The Pneumatic Practice Pad

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ABSTRACT
The Pneumatic Practice Pad is a commercially available 10" practice pad that has been modified to allow for tension changes in a matter of seconds using a small electric air pump. In this paper, we examine the rebound characteristics of the Pneumatic Practice Pad at various pressure presets and compare them to a sample of acoustic drums. We also review subjective feedback from participants in a playing test.

Author Keywords
NIME, percussion, pneumatics, percussion pedagogy

ACM Classification
H.5.2 [Information Interfaces and Presentation] User Interfaces
J.5 [Arts and Humanities] Performing Arts

1. INTRODUCTION
The practice pad is one of a percussionist's most valuable tools. Like a pair of favorite drumsticks, a practice pad can be a very personal device, with many percussionists owning one or two well-worn pads that travel everywhere in backpacks or stick bags for impromptu practice sessions. Students may use them to work on études and rudiments when a drum is impractical, say in their bedroom or dorm room, while professionals often use a pad to warmup before a performance.

Unlike drumsticks or mallets, most percussionists do not purchase dozens of varieties of practice pads to suit different situations. Practice pads tend to be fairly bulky and expensive, with the very cheapest full-size models starting around $25 and more boutique versions costing upwards of $100 [6]. In addition, the selection, though fairly robust in quantity, is generally limited to options that fall into one of three categories with various pros and cons:

- solid rubber or neoprene (e.g. Evans HQ RealFeel, Aquarian Tru-Bounce)
- tunable Mylar head (e.g. Remo Practice Pad, Sabian Quiet Tone)
- special use, often some version or combination of the previous two categories (A. Stubbs Timpani Practice Pad, Ahead Marching Bass Drum Practice Pad)

While all musicians are required to adapt to the sonic characteristics of different practice and performance environments, percussionists must also contend with substantially varied haptic responses as they change instruments. They often work with different arrangements of equipment dictated by repertoire and frequently switch instruments, from snare drum to timpani to marimba, sometimes during the same piece. Unlike a wind or string player, they are usually not in direct contact with their instrument; their sense of touch and feel must come through the medium of the stick or mallet [4].

A precisely and quickly tunable compact practice pad capable of producing a wide range of rebound characteristics or "feel" would be useful for students and professionals alike. Less-experienced percussionists could ensure that they are rehearsing new techniques with the appropriate rebound response, while a professional on tour could mimic the feel of an unfamiliar drum in order to run through material off-stage before a performance. Although existing tunable practice pad models allow for a limited range of tension variation and the rubber models are available in a few different gradations of hardness, none allow for infinitely variable or fast adjustments or a wide range of tensions. Electronic drum pads suffer the same shortfalls and, while very sophisticated and innovative in some regards with a price tag that reflects such advancements, have many similar drawbacks.

In this paper we explore multiple facets of a pneumatically adjustable practice pad, including design strategies and considerations, techniques for quantifying rebound characteristics, and advantages of the Pneumatic Practice Pad (PPP) over other devices. We also conduct playing tests to examine subjective player responses and test correlations between aural feedback and haptic feedback.

2. RELATED WORK
Most examples in the literature explore the sonic phenomena of drums, including acoustic response and modeling, rather than the rebound characteristics. Nevertheless, there are a small number of prior examples that informed the design and testing process for the PPP.

The Haptic Drum [2] takes a very unique approach to providing variable feedback to the percussionist through the stick-drumhead interface. This device used a woofer as an actuator to induce energy back into the drumstick, thus allowing for precision and speed of rebound that is not physically possible for the unassisted percussionist to replicate. In fact, a primary demonstration of the Haptic Drum is that it allows for easy one-handed rolls, freeing the other hand to play other rhythms simultaneously.

The studies in [5] strengthen the case for a continuously adjustable rebound characteristic as a practice tool by finding differences in the forearm muscle utilization of professional and intermediate drummers. Through analysis of myoelectric activity, it was evident that only the professional drummers compensated for the effect of rebound before stick impact and during preparatory motions. Earlier introduction and convenient access to playing surfaces with different tensions can help beginner percussionists progress quickly and professional percussionists maintain existing technique.

3. DESIGN
The PPP is based on a commercially available 10" practice pad. The original pad is comprised of a plastic base, a plastic hoop that retains the head, a standard 10" Mylar drum head, and a foam insert. Our modifications started by drilling holes into the plastic base and hoop

to insert vinyl tubing. The holes were then surrounded with silicone sealant in order to form an airtight seal around the tubes. We also removed most of the foam insert to provide an internal air chamber and make it easier to add components.

With no other changes, this early prototype was pressurized with an industrial compressor controlled by a regulator. We were surprised to find that very little pressure was required to have a noticeable effect - the head became extremely tight and the plastic body began to warp with only 2psi. At this setting, the rebound off of the head was incredibly strong and, anecdotally, beyond what any acoustic drum would produce.

An unexpected benefit of this low psi threshold is that it was quite easy to find a portable pump capable of providing the necessary pressure levels. We sourced a 12V pump capable of 32psi from electronic hobbyist supply shop SparkFun [6]. While we would only be working in the single digit psi range, the additional headroom on even this inexpensive pump may prove useful in future iterations.

Moving away from a steady supply of compressed air to a portable momentary pump proved to be challenging as the constant airflow from the large compressor overcame any leaks in the pad to hold a constant pressure. While the seals around the drilled tube holes were sufficient, we found that the interface between the Mylar head and the plastic rim of the base was not air tight, even under tension from the hoop. To resolve this, a custom gasket was made from a soft and flexible platinum silicone sourced from Tap Plastics [9]. This gasket was made to closely fit the circumference of the practice pad and was placed directly between the drumhead and the base. Under tension from the retaining screws, the gasket allowed us to hold the PPP at a constant pressure when filled from a short run on the portable pump. At pressures up to 0.5psi, the pad maintained set pressure levels for several minutes at a time with very little if any leaking.

4. MEASURING REBOUND

Our method for measuring rebound characteristics combined techniques from multiple sources. Miura used high-speed video to record a metal ball dropped onto a surface from a fixed height [5]. However, since we were interested in seeing the travel of an actual drumstick, a different release mechanism was required. Argo describes a mount with a drumstick attached via rubber bands, which apply downward force, to a central shaft [1]. We adopted the use of a shaft for the fulcrum and instead designed a custom device with laser cut acrylic and ball bearings. Our mount uses only gravity as the downward force, with a solenoid release mechanism to ensure a consistent and reliable drop height. Finally, a black and white checkerboard background with a 0.5cm grid was implemented as it provided a two-dimensional visual reference. This rig can be seen in Figure 1.

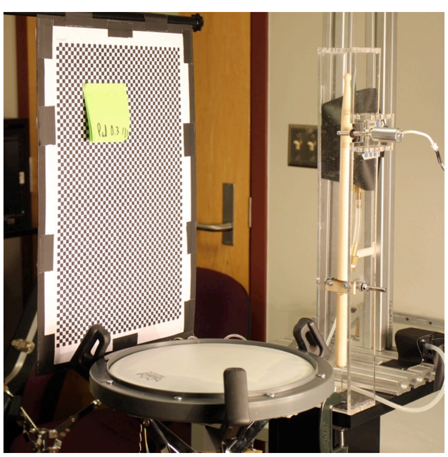

Figure 1. Rebound testing rig

Video was shot at 600fps. The pad was tested at .05psi intervals from 0psi up through 0.3psi. Though the pad is capable of pressures beyond this point, we stopped measurements at 0.3psi as rebound heights at higher pressures were literally off the charts - the limited resolution of our high-speed camera made excessive height measurements impractical. For comparison, we also tested a 14" snare drum and 14" floor tom, sizes standard to drumsets and concert percussion, resulting in a total of nine measurements. Although three takes were recorded at each setting in order to average the results, the rebound heights and speeds were so remarkably consistent that averaging was unnecessary. Since we were interested in the travel of the drumstick tip, the first point of contact with the head and apex after the first rebound were used to calculate the length of the arc using $S=R\theta$ with a radius of 30cm, which was the length of the drumstick from fulcrum to tip. Finally, the number of video frames between the point of contact and apex were counted and used to calculate the drumstick's velocity during the first bounce. The method for arc calculation and results of each test can be seen in Figures 2 and 3 respectively.

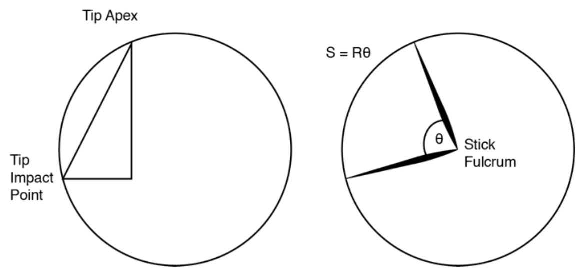

Figure 2. Arc length calculation

5. PLAYING TESTS

Seven current undergraduate and graduate percussion students were recruited for a playing test, all of whom have eight or more years of total playing experience. Each participant was asked to play approximately three minutes of material per trial, which included a few selections from the popular percussion method book Stick Control [8], a few measures of rudiments, and a short piece from the snare drum solo book All-American Drummer [11]. These specific exercises were chosen because they all fall under the rudimental snare drum style as opposed to the classical snare drum style - rudimental style emphasizes double stroke rolls, which are a very good indicator of rebound characteristics.

The exercises were repeated a total of eight times at fixed tempi, each time on a different instrument or PPP pressure setting. The first trial was on the participant's own practice pad as a control, while the final trial was on the PPP with a setting of 0.3psi, chosen because it was the highest pressure tested in our high-speed video measurements and its rebound strength was beyond that of the snare drum. The remaining six trials were randomly presented combinations of 0psi and 0.15psi with both complementary and contradictory aural feedback (see Table 1). These pressure settings were chosen as they most closely matched our floor tom and snare drum measurements respectively. Aural feedback was provided by a simple custom Max sampler instrument using recorded samples of the tested drums and a piezo sensor attached to the PPP for sample triggering.

The participants were not given any information about the PPP ahead of time and were asked only to play with their own natural technique, adjusting accordingly to playing conditions. A click track at the appropriate tempo was provided via isolating earbuds.

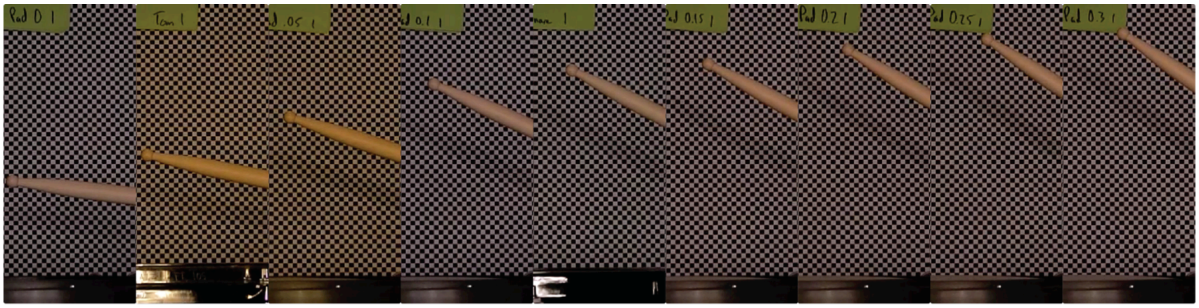

Figure 3. Screenshots of drumstick rebound apex from acoustic drums and PPP at various pressure settings

Table 1. Testing conditions

Trial	Playing Surface	Audio Feedback
1	Personal practice pad	Acoustic only
2	Snare drum	Acoustic only
3	Floor tom	Acoustic only
4	PPP @ 0.15psi	Snare samples
5	PPP @ 0psi	Floor tom samples
6	PPP @ 0.15psi	Floor tom samples
7	PPP @ 0psi	Snare samples
8	PPP @ 0.3psi	Acoustic only

6. RESULTS AND DISCUSSION

As a preliminary attempt to gather feedback about this prototype, each participant was asked to rate their comfort level for each trial on a scale of 1-5, with 5 being the most comfortable and 1 the least. They were also asked to provide general comments about their experience. We were primarily interested in whether the participants noticed relationships between the different pressure settings when compared to their acoustic drum counterparts. We were also interested to see if aural feedback had any impact on perception of rebound, especially when it did not match expectations in correlation with the feel of the drum.

There was a modest correlation between the perceived rebound of the drums when compared to the corresponding settings on the PPP. Four of the seven participants that rated the floor tom lower than the snare drum also rated the 0psi with complementary aural feedback lower than the 0.15psi with complementary feedback. Of the remaining three participants, one stated that their discomfort on the snare drum was due to its sound not being as tight and dry as expected for the style being played (i.e. as the sound of their personal snare drum). A second said the same thing about the audio samples used for the 0.15psi setting with complementary aural feedback (though strangely did not make the same comment about the acoustic snare drum from which the samples were derived).

We did not notice any significant pattern emerge when comparing the complementary versus contradictory aural feedback results. While four of the seven participants rate the contradictory 0psi trials lower than the complementary 0psi trials, the same could not be said about the 0.15psi setting. This suggests that while the sounds do not exactly match the expectations set by certain rebound characteristics, they are still acceptable because they fall under the same category of interaction - that of striking with a drumstick. This outcome is consistent with the findings of Essl et al, in studies with the PebbleBox [3]. They reported that, when the haptic manipulation of pebbles was paired with collision sounds (e.g. of clinking coins or colliding water droplets) participants found the pairing more plausible than when the sounds heard were of birds crying or people munching apples. In other words, the feel of the interaction always dominated and determined the plausibility of the overall haptic-sound pairing. Experienced percussionists already expect that a single drum can have a wide range of rebound and sonic characteristics dependent upon the tuning of the head. As such, they are trained to adjusting playing technique as necessary according to the feel of the drum rather than the sound. Full rating results for the different trials can be found in Table 2.

Table 2. Participant responses

Participant	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8
1	5	5	2	4	3	4	4	3
2	5	5	4	4	3	4	1	5
3	4	5	5	2	3	2	2	3
4	5	3	4	4	4	5	2	5
5	5	5	5	4	2	3	1	4
6	5	4	1	3	1	2	2	5
7	4	4	3	4	2	4	2	5

Regardless of the outcome of the quantifiable ratings, general response to the PPP was very positive. Most participants stated without provocation that the 0psi setting felt very similar to the floor tom, while the highest pressure setting, 0.3psi, was comparable to tightly-tuned rack toms or bongos. This demonstrates that the PPP succeeds in providing a wide range of usable rebound characteristics that match what percussionists encounter on acoustic instruments. One participant stated "if you had lower tension and the low tom sound, that would make more sense to me, and I think was more comfortable for me… I might be able to play more accurately like I would play on a tom-tom if I was using the electronic instrument." Another participant said that this device would be very useful for his practice regime - "I practice when I need things… if I need to get my doubles together, then I'm going to put it at a low tension so I have to really work them out - high tension is for maybe softer stuff."

7. FUTURE WORK

An unexpected drawback to our chosen sample trigger technique, that of a piezo on the drumhead surface, which is the same method used by many commercially available options, was that the response changed with our pressure setting. For example, at the 0psi setting, the trigger seemed to do well with dynamic range, but it completely missed more notes than is acceptable. This result was not measured, but it seemed to drop approximately one out of every fifteen notes. At the 0.15psi setting, there were fewer dropped notes, but the dynamic range was not as consistent, with loud strikes sometimes registering as quiet and vice versa. We do not currently have an explanation for this behavior, although it appears that sensitivity settings of the trigger may need to be tailored to the pressure settings. As such, alternative triggering techniques based on sensors other than piezo transducers are being explored. This becomes a priority particularly when examining the results from Miura's rebound study, in which it was discovered that the rebound characteristics of a tunable mesh head like those used in some of the most prominent high-end electronic drumsets were not nearly as variable as those found on a single acoustic snare drum set at different tensions [5]. The range of rebound characteristics afforded by the PPP has compelling implications for the electronic percussion world.

A common complaint of the model of practice pad we used is that it is too loud for many practice situations, and our modified version is no exception. To combat this, we plan to explore different materials and dimensions for the body of the pad while retaining the standard Mylar head. Drummers will often choose drum shell size and wood construction to suit their volume and tone preferences, so composition of the base, hoop, and internal foam used in the PPP may have a noticeable effect.

Finally, in another rebound study, Wagner found that because of the oscillations of a Mylar head, the tip of the drumstick actually had multiple weaker yet measurable instances of contact with the head after the initial point of contact [10]. Indeed, though the framerate and resolution of our high-speed video was too low to measure this phenomenon, subtle oscillations of the head of the PPP were still faintly observable. In the pursuit of a perfectly replicable rebound, this seems like the next logical characteristic beyond rebound height to model and reproduce in order to capture the feel of an acoustic drum.

8. CONCLUSION

Percussionists are expected to be extremely versatile musicians with facility on multiple instruments ranging from found objects to immaculately crafted marimbas. To attain this versatility, the right practice tools can make all the difference. In this paper, we have shown through quantitative measurements and subjective feedback that the Pneumatic Practice Pad has potential to be the tool that percussionists use to acclimate to different playing surfaces. We have also shown that, despite a percussionist's ability to overcome mismatches in feel and aural feedback, there are advantages to exploring the Pneumatic Practice Pad as an electronic percussion interface, including simple construction from readily available materials and an infinite and wide-ranging customization of rebound characteristics unmatched by currently available products. Given such promising signs at this early stage of development, we are optimistic about the possibilities of pneumatically augmented percussion devices.

9. ACKNOLEDGEMENTS

Thanks to all of the participants for their time and insightful comments, to Nicole Patrick for helping with setup and room access, and to Alex Russomanno for his patient assistance with gauges and valves and regulators and such.

10. REFERENCES

[1] T. Argo. Acoustic Drum Exploration - Basis for Investigation. University of Illinois Department of Physics. Retrieved December 16, 2014. https://courses.physics.illinois.edu

[2] E. Berdahl, H-C. Steiner, and C. Oldham. Practical Hardware and Algorithms for Creating Haptic Musical Instruments. *In Proceedings of NIME*, 2008.

[3] G. Essl, C. Magnusson, J. Eriksson, and S. O'Modhrain. Towards evaluation of performance, control, and preference in physical and virtual sensorimotor integration. *In Proceedings of ENACTIVE05*, 2005.

[4] E. Janners. Spotlight on Percussion: Percussion for the Non-Percussionist Band Director. *Canadian Winds: The Journal of the Canadian Band Association,* 1, 2 (Spring 2003) 28-34.

[5] M. Miura. Playability of electric snare drum based on the rebound feature. *Acoustical Science and Technology*, 33, 3 (2012) 170-179.

[6] SparkFun, Retrieved December 16, 2014 https://www.sparkfun.com

[7] Steve Weiss Music, Retrieved December 16, 2014. http://www.steveweissmusic.com

[8] G. L. Stone. Stick Control. George B. Stone & Son, Inc., 1935.

[9] Tap Plastics, Retrieved December 16, 2014. http://www.tapplastics.com

[10] A. Wagner. Analysis of Drumbeats – Interaction between Drummer, Drumstick and Instrument. *Master's Thesis*, Department of Speech, Music and Hearing, September 2005 – March 2006.

[11] C. Wilcoxon. The All-American Drummer. Ludwig Masters, 1945.