the PTC Car Fan Air Heater is fully self-regulating. A resistance heater is a mechanism that takes electrical energy and converts it into heat as it passes through a conductor. These heaters do not have a built-in method of regulation and continue to create more thermal energy without a limit. While these heaters employ wires and coils to generate heat, PTC heaters use conductive inks printed on thin flexible polymer-based substrates, which are the same material as items like banknotes. PTCs also provide more uniform heating in comparison to the traditional resistance heaters in this size and wattage. This fully removes the risk of the trumpet

stand overheating, damage to the instrument, and any further issues. They also have a much longer lifespan than many other heating products on the market at this size and voltage.[12]

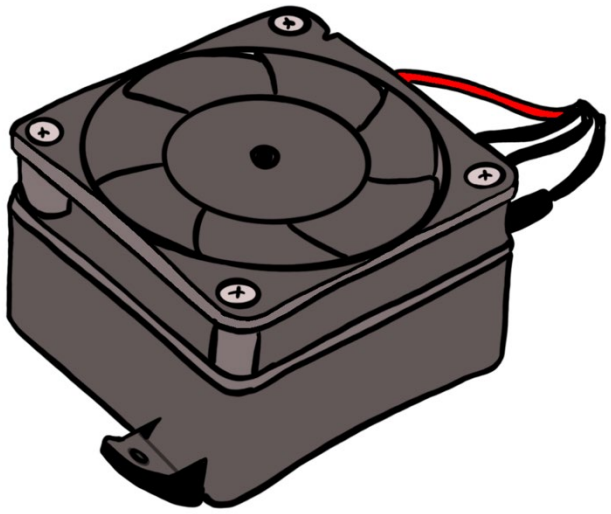

Figure 4: Fdit PTC Car Fan Air Heater

The second step was creating a link between both the fan and the heating mechanisms within the Fdit PTC Car Air Fan Heater, in order to create a constant flow of warm air. I took the positive wires and negative wires of both the fan mechanism and the heating mechanism, stripped them, and connected the wires together so that there is a seamless flow of power for both the fan and heating component. These wires were then inserted into vinyl insulated electrical wire fork connectors for ease of connection to a power supply.

These elements are powered with the use of a 12V rechargeable Milwaukee power tool battery, allowing the device to maintain portability and not have to rely on disposable batteries or

[12] Yu Aimei and Qiana Li, "Study on Thermal Control Behavior by Using BaTiO3-Based PTC Materials With Room Temperature Curie Point," https://asmedigitalcollection.asme.org/MNHT/proceedings-abstract/MNHMT2019/58905/V001T06A001/1071040.

electrical outlets. This also assures that the stand will stay charged and usable for a full gig due to its ability to power approximately five hours of continuous use.

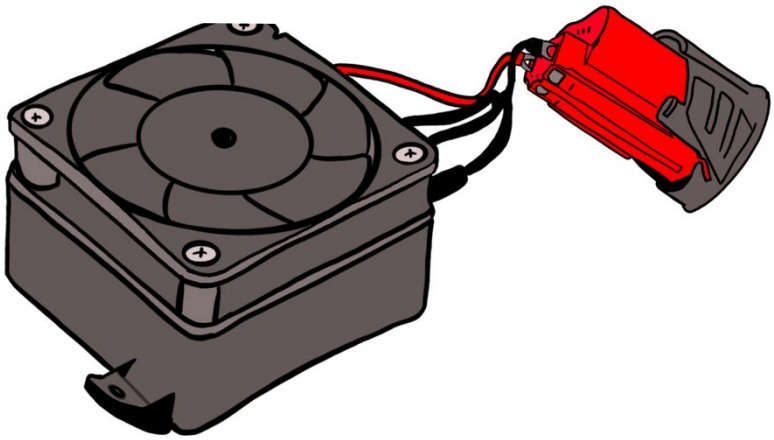

Figure 6: Fdit Car Fan Air Heater Attached to 12V Milwaukee Power Tool Battery

In order to provide a sturdy base structure for the stand, I used an electric saw to cut wooden boards into pieces to create a box to store the electrical components, prevent damage to the mechanisms, and support the weight of a trumpet. This was constructed using stabilizing wood glue and an 18-gauge brad nailer. Within this box, I also constructed a small shelf with a strap to house and hold the battery in place when in use and screwed the Fdit PTC Car Fan Heater into place at the top. To complete the construction of the stands body, I sawed a hole in the top of the box so the warm air could rise into trumpets placed on the stand.

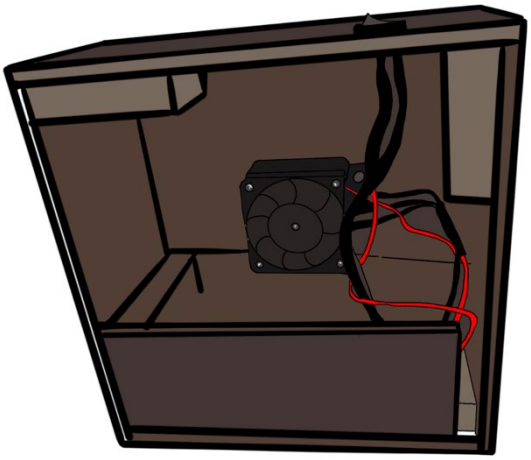

Figure 7: Inside View of Trumpet Stand

After completing the base, I hollowed out the center of a traditional trumpet stand to increase the beneficial airflow into the trumpet, as well as proper supports for any trumpet placed on the stand. This portion of the stand is removable through the use of detachable loop and hook fasteners. This is to allow access to the heating mechanisms of the Fdit PTC heater in case any dust or unwanted material may get stuck on them and allow easy maintenance.

The final addition to the stand was the installation of a switch accessible on the outside of the stand. I spliced the wiring of the switch into the PTC Car Fan Air Heater and used vinyl connectors to ensure that they stayed. This was added to ensure that the stand was quick and easy to turn on and off in between uses.

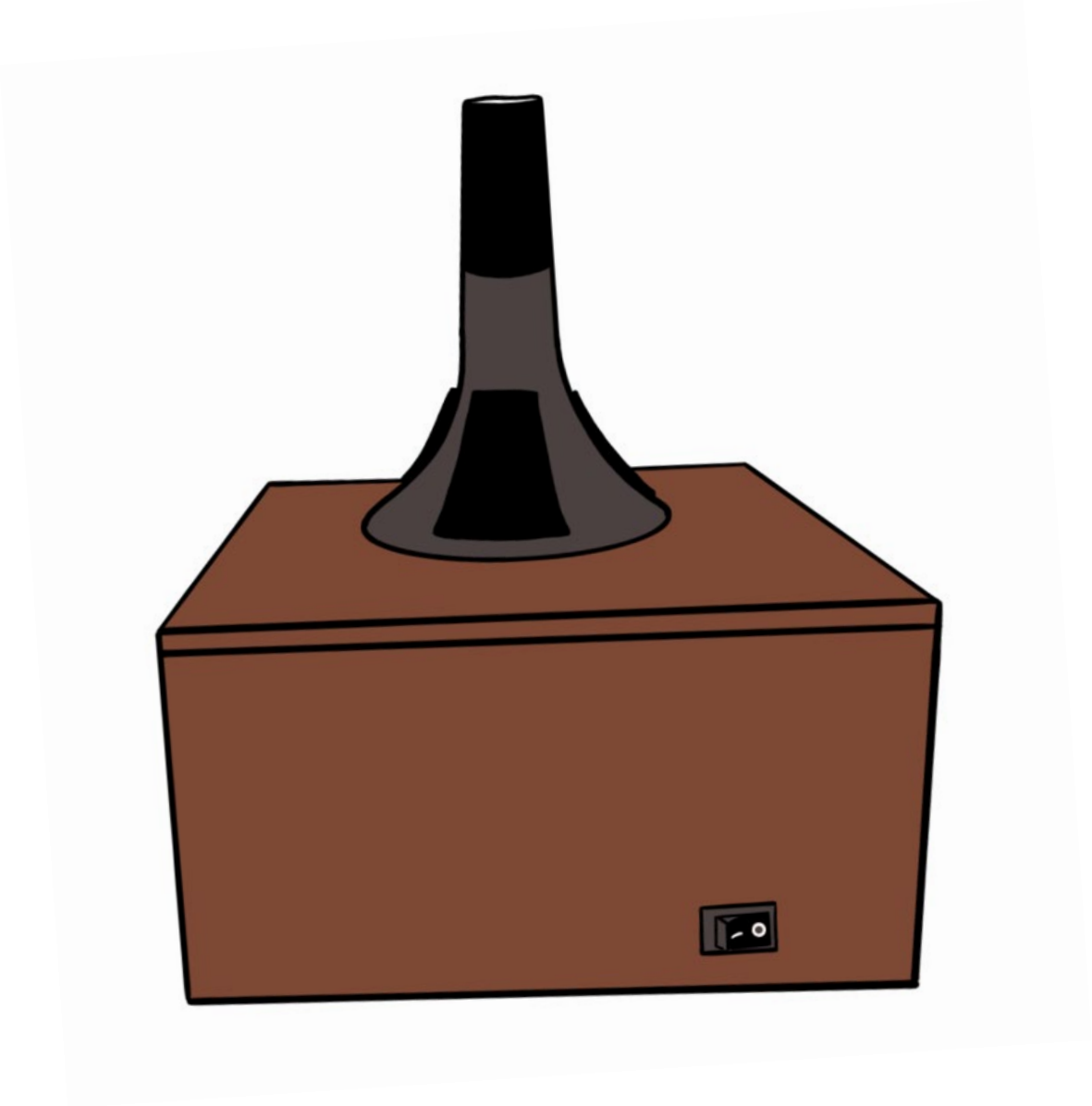

Figure 8: Outside View of Trumpet Stand

STUDENT SURVEY RESULTS

In order to obtain clear and unbiased results, testing of the heated trumpet stand was mapped out in a very clear manner. The initial testing for neutral results was conducted within the same practice room in Kimbrough Music Building. Fifteen tests were conducted, where participants were asked to play a Concert B-flat with the Tonal Energy tuning app, and then asked to play a short excerpt in the same key. Participants are then asked to place their trumpet on a stand outside of the building for five minutes, and once again play a Concert B-flat and the chosen excerpt. A final test was conducted with the participant using the Heated Trumpet Stand for five minutes and playing a final tuning note and the excerpt. The participant was then asked to give comments about their feedback and if they would purchase a heated stand if given the chance.

The results of this survey were measured by the difference in cents sharp or flat based on the environment where the excerpt was played. They were consistent across the shifts of intonation in the different environments, with much colder external temperatures increasing the audibility of intonation changes in each step of the survey.

The data points for this study were taken from three separate sessions so that there would not be outliers in regard to external temperature comparisons.

Participant #: 1 **(39° F)**	
Initial tuning and excerpt Result:	Tuning: +20 cents (sharp) Excerpt: +10 to +15 cents (sharp)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: – 5 to -10 cents (flat) Excerpt: -8 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: +15 cents (sharp) Excerpt: +15 to +20 cents (sharp)
Final comments from Participant about experience and personal comfortability:	"Naturally plays sharp but definitely felt a difference in transitions."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 2 **(39° F)**	
Initial tuning and excerpt Result:	Tuning: +3 to +5 cents (sharp) Excerpt: +1 to +3 cents (sharp)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -16 to -20 cents (flat) Excerpt: -16 to -20 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -3 to +2 cents Excerpt: +1 to +4 cents (sharp)
Final comments from Participant about experience and personal comfortability:	"Mouthpiece still cold but felt a significant difference between tunings and excerpts."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 3 **(39° F)**	
Initial tuning and excerpt Result:	Tuning: -16 cents (flat) Excerpts: -12 to -15 cents (flat)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the	Tuning: -35 to -40 cents (flat)

temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Excerpt: -37 to -42 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -17 to -20 cents (flat) Excerpt: -15 cents (flat)
Final comments from Participant about experience and personal comfortability:	Felt less resistance after using stand, felt smoother
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 4 (39° F)	
Initial tuning and excerpt Result:	Tuning: -6 to -10 cents (flat) Excerpt: -5 cents (flat)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -20 to -23 cents (flat) Excerpt: -15 to -20 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -6 to -8 cents (flat) Excerpt: – 5 to -8 cents (flat)
Final comments from Participant about experience and personal comfortability:	"Going from inside to cold was uncomfortable/ the stand made playing outside more bearable."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 5 (39° F)	
Initial tuning and excerpt Result:	Tuning: +3 to +7 cents (sharp) Excerpt: +5 to +7 cents (sharp)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -14 to -17 cents (flat) Excerpt: -13 to -17 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -4 to -1 cents (flat) Excerpt: – 5 to +1 cents
Final comments from Participant about experience and personal comfortability:	"Could definitely feel a difference between the stands. Hard to play when

	cold, but it got easier after being on the heater."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 6 (53° F)	
Initial tuning and excerpt Result:	Tuning: -3 to -5 cents (flat) Excerpt: – 10 to -13 cents (flat)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -6 to -8 cents (flat) Excerpt: -12 to -15 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: +5 to +7 cents (sharp) Excerpt: In tune to +3 cents (sharp)
Final comments from Participant about experience and personal comfortability:	"Heated stand felt the best and most comfortable. More in tune than cold."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 7 (53° F)	
Initial tuning and excerpt Result:	Tuning: +5 to +9 cents (sharp) Excerpt: +3 to +10 cents (sharp)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -4 to -7 cents (flat) Excerpt: -4 to -10 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -1 to +2 cents Excerpt: in tune to +4 cents (sharp)
Final comments from Participant about experience and personal comfortability:	"Didn't feel too much difference because not too cold outside, but I think this would work well for marching band."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 8 **(53° F)**	
Initial tuning and excerpt Result:	Tuning: -4 to -6 cents (flat) Excerpt: -3 cents to in tune
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -8 to -12 cents (flat) Excerpt: -5 to -9 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -3 to +1 cents Excerpt: -2 to in tune
Final comments from Participant about experience and personal comfortability:	"Felt a small change going from the normal stand to the heated one, not really positive or negative."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 9 **(53° F)**	
Initial tuning and excerpt Result:	Tuning: -2 to in tune Excerpt: -3 to in tune
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: – 4 to -8 cents (flat) Excerpt: – 3 to -8 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -2 to +2 cents Excerpt: -3 to in tune
Final comments from Participant about experience and personal comfortability:	"Felt like I had warmed up a bit after using the heated stand. Was not too cold outside so could not tell much of a difference personally/"
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 10 **(36° F)**	
Initial tuning and excerpt Result:	Tuning: -4 to -9 cents (flat) Excerpt: -3 to -6 cents (flat)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the	Tuning: -17 to -34 cents (flat)

temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Excerpt: -20 to -28 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -5 to -9 cents (flat) Excerpt: – 6 to -9 cents (flat)
Final comments from Participant about experience and personal comfortability:	"Did not like playing on the cold trumpet at all. Heated stand made it hurt less to play and felt like I slotted into notes a little better."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 11 (36° F)	
Initial tuning and excerpt Result:	Tuning: -6 cents (flat) Excerpt: +3 to -6 cents
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -15 to -20 cents (flat) Excerpt: – 16 – 23 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -4 to -7 cents (flat) Excerpt: -5 to in tune
Final comments from Participant about experience and personal comfortability:	"Felt more comfortable with heated stand/ felt a lot better than playing on a frozen trumpet."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 12 (36° F)	
Initial tuning and excerpt Result:	Tuning:-30 cents (flat) Excerpt: -28-37 cents (flat)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -50 -> went down to a concert A because it was so flat Excerpt: -37 to -49 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -20 cents (flat) Excerpt: -15 to -10 cents (flat) "Much more in tune!"

Final comments from Participant about experience and personal comfortability:	"Yay! Enjoyed the experience. Felt like it improved sound with minimal personal adjustments."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 13 (36° F)	
Initial tuning and excerpt Result:	Tuning: -2 cents tuning Excerpt: -25 to -15 cents (flat) +2 occasionally
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -34 cents (flat) Excerpt: -47 cents (flat) almost consistently
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -28 cents (flat) Excerpt: -14 to -17 cents Occasionally leaning sharp
Final comments from Participant about experience and personal comfortability:	"Used to cold trumpets, transition felt different. Could feel difference between the two and could feel it get closer to in tune."
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 14 (36° F)	
Initial tuning and excerpt Result:	Tuning: -5 cents tunings Excerpt: -20 cents (flat) on most notes, highest +4 (sharp)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -45 to -50 cents (flat) Excerpt: -35-49 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -27 to -30 cents (flat) Excerpt: -25 to -30 (flat)
Final comments from Participant about experience and personal comfortability:	"Fun, different, think that it is a good concept as

	someone who has been frozen out of rehearsals. Felt best on the third, felt more comfortable and confident.”
Would Participant purchase a Heated Trumpet Stand?:	YES

Participant #: 15 **(36° F)**	
Initial tuning and excerpt Result:	Tuning: -5cents (5 cents flat).. Excerpt: -10 cents sometimes peaking at +8 (sharp)
Tuning and excerpt result after trumpet has been on traditional trumpet stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -20 cents Excerpt: -37-43 cents (flat)
Tuning and excerpt result after trumpet has been on the Heated Trumpet Stand for 5 minutes within the temperature range of 32 degrees Fahrenheit to 65 degrees Fahrenheit:	Tuning: -13 cents (flat) Excerpt: -7 to +1 cents intonation-wise
Final comments from Participant about experience and personal comfortability:	“Felt more physically comfortable inside when cold, but heated stand felt better afterward compared to the cold stand. More comfortable felt like did better.”
Would Participant purchase a Heated Trumpet Stand?:	YES

After completing this study with three differing external temperatures, I found the mean of cents flat or sharp for the initial intonation, the traditional stand intonation, and the heated stand intonation, and visualized them into bar graphs based on the external temperature in which they were measured. This provides a clear view of the results of this study.

Participants	Mean of Initial Intonation	Mean of Traditional Stand Intonation	Mean of Heated Stand Intonation	External Temperature
Participant 1	15	-7.6	16.6	39°
Participant 2	3	-18	2.5	39°
Participant 3	-14.3	-38.5	-17.3	39°
Participant 4	-7	-19.5	-6.75	39°
Participant 5	5.5	-15.25	-2.25	39°
Participant 6	-7.75	-10.25	3.75	53°
Participant 7	6.75	-6.25	1.25	53°
Participant 8	-3.25	-8.5	1	53°
Participant 9	-1.25	-5.75	0.75	53°
Participant 10	-5.5	-29.75	-7.25	36°
Participant 11	-3	-18.5	-4	36°
Participant 12	-31.6	-45.3	-18.3	36°
Participant 13	-8.75	-40.5	-19.6	36°
Participant 14	-7	-44.75	-28	36°
Participant 15	-2.3	-33.3	-6.3	36°

Figure 9: Table of the Average Cents Flat or Sharp of Each Participant in Study

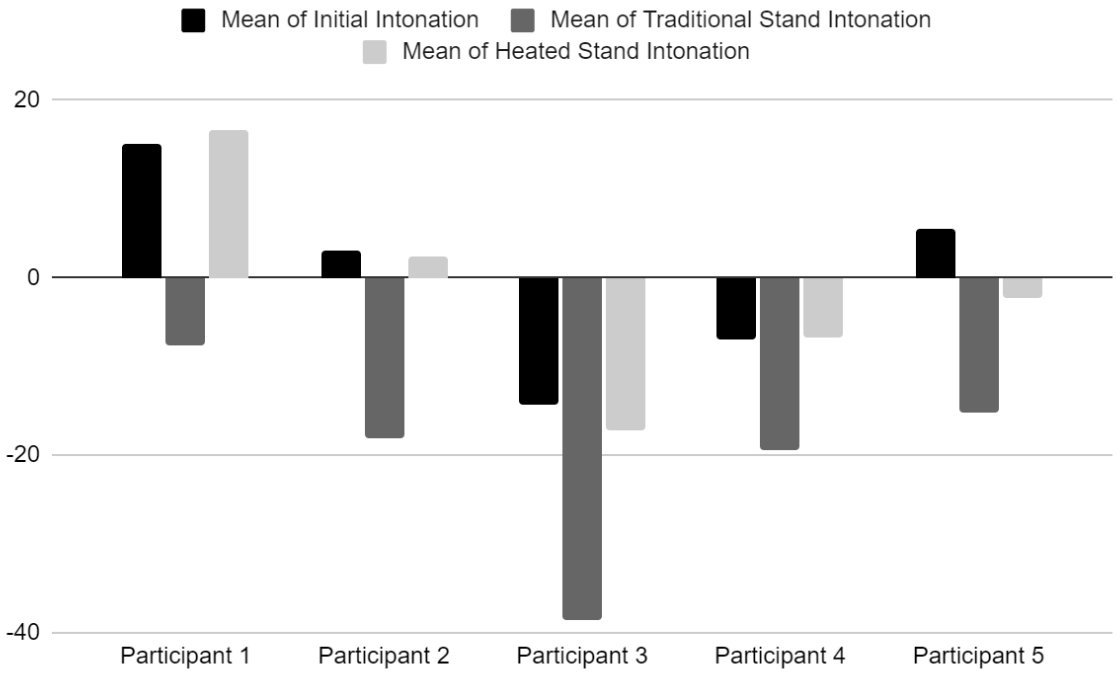

Figure 10: Results of Study in a 39° F Environment

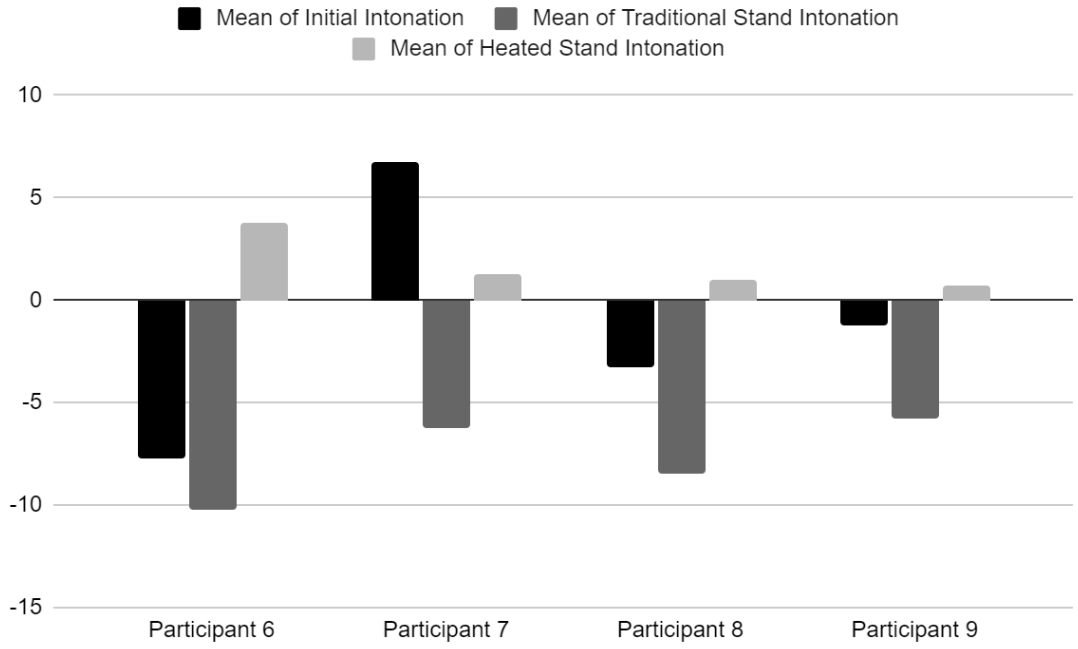

Figure 11: Results of Study in a 53° F Environment

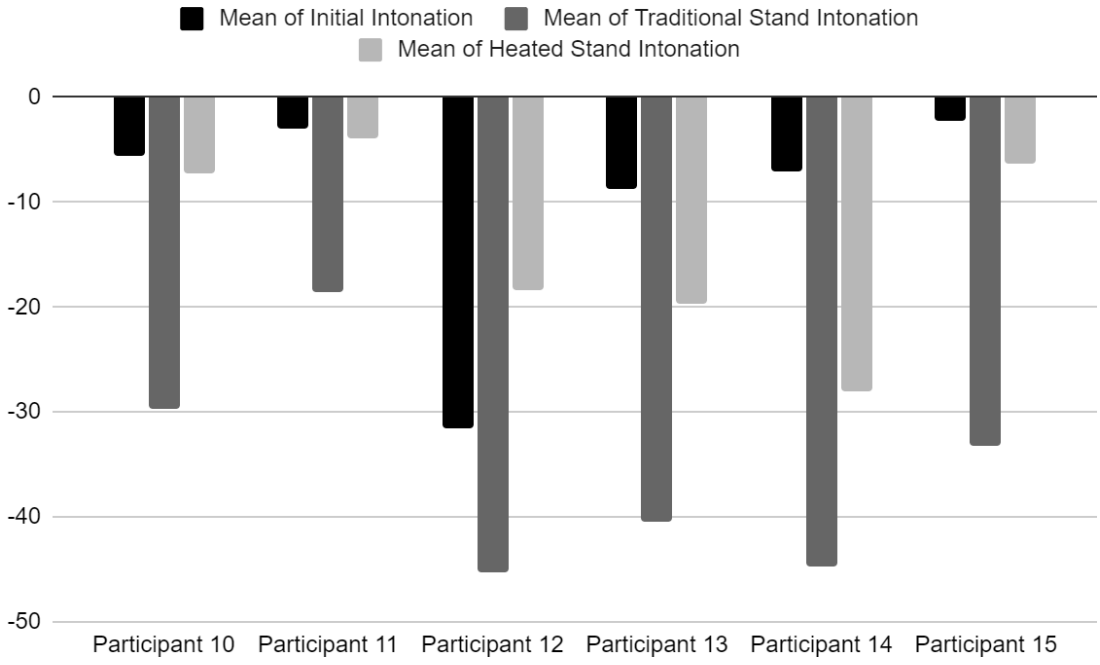

Figure 12: Results of Study in a 36° F Environment

CONCLUSION

In conclusion, the Heated Trumpet Stand is a beneficial solution to remedying intonations issues on the B-flat trumpet, specifically when faced with external temperatures below room temperature, or 68 degrees Fahrenheit.

After studying the intonation changes of multiple trumpet players in a neutral setting with and without the Heated Trumpet Stand, I can confidently state that there is a difference in intonation between the use of the stand and lack of the stand in an outdoor environment. This is shown in the changes of cents flat or sharp within the study results documented in this project.

Regarding further research and adjustments to this project, a higher voltage and more compact PTC heater would be beneficial in speeding up the heating process of trumpets when placed on the stand. One option for a more viable PTC heater would be the use of a Honeycomb PTC heater resistor, which has a flatter disc shape and can operate at a higher power than the Fdit PTC heater used in this initial model. A more compact design than the current prototype would also increase the ease of portability of the Heated Trumpet Stand. A more compact model can be achieved with a combination of the PTC heater change and creating a metal frame similar to trumpet stands that are inserted into only the bell. Regarding possible models for other instruments, similar stands can be made for trombones and French horns, and models that can be inserted into the bells of larger instruments such as euphoniums, baritones, tubas, and sousaphones.

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