Music, language, and fortepianos

Testing the speaking capabilities of *stoss* and *prell*

Robert V. Giglio
Schulich School of Music, McGill University, Montreal
December, 2015

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Master of Arts in Musicology.

Table of Contents

Abstract

In his keyboard treatise of 1789, Daniel Gottlob Türk confirmed a long-standing affinity between music and language. Arguably in more detail than anyone before him, he referred to the loudness and duration of tones as parameters in music that serve in the pursuit of clarity and expression. This study connects Türk's musical parameters to our modern understanding of how speech is effected, finding parallels in Türk's descriptions with the elements of phonetics and the theories of phonology. Türk's speech-based musicality is put forth as an ideal of German-Austrian Classicism, and the applicability of that ideal to keyboard instruments informs an organological investigation. If his ideas are representative for his generation of musicians, then how do they translate from the extremely well-speaking clavichord (Türk's favorite keyboard instrument) to the newer fortepiano? What type of fortepiano mechanism would be best suited? At the time of Türk's treatise, a pushing mechanism (*Stossmechanik*) and a pulling mechanism (*Prellmechanik*) coexisted and competed for survival in the largest German-speaking center for fortepiano building, Vienna. In this thesis, the Viennese *Stossmechanik* and *Prellmechanik* are compared and contrasted using technological means. One element of Türk's speech-based musicality – loudness – is used to determine the effectiveness of each mechanism in creating voice-like gradations of loud and soft. A mechanism model of Mozart's Anton Walter fortepiano was commissioned that can accommodate both *stoss*- and *prell*-actions in the same case, with the same strings; 3D motion capture technology was used to track the hammer and key in-motion, while audio recording equipment captured the tones for analysis. The results suggest that, while the *Stossmechanik* has a slightly greater connection to loudness through overall key speed, the *Prellmechanik* offers a distinct advantage in dynamic control through key dip. It was this distinction, perhaps, that led Viennese builders to favor the *Prellmechanik* in grand pianos by the end of the eighteenth-century.

Résumé

Dans son traité de clavier de 1789, Daniel Gottlob Türk a confirmé une affinité de longue date entre la musique et la langue. Probablement de façon plus approfondie que quiconque avant lui, il a fait référence à l'intensité et la durée des tons comme des paramètres de la musique qui servent dans la quête de clarté et de l'expression. Cette étude relie ces paramètres musicaux de Türk à notre compréhension moderne de la façon dont la parole est effectuée, et établit aussi des parallèles entre les descriptions de Türk et les éléments de la phonétique et les théories de la phonologie. La notion de Türk d'une musicalité fondée sur la parole est proposée comme un idéal du classicisme germano-autrichien; cette enquête organologique vise à étudier l'applicabilité de cet idéal aux instruments à clavier. Si ses idées sont représentatives de sa génération de musiciens, comment se traduisent-elles du clavicorde (l'instrument à clavier préféré de Türk) au pianoforte, qui devenait de plus en plus populaire? Quel type de mécanisme du pianoforte serait-il le plus compatible à ces idées? À l'époque du traité de Türk, un mécanisme de poussée (*Stossmechanik*) et un mécanisme de traction (*Prellmechanik*) ont coexisté et rivalisé l'un avec l'autre à Vienne, le plus grand centre germanophone de construction du pianoforte. Dans cette thèse, le *Stossmechanik* et le *Prellmechanik* viennois sont comparés et contrastés en utilisant des moyens technologiques. Un élément de la musicalité fondée sur la parole de Türk –l'intensité– est utilisé pour déterminer l'efficacité de chaque mécanisme dans la production d'une gradation semblable à la voix –du doux au fort. Un modèle du mécanisme du pianoforte Anton Walter de Mozart a été commandé pour étudier tous les deux mécanismes (*stoss* et *prell*) dans le même coffre et avec les mêmes cordes. Un système de capture de mouvement 3D a été utilisé pour suivre le marteau et la touche en mouvement, tandis que l'équipement d'enregistrement audio captura les tons pour l'analyse. Les résultats suggèrent que la *Prellmechanik* offre un avantage clair en termes de contrôle dynamique. Il était cette distinction, peut-être, qui a mené les constructeurs viennois à favoriser le *Prellmechanik* pour les pianos à queue à la fin du dix-huitième siècle.

Acknowledgements

This project took place over more than two years, and there are many individuals to thank for their guidance and support. Keyboard maker Chris Maene was responsible for creating the mechanism model that made this project possible. His ingenuity is unmatched, and I very much appreciated his thoughtful cooperation during the project. The Center for Interdisciplinary Research in Music Media and Technology (CIRMMT) generously funded my project during the 2013/14 academic year in the form of a Student Research Award. I am extremely grateful for that support and also for the many hours of assistance offered by the CIRMMT staff. Yves Methot was there with me from the beginning to help set up the camera system, develop experiment protocols, and adjust lab equipment. His assistance was invaluable. Julien Boissnot was also extremely helpful with day to day experiment needs at CIRMMT. Former McGill student Benjamin Bacon provided useful advice regarding the Qualisys camera system. Two former sound recording students – James Perrella and Luis Aguirre – were hired as research assistants (at two separate times) to help develop audio-related protocols/analyses and to regulate the sound recording equipment. Their patient, careful, and thorough work was very much appreciated. The pianists who took part in various stages of preparation and experimentation – Tom Beghin, Gili Loftus, and Michael Pecak – devoted much of their time and energies to these tasks, and I am grateful for their enthusiastic support. My friend and student of mechanical engineering, Jacob Shively, provided useful advice regarding mathematical concepts during data analysis. Professor Ichiro Fujinaga was instrumental in designing the experiment and establishing experiment goals from the beginning.

I would like thank my girlfriend, Sylvia Josephy, for helping me to learn, develop, and implement statistical protocols for this project, for helping me design experiment parameters, and for giving invaluable advice during the research and writing process. Moreover, she helped me to find the right path during times of stress, and her constant love and support meant the world to me. My family – Don Giglio, Jean Bernarducci, Mary Jacobs – has always been there to encourage me and to help me through difficult times. They are so supportive of my every pursuit, and their advice and love has helped me to be the best version of myself that I can be. I would also like to dedicate this work to my late mother, Nina Giglio, who was my example in life. My friends from my hometown – the "lumberjacks" – have always been able to make me laugh and see the bright side in things. I look forward to many more decades together. My friends from Montreal have made my time here so enjoyable. Mike Cisneros-Franco has been my good friend and roommate throughout my degree, and he was among the first people to hear about my project. I would also like to thank him very much for translating the above abstract into French. Michael Pecak is a kindred spirit, and our many conversations about life, work, and this project have been wonderful.

My supervisor and mentor, Professor Tom Beghin, has provided me with constant support, encouragement, and guidance. His honest and helpful feedback during my degree, and his genuine investment in my well-being and success, have been so greatly appreciated. He advised me on every step of this project, and his input was vital. Moreover, the project would not have come to fruition without the opportunities provided by Professor Beghin: he established the connection with keyboard maker Chris Maene, he provided the funds to the purchase the mechanism model, he supported me financially through research assistantships, and he made it possible to hire sound recording engineers for the audio component of this research.

Preface and Contribution of Authors

Material from this thesis will be included in the preparation of a publishable manuscript. I am the first author on this project, and I have been responsible for the successful planning and execution of all experimentation, data analysis, research, and writing. I have received extremely valuable assistance and feedback in this pursuit from the many individuals listed above. Professor Ichiro Fujinaga was involved in discussions and decisions about experimentation from the beginning. His advice led us toward controlling for loudness in our experiments, which yielded the interesting results presented here. My supervisor Professor Tom Beghin provided constant support during the planning stages, the experiment stages, and the research and writing stages. He helped to define the parameters of this project; he participated in earlier stages of experimentation as a pianist; he assisted in the outlining and writing process; and he was heavily involved in the editing process.

Introduction

Eighteenth-century writers on both composition and performance indicate speech as an appropriate analog to music. In his keyboard treatise of 1789, Daniel Gottlob Türk writes:

> The words: will he come soon? can merely through the tone of the speaker receive a quite different meaning. Through them a yearning desire, a vehement impatience, a tender plea, a defiant command, irony, etc. can be expressed. The single word: God! Can denote an exclamation of joy, of pain, of despair, the greatest anxiety, pity, astonishment, etc., in various degrees. In the same way tones by changes in the execution can produce a very different effect.[1]

The keyboardist, then, should seek to emulate the variability of our voices, but at what level does this comparison fall apart? Are specific elements of speech transmittable through the tones of keyboard music, as Türk would have us believe? Or is the analogy pointing toward a more general aesthetic – one in which the details of how exactly music functions as language do not matter? These questions go to the heart of the relationship between language and music in the second half of the eighteenth century, and here, I can only address a small aspect of that vast topic. In this thesis, I seek out parallels between our modern understanding of how speech is effected and Türk's prominent eighteenth-century concept of keyboard performance. I do not intend to investigate how accurately Türk's concept of musical speech accords with eighteenth-century theories of language or elocution. Rather, I intend to specify how the concepts of eighteenth-century keyboard performance are reflective of natural speech processes. For these reasons, I opt not to explore the analogy through historical sources—at least not on the linguistic

[1] Daniel Gottlob Türk, *School of Clavier Playing*, translated by Raymond H. Haggh (Lincoln, NE: University of Nebraska Press, 1982), 337-338.

side[2]—but rather I utilize a present-day textbook on phonetics and phonology that is comprehensive and reflective of the current field of linguistics.[3]

The parallels between speech and keyboard performance provide a basis for an investigation of two fortepiano mechanisms that coexisted and competed in one of the largest musical capitals of Türk's time. The *Stossmechanik* and the *Prellmechanik* represent a basic divide between all hammer mechanisms: one is made to push, the other is made to pull. As the result of migratory ideas from European nations and also of independent invention, Vienna put forth a version of each fortepiano mechanism, which competed simultaneously for the city's favor. By the end of the century, the preference of builders swayed toward the *Prellmechanik* in grand pianos. What was it about the pulling mechanism that won their affection? I propose that Türk's lessons provide insight into the ideals and preferences of German-Austrian keyboardists.

Drawing from modern phonological theories and phonetic elements of prosody and pronunciation, Chapter One illustrates that Türk's concepts of emphasis and mechanical clarity point to very similar functional parameters. In language, the alteration of three speech elements – pitch, duration, and loudness – take part in the production of rising and falling vocal patterns referred to as prosody. These patterns are influenced, however, by the small structural units of speech – consonants and vowels – and by their pronunciation according to a specific language. In music, Türk's lessons state that mechanical clarity and effective expression are achieved through the proper use of loudness and duration, and furthermore that those parameters are regulated by eighteenth-century musical convention. I propose that Türk's speech-based musicality is

---

[2] This has been explored in such works as Stephanie Vial's *The Art of Musical Phrasing in the Eighteenth Century: Punctuating the Classical 'Period'* (Rochester, NY: University of Rochester Press, 2008) and Mark Evan Bonds' *Wordless Rhetoric: Musical Form and the Metaphor of the Oration* (Cambridge, MA: Harvard University Press, 1991).

[3] John Clark, Collin Yallop, and Janet Fletcher, *An Introduction to Phonetics and Phonology*, 3rd ed. (Oxford: Blackwell Publishing, 2007).

representative of an ideal in German-Austrian Classicism – one that could have influenced the Viennese in their selection of *prell* over *stoss*.

Chapter Two features a technological experiment that examines the performance of one speech element – loudness – on the two competing mechanisms of late eighteenth-century Vienna. An open-sided model was commissioned which could hold both *stoss* and *prell* in the same case, with the same strings. A 3D motion capture camera system was used to track the movement of the hammer head and the key at 4,000 frames-per-second, and the tones were recorded for analysis. Three dynamic levels were tested on each mechanism, and the collected data made it possible to examine the mechanical properties of each mechanism as related to the performance of loudness.

This experiment is predicated on the idea that the modification of loudness, *per tone*, is a significant element in the performance of speech-based, eighteenth-century music. Therefore, the results present various relationships between performed decibel levels, measured key depression, hammer head travel, and change in hammer head angle. The relationships between these elements project a picture of each mechanism's ability to modify loudness, and the results show that *stoss* and *prell* rely on different means to achieve that goal.

Chapter One

Phonetics and Phonology

The third edition of *An Introduction to Phonetics and Phonology* (2007) by John Clark, Colin Yallop, and Janet Fletcher is the result of continuing improvement upon a comprehensive and well-received text. A reviewer of the first edition (Bruce Connell, 1994) points out that he has made good use of the text in his undergraduate and graduate courses at the University of Oxford and writes with high praise regarding the chapter on prosody, which is of special interest to us. Gerry Docherty from the University of Newcastle upon Tyne writes, "The third edition of *An Introduction to Phonetics and Phonology* is a welcome update to an introductory volume which for many years has informed and challenged students in equal measures, and will clearly continue to do so." The main misgivings with the text have to do with a wish for more explicit fusion between phonetics and phonology and also for an expansion of phonological concepts. For the purpose of this musical foray into linguistics, the text serves as a clear and well-positioned window into phonetic elements and phonological theories that can then be compared with eighteenth century musical practice. Indeed, another reviewer of the third edition (Benjamin Schmeiser, 2011) writes, "the authors succeed in writing a textbook that is just as highly valuable for the specialist in the field, as it is for the beginning linguistics student."[4]

In the textbook's early pages, the title terms are defined and distinguished. The authors describe phonetics as the study of speech sounds and the processes by which they are created and perceived. Phonology, on the other hand, is focused on the organization of "patterns of sounds" into a particularly meaningful and communally recognized language. While the former field has

[4] Bruce Connell (*Phonology* 11, 1994), 196-199; Gerry Docherty, advertised by the publisher on the book's back cover; Benjamin Schmeiser (*Journal of the International Phonetic Association* 41/3, 2011), 369-371.

a history of scientific and instrumental analysis of quantifiable parameters (sound waves and organ movement), the latter has a history of theoretical development based on the observation of individuals using language.[5] Certainly since the nineteenth century, phoneticians and phonologists have attempted, in academic contexts, to investigate and create models for speech that describe all of its many facets.[6] It can be likened to the study of our universe – experimental physicists searching always for particles (how they can be found, perceived, examined) and theoretical physicists searching always for a unifying theory that makes sense of the particles' existence.

Certain phonetic aspects – those quantifiable elements of speech such as pitch, duration, and loudness – will be invoked directly in the comparison to music. In addition, the theoretical models of phonology will play a primary role in constructing functional models of those elements. Indeed, organizing sounds into a hierarchical framework not only helps describe the process of speaking a language but also that of performing a melody according to eighteenth-century practices. I do not intend to position this study as an original theory of phonology or even as a comprehensive overview of phonological theories--rather, I wish to arrange a framework of selected phonetic/phonological elements and theories that have the potential to resonate with eighteenth-century musical practice.

In speech, the act of organizing sounds into time-functional patterns of pitch, duration, and loudness is referred to as *prosody*. Though a more precise definition of the term is elusive, the summary by Clark et al. offers two possibilities. The first characterizes prosody as a dynamic, overarching pattern of the variables (pitch, loudness, duration). This view lends itself to analysis on a large scale, in that the stream of speech is taken as a unit with fluctuating

---

[5] Clark, Yallop, and Fletcher, *An Introduction to Phonetics and Phonology*, Chap. 1 "Introduction," 1-4.
[6] Ibid., Chap. 11 "The Progress of Phonology," 399-403.

characteristics. The second definition recognizes this overarching pattern of variables, however it also accounts for the influence of small-scale speech units. These units are called *segmentals* – consonant and vowel sounds – and according to this second definition, they are heavily implicated in the creation of prosody.[7]

A theoretical model called CV phonology (with C standing for "consonant sound" and V for "vowel sound") serves to represent speech from the smallest level upward – that is, from segmentals upward to syllables, words, and phrases.[8] The theory makes use of a "CV tier," or "a tier of C and V 'slots' which are filled by segments." For instance, the word "beat" breaks down as in **Figure 1.1**.[9]

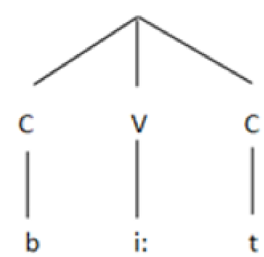

Figure 1.1

The two consonant sounds are fitted into their "slots," while the vowel – though comprised of the entities "e" and "a" – is represented as a single long sound by the sign [i:]. Each segment combines to form the monosyllabic word "beat," as shown by the "single node" at the top of the structure. CV Phonology not only enables an ordering of segments into higher units but also makes possible the characterization of segment relationships. The example used by Clark et al. is

---

[7] Clark, Yallop, and Fletcher, *An Introduction to Phonetics and Phonology*, Chap. 9 "Prosody," 326-327.
[8] Ibid., Chap. 11 "The Progress of Phonology," 415-417.
[9] The example shown here is based upon examples shown in the text (ibidem), however with a different word choice.

one from the language Luganda (spoken in Uganda). The word "mweezi" (sweeper) can receive various representations, each more detailed than the previous, as shown in **Figure 1.2**.[10]

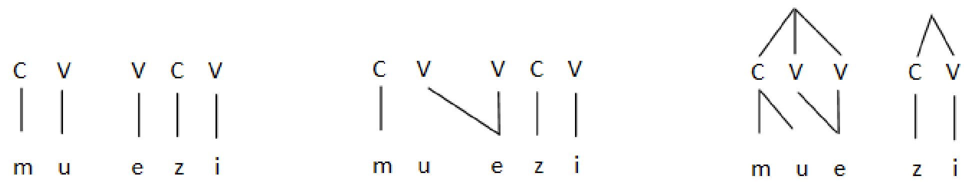

Figure 1.2

In the leftmost example, each segment is positioned under its appropriate label – C or V. However, in accordance with the pronunciation of Luganda, the second consecutive vowel sound should "dissociate the first." Therefore, the middle example shows the segment [e] as belonging to two vowel "slots," and the final example shows that the dissociated vowel [u] "can combine with the preceding consonant." The segments can then be grouped together by a "single node" placed above each syllable.

The process of *pronunciation* acts in conjunction with the placement of *stress* to create the dynamic patterns of prosody. The pronunciation of the word "mweezi" is determined by the relationship of segments as prescribed by Luganda. Inherent to that pronunciation, however, is a certain pattern of stress that is also caused by the nature of, or the juxtaposition of, segments. Because the second consecutive vowel sound in Luganda always displaces the first, that second sound will have a longer duration, and it is the duration of vowel segments that can serve to indicate the addition of other stress factors:

> In many languages…the location of stress placement is sensitive to the internal composition of syllables. In these languages, called quantity sensitive, syllables which contain long vowels are considered heavy and tend to attract stress.[11]

---

[10]Clark, Yallop, and Fletcher, *An Introduction to Phonetics and Phonology*, Chap. 11 "The Progress of Phonology," 416-417. The examples were reproduced exactly from these pages of the text.

[11] Stefanie Shattuck-Hufnagel and Alice E. Turk, "A Prosody Tutorial for Investigators of Auditory Sentence Processing," *Journal of Psycholinguistic Research* 25/2 (1996): 219-220.

Pitch and loudness are the prime additional phonetic factors of stress. Both are linked, just as duration, to the nature and juxtaposition of segments. "There are important interactions," writes Clark et al., "between the segmental structure and its accompanying pitch pattern." With regard to loudness, the same authors write that "intensity [i.e., loudness] is primarily controlled by subglottal pressure…but is also influenced by the natural sonority of the segments or sequences of segments in the relevant syllables."[12]

The question of which phonetic factor is most significantly or most often influential in stress is under debate in the linguistics realm. Some earlier twentieth-century studies identify pitch as the more significant factor in stress.[13] On the other hand, a 2005 study affords greater significance to the parameter of loudness.[14] With a more all-encompassing perspective, Shattuck-Hufnagel and Turk write in 1996 that, "in general, the results of quantitative studies support the view that prosodic prominence is not a single parameter, but that there are different types or levels of prosodic prominence, associated with a different dominant acoustic cue or set of cues."[15] This view suggests that stress can be produced by the isolation and/or interplay of all factors, depending upon the specific situation.

As we have seen, the relationship of segments and their pronunciation determines the likely possibilities for stress. However, our intentions play an active role as well. Clark et al.

---

[12] Clark, Yallop, and Fletcher, *An Introduction to Phonetics and Phonology*, Chap. 9 "Prosody," 334.
[13] The example given by Clark et al. (331) is: Fry, D.B, "Experiments in the perception of stress," *Language and Speech* 1 (1958): 126-52.
[14] Kochanski, G., Grabe, E., Coleman, J., and Rosner, B, "Loudness predicts prominence: fundamental frequency lends little," *JASA* 18 (2005): 1038-54. Clark et al. refer the reader to this study as a counter to their statement that loudness "seems to be the least salient and least consistent of the three parameters of pitch, duration and loudness – at least for linguistic purposes such as signaling prosodic prominence." (Clark, Yallop, and Fletcher, *An Introduction to Phonetics and Phonology*, Chap. 9 "Prosody," 334).
[15] Shattuck-Hufnagel and Turk, "A Prosody Tutorial," 223. Clark et al. (331) make note of a study in 1960 that also proposes the all-encompassing view of phonetic factors in stress: Lieberman, P., "Some acoustic correlates of word stress in American English," *JASA* 33 (1960): 451-4.

explain that certain monosyllabic words are usually unstressed in English, but can be manipulated by the speaker:

Joe was angry and Joe WAS angry

In the first case, the verb is joined to the preceding word as a suffix, creating one "phonological word." In the second, that verb is emphasized and made into its own phonological word. "English intonation does allow the option of stressing or accenting these words, but the stress or accent is then meaningful, in contrast with the normal or unmarked pronunciation."[16] Therefore, it is the concordance of pronunciation with subsequent possibilities for and choices of stress that allows the single word "God!" to be expressed with many meanings, as suggested by Türk. And furthermore, it is that concordance which enables the prosodic phrase "will he come soon?" to convey a particular message.

Türk the Phonetician

According to the view of prosody considered above – in which the pronunciation of segmentals influences overarching patterns of loudness, pitch, and duration – the stream of speech is built from within. This is also the view of eighteenth-century theorists and performers of music. In the section "Concerning the Clarity of Execution," Türk outlines three essential factors:

> The clarity of execution is chiefly dependent upon (1) the mechanical execution itself, (2) the emphasis which certain tones receive, and (3) the proper connection and separation of musical periods…[17]

The first of these – "mechanical execution" – refers to the proper production of tones in service of a clear message. This can be likened to the mechanics of pronunciation in speech. For

[16] Clark, Yallop, and Fletcher, *An Introduction to Phonetics and Phonology*, Chap. 9 "Prosody," 350-351. The example "Joe was angry" was taken directly from these pages of the text.
[17] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 324.

example, Türk points to poor performances in which "the tones are 'choked out' or 'skipped over,'" just as a poor pronunciation may involve segmentals that are unrecognizable or unnecessarily eliminated. Furthermore, Türk links the factor of mechanical clarity to that of emphasis – just as pronunciation is linked to stress in phonology. Türk explains,

> Mechanical clarity requires that even for the most rapid passage as well as for the essential and extempore ornaments, every tone must be played with its proper intensity, plainly and clearly separated from the others. […] when the keys are struck too hard or soft, the execution can become unclear. This is also true if the keys are played in a too detached manner, or if the fingers are allowed to remain on the keys too long.[18]

Here, Türk refers to two prosodic parameters of stress – loudness and duration – and the phonological relationship between pronunciation and stress is mirrored in that between mechanical clarity and emphasis. However, what characterizes a clear pronunciation is prescribed by a particular language. Just as the second vowel sound of the Luganda word mweezi should be long according to the procedures of that language, strong beats in eighteenth-century music (such as the first in common time) should be emphasized relative to the following. Thus, a clear mechanical pronunciation of musical tones is prescribed by the language of eighteenth-century music.[19]

Türk continues with further detail on the prescriptions of contemporary musical language, and the resultant effect on mechanical clarity and emphasis:

> Whoever would read a poem and the like in such a way that it becomes comprehensible to the listener must place a marked emphasis on certain words or syllables. The very same resource is also at the disposal of the practicing musician.[20]

---

[18] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 324.

[19] Malcolm Bilson explores the concept of stress in eighteenth-century German-Austrian music in "Keyboards," Chap. 11 in *The Norton/Grove Handbooks in Music: Performance Practice: Music after 1600*, edited by Howard Mayer Brown and Stanley Sadie (New York: W.W. Norton & Company, 1989), 228-229.

[20] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 324.

He makes clear that he cannot outline every tone that requires "special emphasis (accent)," however he goes so far as to point out the most essential tones for such treatment: those that receive metrical accent, those that begin sections or phrase members, and finally various isolated tones including appoggiaturas, dissonances, preparations for dissonances, syncopations, tones foreign to the key (excepting "short and merely passing notes"), outlier tones ("distinguished by their length, highness, and lowness"), and chords essential to the harmonic progression.[21] Türk later describes a distinction between loudness and "another means of accent"– duration.[22] The latter is less frequently used, according to Türk, but important nonetheless. "The orator," he says, "not only lays more emphasis on important syllables and the like, but he also lingers upon them a little." In music, the degree to which one lingers on a certain tone is determined by three factors: "(1) the greater or lesser importance of the note, (2) its length and relationship to other notes, and (3) the harmony which is basic to them."[23]

So, tones are to be emphasized through loudness and duration in concordance with the pronunciation of eighteenth-century musical language. But is emphasis also chosen by the player according to the meaning or character of what he wishes to play? Türk devotes a section – "Concerning the Expression of the Prevailing Character" – to this very question, and his answer is certainly in the affirmative. He asserts that, while such expression is primarily contingent upon the "sensitive soul" of the musician, there are certain tangible parameters that aid in the process.

---

[21] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 324-327.

[22] In the preceding examples of tones that receive "a marked emphasis" ("*einen merklichen Nachdruck*"), it seems that Türk has been referring to loudness, whereas now "another means of accent" ("Ein anderes…*Mittel zu accentuiren*") refers to duration. The German is from a copy of the first edition: Daniel Gottlob Türk, *Klavierschule: Anweisung zum Klavierspielen für Lehrer und Lernende, mit kritischen Anmerkungen*, (Leipzig and Halle: Schwickert, Hemmerde and Schwetschke), 1789. IMSLP.

[23] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 327-328.

Unsurprisingly, these again include volume of the tones and duration or connection of the tones. A third parameter is tempo – in effect, the result of successive durations.[24]

Türk admits that one cannot design labels that dictate what degree of loudness is appropriate for which kind of expression: "To what an excess would these words have to be added if every note which required a special shading would be so indicated."[25] Therefore, he only briefly remarks on loudness associated with various characters, and he also describes certain dissonances and cadences that can effect a particular character by means of loudness. For instance, an unexpected modulation can be played more loudly in order to convey surprise at the sudden shift in character. The same impossibility of explanation applies to duration, referred to here as "heavy or light execution":

> It is just as difficult each time to specify exactly the requisite heavy or light execution for individual passages or tones as it is to indicate every degree of loudness or softness exactly. It is chiefly a matter of the proper application of detached, sustained, slurred, and tied notes.[26]

This notion of heavy vs. light execution is an important one, in that it represents a conceptual mixing of emphasis parameters. Türk wishes to align the heavy vs. light paradigm primarily with duration, but he recognizes the fact that loudness is implicated as well:

> In order to avoid a misunderstanding I must also remark that the terms heavy and light in general refer more to the sustaining or detaching of a tone rather than to the softness or loudness of the same. For in certain cases, for example in an allegro vivo…the execution must be rather light (short) but at the same time more or less loud, whereas pieces of a melancholy character….although played slurred and consequently with a certain heaviness, must nevertheless not be executed too loudly. In most cases, however, heavy and loud are indeed to be combined.[27]

---

[24] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 337-338.
[25] Ibid., 338.
[26] Ibid., 342.
[27] Ibid., 347.

It seems that shorter, detached tones belong to light execution and longer, slurred tones belong to heavy execution – each pair (detached/light and slurred/heavy) retaining the option of various degrees of loudness.

Implicit in this section is the assertion that the choice is the player's alone – just as it is the speaker's choice to emphasize a particular syllable in order to convey a particular meaning. The player has at his disposal the list of potential stress tones according to musical pronunciation, but he alone can choose which tones are sufficiently different or important to the meaning of the overarching message.

Türk's Pedagogy and the Question of Instrument

If the contents of his library are any indication, then it can be said that Türk had an intelligent and sophisticated musical mind. The translator of his *Klavierschule*, Raymond H. Haggh, conveys a summary of the library's holdings, which is worth quoting in its entirety. It included

> treatises on the art of playing string, keyboard, and wind instruments, copies of Martin Gerbert's *Scriptores* and a volume of *De cantu et musica sacra*, general introductions to music, works on the aesthetics and theory of music including many important theoretical works, histories such as Esteban de Arteaga's *Geschichte der ital. Oper*, G. A. Bontempi's *Historia musica*, G. B. Martini's *Storia della musica*, and others, works on the physics of music, works on organ construction, J. N. Forkel's, Johann Mattheson's, F. W. Marpurg's and A. Werckmeister's important works, books on non-western music, works on church music, Samuel Scheidt's *Tabulatura nova*, dictionaries, collections of music, atlases, books on geography, grammars, periodicals of a general nature, books on anatomy, and others on the elements of metaphysics, medicine and pharmacopoeia, philosophy, arithmetic and mathematics, natural science, religious writings, other literary works and classical literature.[28]

---

[28] Raymond H. Haggh, "Translator's Introduction," in *School of Clavier Playing*, xxxiv-xxxv. Haggh obtained this information from an 1816 auction catalog reprinted in *Auction Catalogues in Music* with an introduction by A. Hyatt King (Amsterdam: Frits Knuf, 1973).

In addition to his apparent musical/academic acumen, Türk also exhibited an inclination toward pedagogy. In 1774, in his mid-twenties, Türk assumed his first teaching post at the Lutheran gymnasium in Halle, and he would later hold positions at the *Friedrichs-Universität* in Halle, including director of the *Collegium musicum* (which he founded).[29] A contemporary student from Halle expounds upon Türk's devotion to many pedagogical roles:

> You should, however, acquaint yourself with or observe his indefatigable diligence by day or night, in order to marvel at the unbelievably effective activity of this man. He is a teacher at the Lutheran Gymnasium in Halle, he performs his duty as cantor in the local St. Ulrich's Church, he gives vocal instruction in practical music, and he lectures to his own Collegium on the theory of music. In addition, he has composed a number of new pieces, he continues to study music and other sciences, he writes, he lectures and cultivates social life, he painstakingly instructs children in music who are capable of it, he takes care of the Halle chorus (that is, the municipal chorus), and with all of this, he devotes every remaining minute to his concerts.[30]

His teachings benefit from a broad knowledge of German and Austrian composers. In the introduction to his work, Türk provides the student and teacher with a strikingly thorough reference to works by composers, listed approximately in terms of length and difficulty. Some of the most noteworthy individuals on that list include: C. P. E. Bach, J. F Reichardt, J. A. Hiller, J. A. P. Schulz ("the author of many of the articles in Sulzer's *Allgemeine Theorie der schönen Künste*"), Johann Kirnberger, H. O. C. Zink (student of C. P. E. Bach), J. G. Vierling (student of Kirnberger), Joseph Haydn, J. W. Hässler, W. A. Mozart, L. A. Kozeluch, G. F. Handel, and J. S. Bach.[31] Türk was also aware of developments following the publication in 1789 of his *Klavierschule*. After Johann Peter Milchmeyer's 1797 publication, *Die wahre Art das Pianoforte*

[29] Raymond H. Haggh, "Translator's Introduction," in *School of Clavier Playing*, xxiii-xxiv.
[30] Ibid., xxv. Haggh's source is: Walter Serauky, *Musikgeschichte der Stadt Halle*, vol. 2 zweiter Halbband (Halle: Halle/Saale, 1942), 143.
[31] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 23. See also n.58 (417) regarding J. A. P. Schulz and n.64 (420) regarding J. G. Vierling and H. O. C. Zink.

zu spielen, Türk was compelled in his second edition (1802) to respond to some demeaning remarks made toward the clavichord:

> That Milchmeyer writes in his manual, *The True Art of Playing the Pianoforte*, p.2: "For this reason I do not believe that the harpsichord as well as the clavichord are the right instruments on which one can learn to play correctly. Seeking to play expressively on the latter causes unending (?) contortion of the fingers, etc." is a statement for which he himself must be held responsible. Fortunately for the clavichord, on page 58 he nevertheless states that next to the pianoforte it is the best instrument for musical expression. It appears that the author following the detrimental things he says about the poor old clavichord actually did not have such bad intentions after all.—To be sure, in the last decade the pianoforte has gained a considerably increasing favor, meanwhile the clavichord probably can and will continue its further existence beside the pianoforte.[32]

Türk is obviously a well-read and musically informed individual, but is his emotional defense of the clavichord indicative of a somewhat antiquated generational stance? More specifically, does Türk's unyielding support of the clavichord render his teachings inapplicable to other keyboard instruments, and specifically to the fortepiano, which "in the last decade…has gained a considerably increasing favor?" In the very first pages of the *Klavierschule*, Türk provides a description of the up-and-coming keyboard instrument:

> The pianoforte has the form of a small harpsichord, however, its strings are struck by little hammers. One can play on this instrument (of which there are many kinds at present) as one plays upon the clavichord, achieving a louder or softer tone by a stronger or weaker touch, without the need of pulling a stop. A few small, new types have the form of a clavichord.[33]

Here, Türk brings the clavichord and the fortepiano together in terms of their shared mechanical capability for dynamic shading. Furthermore, whenever Türk engages in comparison of keyboard instruments, the fortepiano is usually left out of denigrating remarks. For instance, one of the advantages of the clavichord is

[32] Raymond H. Haggh, "Translator's Introduction," xviii. The awkwardly skeptical question mark after "unending" is Türk's.
[33] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 9.

> that it can bring out the various levels of strength and weakness available to other instruments in rapid alternation, and that one can consequently play with much more expression than is possible, for example, *on the harpsichord*.[34]

Likewise, he says the following with regard to purchasing instruments:

> If, in addition [to the clavichord], a harpsichord or a good pianoforte could be acquired later, the pupil would gain even more, for by playing on these instruments, the fingers achieve more strength and elasticity. One must, however, not play on the *harpsichord* exclusively, because execution might suffer. Whoever is not able to have *both* instruments should choose the clavichord.[35]

While only playing on the fortepiano is not an option that crosses his mind, it seems that Türk avoids including the fortepiano in his negative remarks, and perhaps he even recognized the potential similarity of spirit between the clavichord and the fortepiano.

For our purpose it is significant, furthermore, that Türk acknowledges the "many kinds" of fortepiano circulating during his time. If Türk's lessons regarding the phonetic parameters of loudness and duration are indeed applicable to the fortepiano, the question then becomes: which of the "many kinds" is best suited; which can most effectively produce – as the clavichord does – "a louder or softer tone by a stronger or weaker touch?" Focusing only on grand fortepianos, there were at least three significantly different mechanism types available in Germany[36], and in the Austrian city of Vienna, there existed a kind of estuary where the basic principles of those mechanisms were made to compete.

Fortepiano Mechanisms in Germany

In his book, *The Pianoforte in the Classical Era*, Michael Cole describes four categories of the

---

[34] Daniel Gottlob Türk, *School of Clavier Playing*, trans. Raymond H. Haggh, 15-16. Emphasis mine.
[35] Ibid., 19-20. Emphases mine.
[36] "Germany" here refers to that area of land in the second half of the eighteenth century that lies in the territory of the Holy Roman Empire, but does not belong to the Austrian empire. This includes Saxony, Brandenburg, and Bavaria.

grand fortepiano that existed in Germany from 1770-1790.[37] These include the fortepianos of Gottfried and Johann Heinrich Silbermann, the fortepianos by Johann Andreas Stein and his imitators, the *Tangentenflügel* by Franz Jacob Späth and Christoph Friedrich Schmahl, and the imported English grand fortepiano. The following section on piano mechanisms arranges three of these categories in a somewhat different constellation. The *Tangentenflügel* is excluded because its mechanism does not make use of a hammer rotating about an axis; rather, a vertical tangent is propelled upwards within a defined path toward the strings.

Most all up-striking hammer mechanisms fall into one of two categories: a mechanism that pushes the hammer up toward the strings or a mechanism that pulls the hammer up toward the strings. These mechanisms are referred to, particularly in an historical context, by their German names – *Stossmechanik* and *Prellmechanik* respectively. In the 1740s, Gottfried Silbermann built fortepianos in Saxony that contained imitations of Bartolomeo Cristofori's Florentine *Stossmechanik*. This type of action was also circulating in the 1770s, but it was constructed just across the French border in Strasbourg by Silbermann's nephew, Johann Heinrich.[38] Cristofori's, and subsequently the Silbermanns', *Stossmechanik* makes use of an intermediate lever between the key and the hammer.

Johann Adam Hiller, writing in Leipzig in 1769, provides a mixed review of Silbermann fortepianos (he could either be referring to the instruments made earlier in the century by the late Gottfried Silbermann, or to the instruments of Johann Heinrich). He begins with the following positive statement, singling out Silbermann fortepianos as one of the only available instruments worth noting:

---

[37] Michael Cole, *The Pianoforte in the Classical Era* (Oxford: Clarendon Press, 1998), 194-197. Cole includes Austria in the description of these categories, but the existence of such fortepiano types in Austria (and more specifically in Vienna) will be discussed below.
[38] Cole, *The Pianoforte in the Classical Era*, 194.

> The instrument which is called the Fortepiano, as made till now only by Silbermann (not to be mentioned in the same breath as a number here and there—some copied, and some independently invented instruments) is for most music lovers uncommonly charming, especially if dampers are used.[39]

With that, however, the positive review ends. Hiller continues by reporting a quote from "a fine organist from Notre Dame," Mr. Daquin, who compares the Silbermann fortepiano to "a delicious dish, with which one soon becomes satiated." Furthermore, Hiller complains that the Silbermann fortepiano is known to have a "heavy touch…and that not all of the embellishments could be equally well brought out on it."[40]

Another variety of *Stossmechanik* – one without intermediate lever – existed in two forms: the English form by (or inspired by) Americus Backers, and the German form by individuals such as Mathias Schautz. In these mechanisms, a tangent is attached to the key and comes into contact with the hammer directly, slipping out of contact (escaping) before the hammer meets the strings. The hammers are hinged on a rail above the key and can point either toward or away from the player.

Katalin Komlós, in her book *Fortepianos and their Music: Germany, Austria, and England, 1760-1800*, reports that English instruments made their way to Germany through individuals such as Dussek – who "as early as 1782…gave a concert in Hamburg on an English fortepiano."[41] Likewise, Cole adds that "Clementi was exceedingly active in promoting the English grand throughout Germany and Austria after 1785, and later in Russia."[42] There was most likely some kind of market during the 1780s and 90s for the purchase of English

---

[39] Cole, *The Pianoforte in the Classical Era*, Appendix I: Selected Passages from Early Sources, 335. The source is: J. A. Hiller, *Wöchentliche Nachrichten und Anmerkungen die Musik betreffend* (Leipzig, 1769), 32.
[40] Cole, *The Pianoforte in the Classical Era*, Appendix I: Selected Passages from Early Sources, 335.
[41] Katalin Komlós, *Fortepianos and their Music: Germany, Austria, and England, 1760-1800* (Oxford: Clarendon Press, 1995), 15.
[42] Cole, *The Pianoforte in the Classical Era*, 196-197.

instruments in Germany, and this was certainly the case by the turn of the century. Komlós reports that "between 1800 and 1802 Dussek lived in Hamburg, and, according to his letters, he promoted the sale of the grand pianos of Clementi there."[43]

The German form of *Stossmechanik* is not included among Cole's four categories, most probably because that action is much less common in extant German grands. Cole does make reference to a German fortepiano from ca.1770-80 "with a unique form of direct-action *Stossmechanik* (with escapement)."[44] Alfons Huber, in his study "Was the 'Viennese Action' Originally a Stossmechanik?", shows that the mechanism of a grand fortepiano built by Mathias Schautz in Augsburg in 1792 is also is a direct-action (without intermediate lever) *Stossmechanik* with escapement. Strangely enough, Schautz was a student of Johann Andreas Stein – a man made famous for inventing an entirely different type of mechanism.[45]

Johann Andreas Stein of Augsburg is credited with the creation of the *Prellmechanik* with escapement. Here, the hammer is attached to the key itself, held on a y-shaped hinge called a *Kapsel*. The *Prellmechanik* uses an escapement lever, independent of the key, to catch and pull the hammer upward, letting go when it nears the strings. Stein's *Prellmechanik* was taken up by many of his former workmen (except, it seems, Mathias Schautz).

During his career as a builder in Augsburg, Stein seemed to revel in the creation of new instruments with exciting tonal possibilities. Cole makes note of J. F. Reichardt's experience

---

[43] Komlós, *Fortepianos and their Music*, 15.
[44] Cole, *The Pianoforte in the Classical Era*, 197.
[45] Alfons Huber, "Was the 'Viennese Action' Originally a Stossmechanik?" *The Galpin Society Journal* 55 (2002), 179. See also a quote by Paul von Stetten: "A pupil of Herr Stein, Herr Matthäus Schauz from Sontheim an der Brenz, has settled here from 1783, and makes good Piano fortes, clavichords, and other similar instruments." Cole, *The Pianoforte in the Classical Era*, Appendix I: Selected Passages from Early Sources, 338. The source is: Paul von Stetten, *Kunst- Gewerb – und Handwerks Geschichte der Reichs-Stadt Augsburg, Erster Theil* (Augsburg, 1779), 160.

with Stein and his invention, the *Saitenharmonica* (a kind of combination spinet and piano mechanism):

> The aged master could not stop describing to me the nature of the instrument with deep love and great fervor, and pointed out to me the perfection of the *diminuendo*. He said with the utmost possible emotion and demeanour, 'You think that you still hear something at the end; but you hear nothing, absolutely nothing, absolutely nothing at all'. Under the hands of that fine player [identified earlier in the quote as Stein's daughter, Nannette] it was really true.[46]

It seems that this enthusiasm was also applicable to the fortepiano mechanism alone. Paul von Stetten writes the following in Augsburg in 1788:

> Among the latest creations of our famous Herr Stein is a *Clavecin-organisé* made for Sweden, after that a so-called *Vis-à-vis*, or double harpsichord, which by means of its special action can be played at both ends by a single person, whereby numerous changes [*Menge Veränderungen*] can be produced, and that not by artifice, but as a natural confusion [combination?] of the thing itself; also a pianoforte, ordinary in its appearance, but different in tone. The crescendo and diminuendo is so extensive that from the greatest fortissimo it can gradually transform to absolutely nothing at all. The artist [Stein] exhibited both of the latter at his house during the 1783 exhibition of craftwork.[47]

It is somewhat unclear whether von Stetten referred to an individual fortepiano or rather to a fortepiano coupled with a harpsichord in a *Vis-à-vis* instrument.[48] Either way, the fortepiano mechanism was praised as something "different" and capable of great dynamic shading. It is likely that this mechanism was Stein's *Prellmechanik*, since the earliest extant example of that action is from two years earlier in 1781.[49]

---

[46] Cole, *The Pianoforte in the Classical Era*, 185. See also Michael Latcham's article on Stein's combination instruments, "Johann Andreas Stein and the search for the expressive *Clavier*," in *Bowed and Keyboard Instruments in the Age of Mozart* (Berne: Peter Lang, 2010), 133-215.
[47] Cole, *The Pianoforte in the Classical Era*, Appendix I: Selected Passages from Early Sources, 338. Brackets by Cole.
[48] An example of the latter type from 1783 does survive. See Latcham, "Johann Andreas Stein," especially 143-144 and 201-204.
[49] Stein's *Claviorganum* (organ and fortepiano combination). See Latcham, "Johann Andreas Stein," 196-199.

The fundamental principle of the Silbermann/Cristofori action, and also of the German/English form *Stossmechanik*, is that the hammer is pushed toward the strings. Stein's *Prellmechanik* changed that fundamental operation. Cole points out the many innovations within Stein fortepianos that are without precedent, and of the mechanism in particular he states,

> Finding antecedents for the hammer mechanism is equally difficult. It has been surmised that Stein's distinctive German action was developed by him from a simple *Prellmechanik*, or 'flip action', frequently seen in German-made square pianos. But the difficulties in dating surviving square pianos of this type, and the uncertainty as to when Stein first used the retro-oriented hammers mounted on the key, preclude a definitive statement on the matter.[50]

It was this innovative mechanism that would take Germany and Austria by storm in the late eighteenth and nineteenth centuries. However, the fundamental difference between *Stossmechanik and Prellmechanik* – to push or to pull – was thoroughly tested in the region's largest center for piano manufacture: Vienna.

Fortepiano Mechanisms in Vienna

It is common wisdom that the fortepiano gained popularity in Vienna during, approximately, the last twenty years of the eighteenth century.[51] The city became a musical hotbed in which various ideas for fortepiano manufacture could be tested, and Stein fortepianos were represented early in this timeframe. Cole explains that, "as a result of his visit in 1777 when he exhibited his *Vis-à-vis* combination instrument at the Imperial Court, Johann Andreas Stein was able to sell a number of fortepianos to influential clients in Vienna over the next five years." Additionally, Mozart is known to have used the Stein fortepiano of Countess Maria Thun in 1781.[52]

---

[50] Cole, *The Pianoforte in the Classical Era*, 187.

[51] This is due to the lack of written records or extant instruments from the decades prior to ca. 1780. See Cole, *The Pianoforte in the Classical Era*, 212-219.

[52] Ibid., 216.

Furthermore, Stein's daughter Nannette established a prosperous and well-respected piano making firm in Vienna after her father's death in 1792 (the move to Vienna occurred in 1794). She continued to build a *Prellmechanik* in the style of her father, and she used (for a time at least) many nuances of his design, including wooden *Kapseln* and no check for the rebounding hammer.[53] In terms of English fortepianos in Vienna, Cole explains that such instruments were available at high cost:

> London-made pianos were priced at somewhere between one and a half and twice the price of locally manufactured fortepianos, so only the most wealthy or most powerfully persuaded, would be likely to buy them.[54]

Cole also relays an anecdote of Reichardt:

> Reichardt mentions a meeting with Clementi in Vienna, *c.*1808, reporting that he was unable to persuade the visitor to play in public. He cannot make the excuse that there are no suitable instruments here, observes Reichardt, because some of Clementi's pupils in Vienna have had English pianos specially imported.[55]

Of course, there was also the English grand by Longman and Broderip, which Haydn brought to Vienna in 1795, and the English grand by John Broadwood & Sons, which Beethoven received in 1818. It is uncertain whether the Silbermann type of fortepiano was highly sought after in Vienna. However, Huber notes that there was a significant tradition of keyboard importation from Italy--perhaps this included examples by Cristofori.[56]

Certainly by the 1780s, *Orgelmacher* of Vienna began to build fortepianos of their own. Michael Latcham, in his significant article "Mozart and the pianos of Gabriel Anton Walter," speaks to the importance of Vienna for piano building:

---

[53] Michael Latcham, "The Development of the Streicher firm of piano builders under the leadership of Nannette Streicer, 1792 to 1823," in *Das Wiener Klavier bis 1850*, edited by Beatrix Darmstädter, Alfons Huber, and Rudolf Hopfner (Tutzing: Hans Schneider, 2007), 48-59.
[54] Ibid., 139.
[55] Ibid., 139-140.
[56] Huber, "Was the 'Viennese Action' Originally a Stossmechanik?", 171.

> Mozart settled there in 1781, Haydn in 1790 and Beethoven in 1794. Mozart, Haydn, Beethoven and Schubert all died in Vienna. Their presence must have been a powerful stimulus for makers of musical instruments, especially the piano, the supremacy of which had certainly been established by 1795. With the possible exception of London, Vienna was at that time the most important centre for piano manufacture in Europe.[57]

Through what was likely a combination of diasporic dissemination of ideas as well as independent Viennese invention, the piano makers of this single city began to build two competing mechanism types, and these types exemplified the basic divide between all hammer mechanisms. One was made to push, and one was made to pull.[58]

The developed Viennese *Stossmechanik* was extremely similar to the German form discussed above. A short hopper was used for direct propulsion of the hammer, and the hopper was made moveable on a spring for escapement. Ignaz Kober, member of the Viennese *Orgelmacher* guild, is the primary figure associated with this mechanism in the literature. This is because early examples by him are extant (ca.1785-1791). In Richard Maunder's book, *Keyboard Instruments in Eighteenth Century Vienna*, Kober and his mentor Franz Xavier Christoph are positioned as representatives of the normal style of fortepiano building – that is, with *Stossmechanik*. Both Maunder and Huber show that there is evidence of a developing *Stossmechanik* in Austria, from one without escapement, to the version seen in the instruments of Kober. They assert that this was the current of fortepiano building in Vienna, and that the *Prellmechanik* was an unconventional addition to the scene.[59]

Maunder identifies Gottfried Mallek and Ferdinand Hoffmann – two guild members in Vienna, working in the same timeframe as Christoph and Kober – as builders of a Stein-like

---

[57] Latcham, "Mozart and the Pianos of Gabriel Anton Walter," *Early Music* 25/3 (1997): 383.
[58] For detailed line drawings of Viennese mechanisms discussed in the following section, see: Richard Maunder, *Keyboard Instruments in Eighteenth-Century Vienna* (Oxford: Clarendon Press, 1998), 62-68.
[59] Ibid., 63; Huber, "Was the 'Viennese Action' Originally a Stossmechanik?", passim.

Prellmechanik in Vienna.[60] The builder famously associated with the development of a Viennese *Prellmechanik*, however, is Anton Walter. He was somewhat of a "maverick," according to Maunder, and the many instances of recorded conflict with Vienna's *Orgelmacher* guild support that label.[61] It seems his tendency toward the path less traveled is evident in his *Prellmechanik* as well, which contains important differences compared to the Stein model. Cole makes note of the following most significant items: (1) the absence of a hammer rest post, and subsequently the creation of taller hammer heads; (2) the significant graduation in weight concomitant with range; (3) the use of brass *Kapseln* with "an almost friction-free bearing"; (4) the presence of a check; (5) the use of escapement levers that are "thinner, lighter, and therefore more prompt in action" and that also are made to lean forward toward the key instead of upright; (6) the presence of a slap rail to limit the backward motion of the escapement lever.[62]

Since discoveries made by Rita Steblin in her article, "Anton Walter's Difficult Early Years in Vienna: New Documents, 1772-1779," we know that after a short stay in 1772, Walter moved to Vienna for good around 1775. Furthermore, it seems that Walter was making keyboard instruments on his own starting in the Fall of 1776. However, when he began making *fortepianos* is still debatable.[63] Michael Latcham's summary of extant Walter grands (discounting later examples, constructed after Walter's stepson joined the firm) reveals eighteen grand fortepianos with dates ranging from ca.1782 to ca.1800 (two of which are attributed to the *school* of Walter).[64] All of these instruments currently have a *Prellmechanik*, but importantly, some of the

[60] Maunder, *Keyboard Instruments*, 25 and 63-66.
[61] Ibid., 26-27. For Walter's feuds with the guild, see Rita Steblin, "Anton Walter's Difficult Early Years in Vienna: New Documents, 1772-1779," *Journal of the American Musical Instrument Society* 33 (2007): passim.
[62] Cole, *The Pianoforte in the Classical Era*, 223.
[63] Steblin, "Anton Walter's Difficult Early Years in Vienna," 53-54.
[64] Latcham, "Mozart and the Pianos of Gabriel Anton Walter," 385.

earliest examples contain evidence of an older action that may have inhabited the instruments – likely some kind of *Stossmechanik*.[65]

It seems, then, that two fundamental types of hammer mechanism inhabited a single musical culture in the waning years of the eighteenth century. The *Stossmechanik* was represented in its developed Viennese form by Kober and his followers, while the *Prellmechanik* was represented both in its Viennese form by Walter and his followers and also in its German form by the Stein progeny. It is generally accepted, though, that by century's end, the favor of builders swayed toward the *Prellmechanik* in grand fortepianos. While Huber states that "the *Stossmechanik* was never entirely given up in Vienna," he also notes that "the only instruments made there after 1800 equipped with it were square pianos."[66] Why, then, was Kober's elegant *Stossmechanik* eventually outmoded by the unconventional *Prellmechanik* in grand pianos? What were the differences between them, and how were they significant to musicians?

In 2005, fortepianist Tom Beghin and historical keyboard maker Chris Maene completed a project to replicate Mozart's Anton Walter grand fortepiano (built during or before 1782). This replica was built in response to some groundbreaking research by Michael Latcham. His study, and also a number of following studies, showed that certain early Walter grand fortepianos may have originally been fitted with some kind of *Stossmechanik*. There are conflicting ideas about when and how alterations were made, but it is possible that Mozart owned his Walter fortepiano with a developed Viennese *Stossmechanik*.[67] This idea – a supporting factor in the theory of an

---

[65] Latcham, "Mozart and the Pianos of Gabriel Anton Walter," 386-392. See in particular the sections on the Eisenstadt piano, the Mozart piano, and the Technisches Museum piano.

[66] Huber, "Was the 'Viennese Action' Originally a Stossmechnik?", 182. Both Huber and Maunder note that Johann Baptist Streicher's "*Patentmechanik*," appearing in 1831 in Vienna, was indeed a version of Kober's *Stossmechanik* (See Ibidem and also Maunder, *Keyboard Instruments in Eighteenth-Century Vienna*, 63). However, it seems that Streicher's development was not so much a continuation of the Viennese *Stossmechanik*, but rather it was part of a mid-eighteenth-century move toward the English tonal ideal of powerful evenness.

[67] Maunder believes that there is not sufficient height under the wrestplank to fit the hoppers of a Kober-like *Stossmechanik* as they slide into the case; he also notes the lack of evidence for hopper springs on the key levers;

early developing, but later outmoded, Viennese *Stossmechanik* – is one that opened the door for musical investigation. Beghin and Maene therefore undertook a project to reverse-engineer a *Stossmechanik* for Mozart's piano, in-line with Kober's mechanism, which could have inhabited the instrument before its alteration. Even more fascinating is the fact that Maene made the action replaceable, so that by swapping out one for the other, the performer could play Mozart's piano with either a Viennese *Stossmechanik* (after Kober) or a Viennese *Prellmechanik* (of Walter).

As the only player to experience both a Viennese *Stossmechanik* and *Prellmechanik* in the same instrument, Beghin explains his impressions in his 2008 article, "Playing Mozart's Piano: An Exercise in Reverse-Engineering." Regarding the *Stossmechanik*, he describes

> an extremely smooth action, much lighter, in fact, than the *Prellmechanik*, but one that constantly requires a certain minimum of finger pressure for the hammer to hit the string at all. It produces either hard, harpsichord-like tones or disarmingly warm and tender sounds, with surprisingly little, or nothing, in between.[68]

While the *Prellmechanik* loses "percussive bite" and "overall intimacy," the mechanism effectively accomplishes dynamic nuance:

> The dynamic focus shifts from loud and soft to the many shades in between […] The new action turns the instrument into one that is more expansive, indeed more expressive—one that effectively combines the full qualities of a clavichord with the strength of a grand piano.[69]

Beghin continues with a quote from Huber:

> The new geometry for the escapement levers, adjustable escapement rail and back check rail, as developed by Walter in his *Prellzungenmechanik*, allow for greater expressive dynamics, more than the *Stossmechaniken* of his time. Especially when playing cantabile

---

he suggests that the piano could have originally held a *Stossmechanik* without escapement. Maunder, *Keyboard Instruments in Eighteenth-Century Vienna*, 73-74.

[68] Tom Beghin, "Playing Mozart's Piano: An Exercise in Reverse-Engineering," *Keyboard Perspectives* 1 (2007-2008): 21.

[69] Ibidem.

> and when applying very soft ornaments, the new "Viennese action" [*Prellmechanik*], with its low key dip, creates a tactile impression closest to the clavichord.[70]

If the lessons of clavichordist Daniel Gottlob Türk are applicable to the fortepiano, it seems likely that they would be best performed on the mechanism that imitates the clavichord's possibility for expression. Subsequently, such an advantage could have contributed to the eventual primacy of the *Prellmechanik* in grand fortepianos. How, then, can this idea be investigated further? How can the mechanisms be tested?

Stoss vs. Prell

In a fascinating chapter, Michael Cole reports the results of static measurements of key dip, hammer travel, and touch weight on historical pianos. Cole made excellent use of a physical apparatus to measure the mechanical components in 1mm increments, and he also used scaled weights in the measure of touch weight. At chapter's end, however, he projects the future application of technology in the analysis of *performance,* rather than static measures.[71] This was accomplished by Stephen Birkett in his 2010 article, "Observing the 18th-century *Prellzungenmechanik* through high-speed imaging – Pianissimo and forte response compared." Birkett used model mechanisms, high-speed video cameras, and video processing software to describe the relationship of mechanical components in the two general types of *Prellmechanik* – Stein and Walter – in the German-Austrian realm.[72]

Following Birkett's lead, this study uses advanced technology to examine the Viennese *Stossmechanik* and *Prellmechanik*. A mechanism model of the Mozart piano replica was commissioned from Chris Maene, and this model was made with the same remarkable feature as

[70] Beghin, "Playing Mozart's Piano," 21.
[71] Cole, *The Pianoforte in the Classical Era*, 310.
[72] Stephen Birkett, "Observing the 18th-Century *Prellzungenmechanik* through high-speed imaging," in *Bowed and Keyboard Instruments in the Age of Mozart* (Berne: Peter Lang, 2010), 305-326.

its antecedent: interchangeable *stoss* and *prell* mechanisms. This meant that the mechanisms could be isolated from the variables of stringing and case construction during experimentation. A 3D motion capture camera system was used to track mechanism components in motion at extremely high frame rates, and an experiment was designed to differentiate the two mechanisms in terms of one of Türk's phonetic parameters: loudness. Ultimately, this study asks which fundamental mechanical principle – to push or to pull – is better suited to effect the varying degrees of "emphasis" required in order to speak the language of eighteenth-century music.

Chapter Two

Section 1. Materials and Methods

Mechanism Model

With the support of Tom Beghin, and in consultation with Beghin and Chris Maene, I commissioned a mechanism model of Mozart's piano with interchangeable *stoss* and *prell* actions. The model was completed in the workshop of Chris Maene in February 2014.

Image 1 - Mechanism Model with *stoss* and *prell*

It is built with six strings (FF, F, f, f1, f2, f3), the three highest of which are to-scale; it has a functional soundboard; the dampers are removable (and were in fact removed during experimentation); and finally, a six key *prell* or *stoss* mechanism sled can be placed under the same set of strings. The keys are constructed in a chromatic layout, even though each is paired with an f-string. This was done to keep open the doors for future experimentation involving trills, for example. A front-pin guidance system was used instead of the extant *Kanzellenführung*. This modification has a basis in history: for example, in the later addition of front-pins to the so-called Eisenstadt fortepiano by Walter, and also in the apparently original existence of front-pins in a

Walter grand of c.1785.[73] The fifth octave f2 was used for experimentation and corresponded to a natural key on both mechanisms. All other keys and hammers, as well as the *prell* mechanism's backcheck, were removed for greater visibility. Both *stoss* and *prell* hammers were fitted with three identical layers of leather--this was done in order to eliminate leather as a variable in the study of each mechanism's method for moving the hammer. The hammers for both *stoss* and *prell* were made to correspond with their respective octaves.

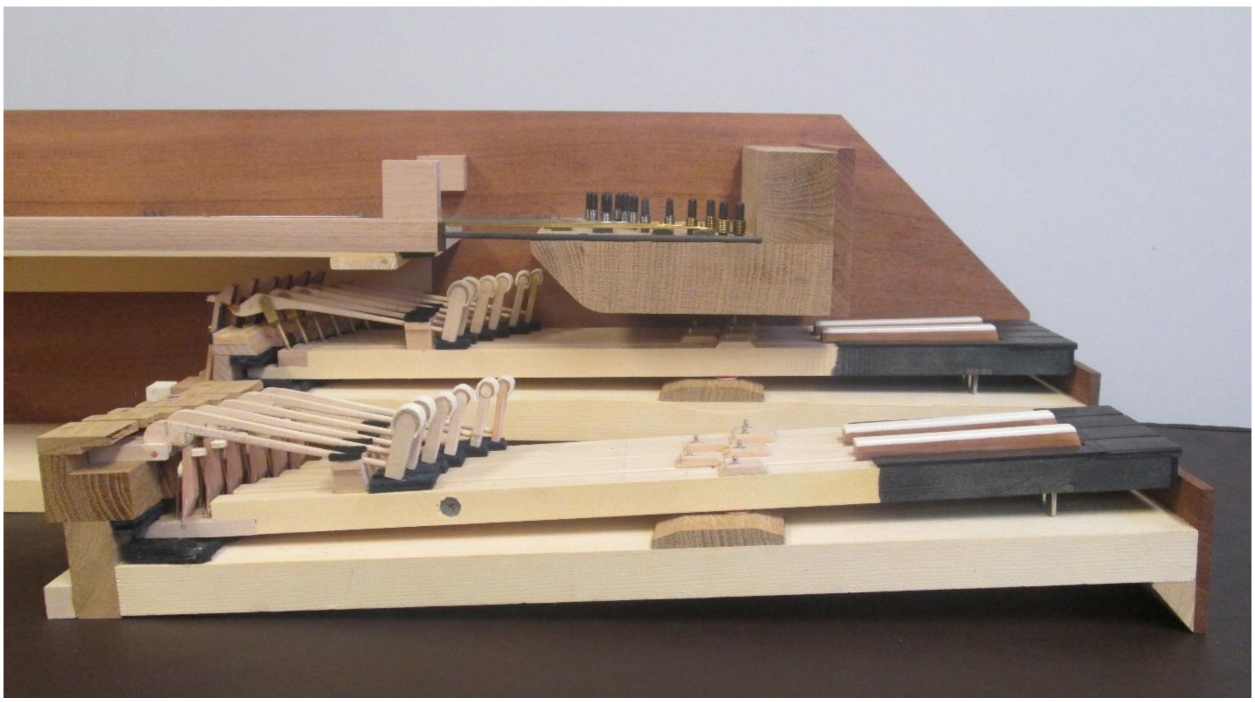

Image 2 - Another View of the Model with *stoss* and *prell*

[73] Latcham, "Mozart and the Pianos of Gabriel Anton Walter," 386 and 396.

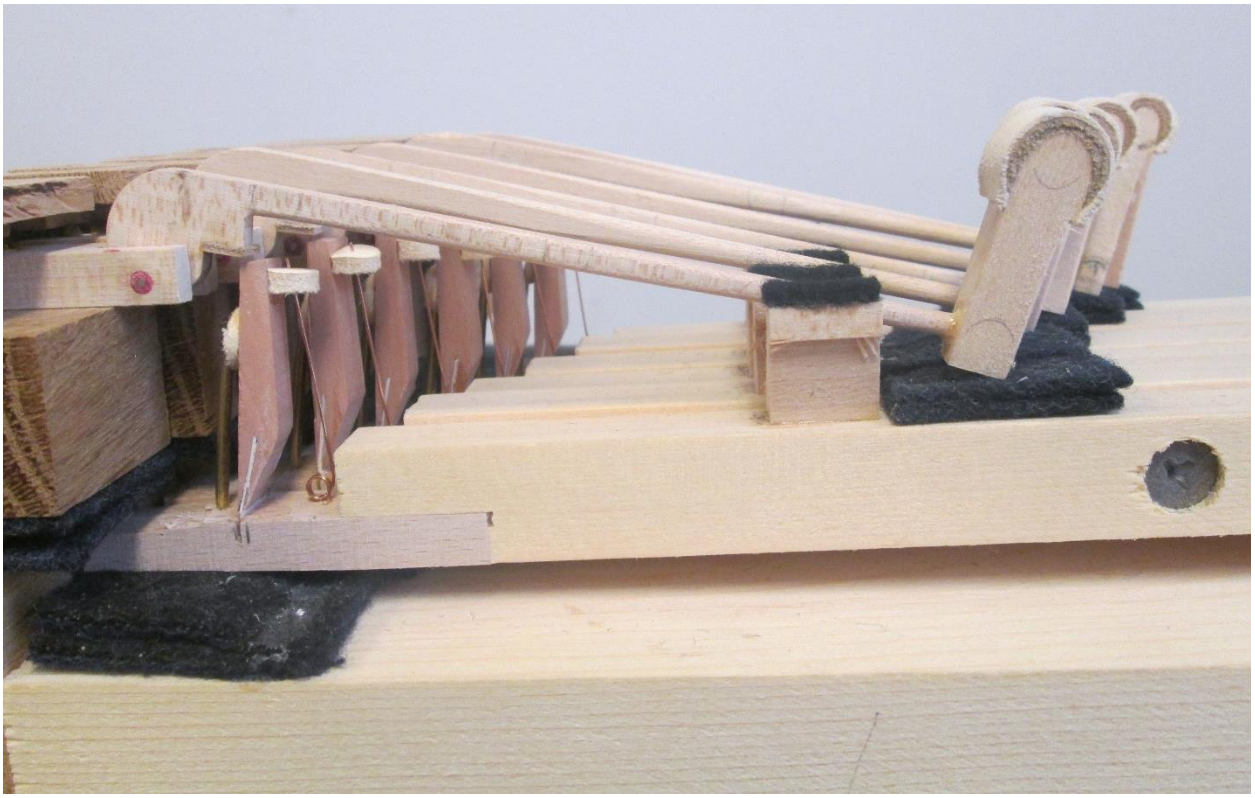

Image 3 – *stoss* Mechanism with all Hammers

Image 4 – *stoss* Mechanism with only f2 Hammer

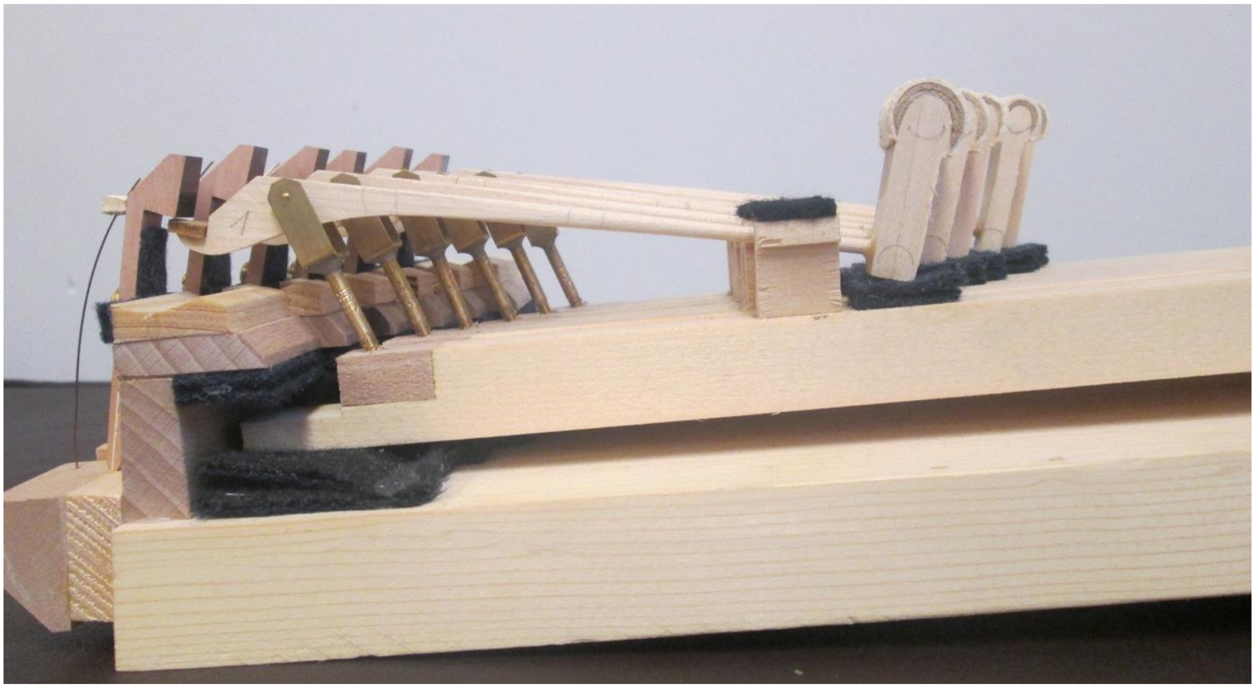

Image 5 – *prell* Mechanism with all Hammers

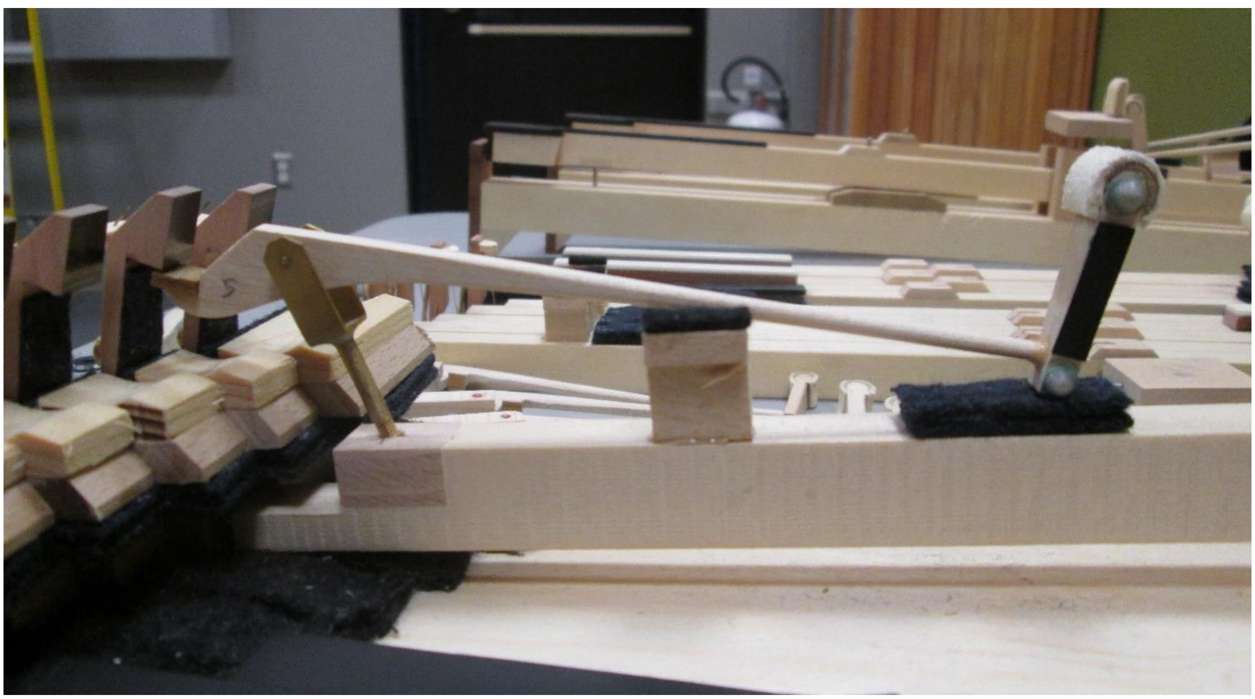

Image 6 – *prell* Mechanism with only f2 Hammer

Pianist

In order to obtain meaningful data, we needed a fortepianist with an understanding of these subtly different mechanisms, but also with an appreciation of the experiment goals. In other words, the player needed to be able to control both mechanisms effectively, but also, he needed to take on the role of a mechanical depressor, attempting to achieve consistent loudness with a straight-forward, gesture-less stroke. Fortepianist and DMus candidate Michael Pecak was involved in the project from the beginning. His experience as an historically informed performer, and his academic interest in the impact of mechanical components on musical possibilities, were fitting qualities for the effective and controlled performance of tones on *stoss* and *prell*.[74] Furthermore, both he and Beghin participated in early experiment trials, developing the mindset and method necessary for mechanical repetition.

Audio Recording

This experiment required the measurement of decibels. Therefore, the tones produced on the model were recorded by two DPA 4006-TL microphones with an RME Fireface UC and ProTools9 software on a PC laptop. The microphones were in the same position for recordings of both mechanisms and did not account for differences in the directional projection of sound.

Video Recording – 3D Motion Capture

The Qualisys Motion Capture camera system uses infrared light to illuminate passive markers. Before a measurement, the system learns the position of markers on an L-shaped reference structure, which is then removed from the measurement area. During a measurement, the system is able to track the position of each moving marker relative to the learned source, and furthermore, the Qualisys Track Manager software reports the position of each marker on the x, y, and z axes. This serves to create a virtual 3D representation of any movement.

---

[74] Michael Pecak has been recognized and awarded by the Chicago Chopin Society, the Kosciuszko Foundation, Early Music America, Early Music Vancouver, and the Historical Keyboard Society of North America. He studied fortepiano as a graduate fellow with Malcolm Bilson, and he is currently completing his Doctor of Music degree in fortepiano and historical performance practice with Tom Beghin.

Hemispheric markers measuring 4mm in diameter were placed on the side of the key and on the side of the hammer head's tip and base. On both mechanisms, key markers were aligned with an L drawn approximately 6mm inward from the end of the key and 8mm down from the top of the key. Hammer base markers were positioned so that the bottom of the marker met the edge of the hammer base--they were then centered on the hammer body. Hammer tip markers were centered on the hammer tip and positioned approximately 2mm below the end of the wooden tip. The markers were attached to the mechanism using an adhesive putty. Added weight was minimized as much as possible by applying the putty only around the rim of the hollow hemispheric markers, making the application as consistent as possible between mechanisms.

Image 7 - Hammer Head Markers, *stoss*

Image 8 - Hammer Head Markers, *prell*

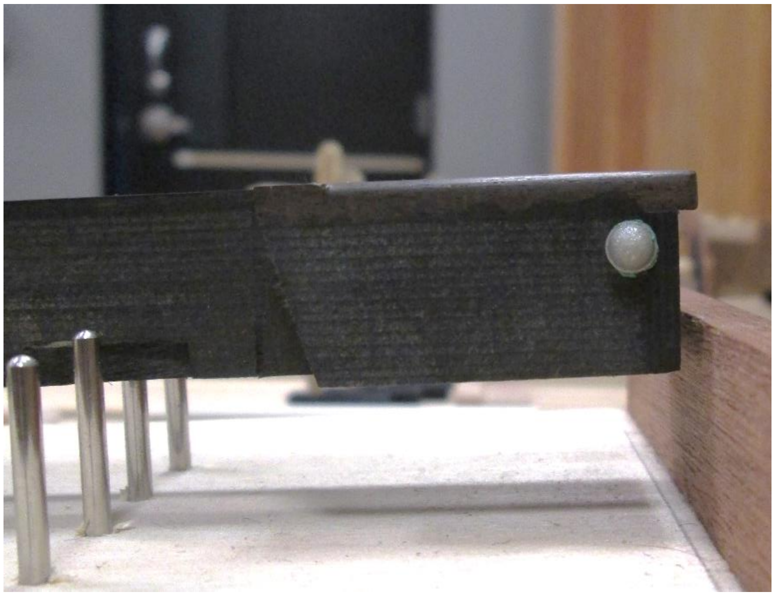

Image 9 - Key Marker **Image 10 - Adhesive Application**

In order to reduce reflections from material other than the markers (wood and especially metal were reflective of infrared light to various degrees), black construction paper was used to cover certain areas of the model. The construction paper was only placed on one moving part of the model: the hammer head. This was necessary in order for the system to clearly distinguish the hammer head markers from the hammer head itself. The size and weight of the coverings were minimized as much as possible and made approximately consistent between mechanisms.

The model was placed on moveable and height-adjustable tables so that the ideal position relative to the cameras could be found. The tables were then locked in place and stabilized by a system of tripods placed underneath. Markings on the tables indicated the proper position of the model.

Three Qualisys cameras were used to view the mechanism, two of which were able to maintain view of the hammer head markers throughout the strike. The key marker was viewed by all three cameras for the entirety of the strike. The movement of the hammer head and key were recorded at 4,000 frames-per-second by all cameras. In *stoss* measurements, between 0 and 5 frames were "gap filled" during the hammer strike (out of a total of 161 to 1,204 frames, depending on the dynamic level). This means that the system did not record the hammer head tip/base marker positions but estimated their position relative to information in the surrounding frames. In *prell* measurements there were no gap fills. The *stoss* measurements also contained a greater degree of spiking (i.e., slight erroneous fluctuations) than the *prell* measurements.

Image 11 - Stabilizing Tripods

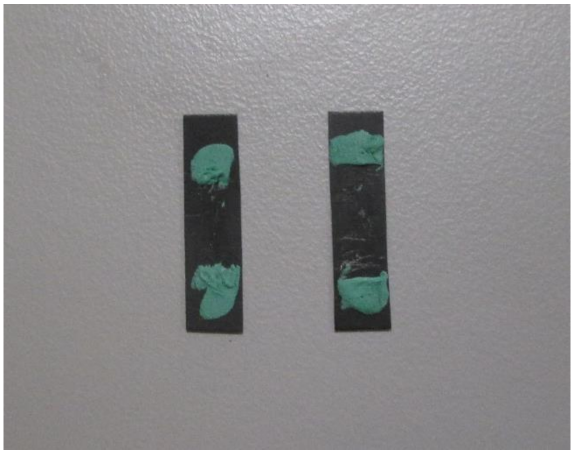

Image 12 - Construction Paper for the Hammer Head of *stoss* and *prell*

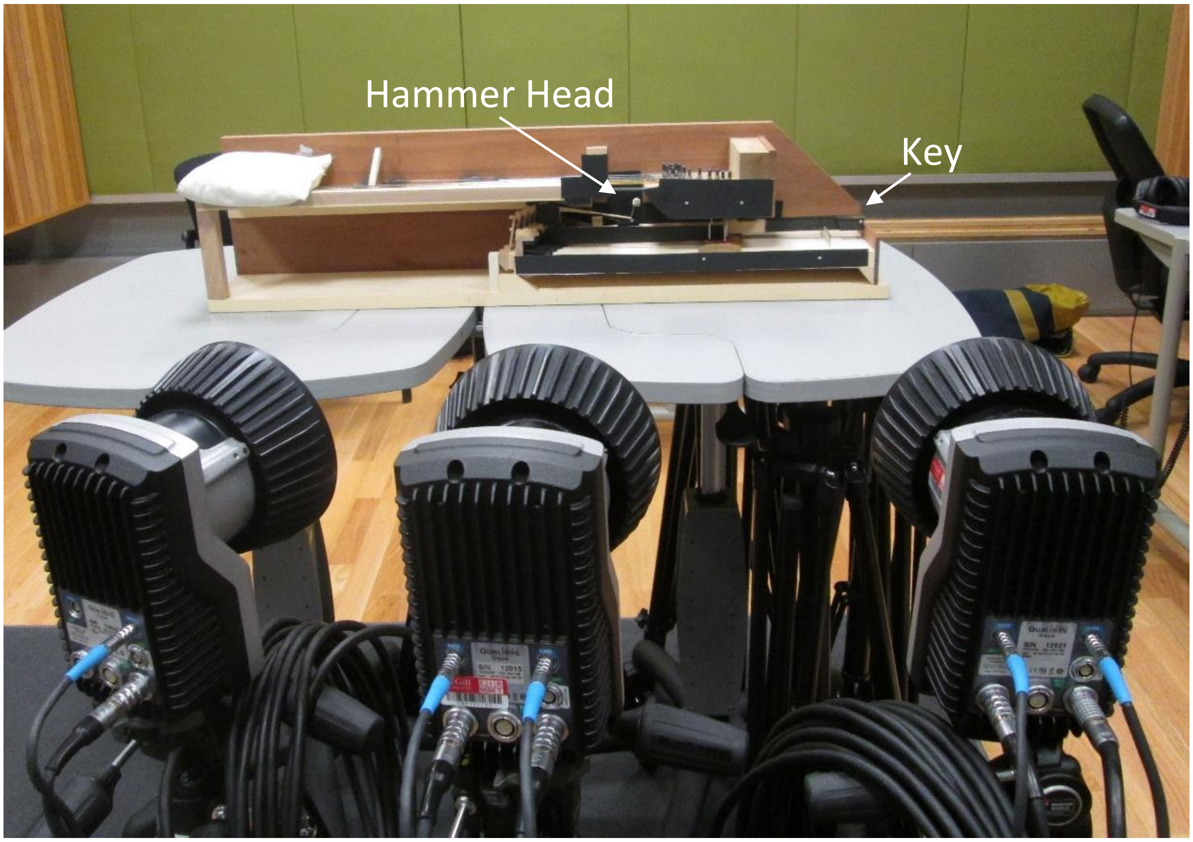

Image 13 - Experiment Set Up

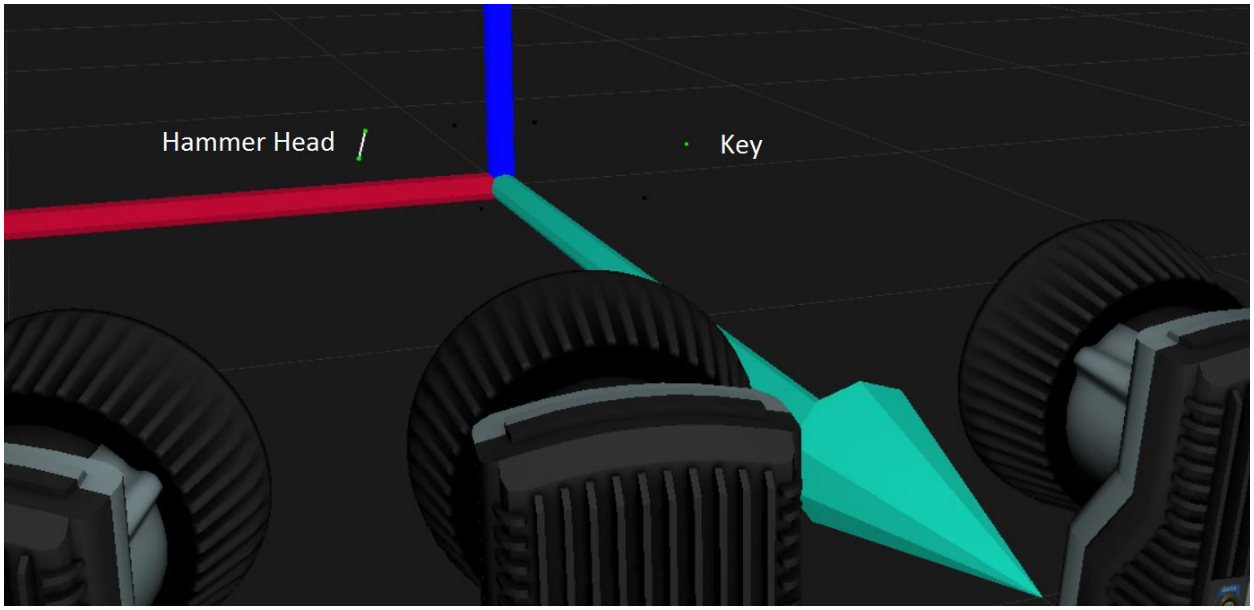

Image 14 - Camera View

Laboratory

All experimentation was conducted at Montreal's Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT) in the Performance and Recording Lab, a room designed for audio recordings and motion capture. The thermostat for the lab was kept always at 21 degrees Celsius, but temperature fluctuations could not be strictly controlled.

Experiment Protocol

The experiment took place over two days. The *stoss* mechanism was tested on day one and the *prell* mechanism on day two. Key strikes on each mechanism were recorded fifteen times at each of three dynamic levels in the following order: piano, forte, and mezzo (literally in-between). The pianist was instructed to depress the key as mechanically as possible – that is, without gesture or extraneous finger/wrist/arm movements – and the finger was to assume light contact with the key already before the strike. On both days, the camera system was calibrated before experimentation, and the f2 strings were tuned (a1 = 430 Hz, Vallotti, using the Cleartune iPhone application). In lieu of dampers, the f1 strings were damped with a tuning wedge, and a sandbag was placed on the hitchpins to damp the lower string choirs. The highest string choir (f3) was left undamped. Prior to the first day of experimentation, the let off was set to around 1mm from the string on each mechanism (*stoss*, slightly more than 1mm and *prell*, slightly less than 1mm).

At each dynamic level, the pianist performed at least fifteen preliminary strikes. After each of them, he was told the decibel reading. This established a target decibel range for each dynamic level. The following fifteen strikes were recorded, and decibel readings were again provided for the pianist after each strike. This procedure was enacted in order to observe the mechanical components of each mechanism when producing the same or similar decibel readings.

Analysis of Audio Recording

The tones were analyzed using iZotope Rx2 software. Maximum decibel readings were recorded at the attack (beginning of the tone), and the readings from each of the two microphones were always averaged in the results. The use of the same benchtop model for both mechanisms is intended to provide a basis of comparison for *stoss* and *prell*, without the variables of different strings, soundboards, bridges, etc. – factors that otherwise, among a population of different pianos, would play a role in decibel output.

Analysis of Video Recording – Key Depression

Because the system calculates positions down to a hundredth of a millimeter, it was difficult to discern objectively and consistently where the key strike begins and ends. The following paradigm was used: the movement of the key along the Z (vertical) axis was plotted in QTM; working frame by frame, a plateau (portion of the recording without much key movement) was identified that was attached to the period of consistent descent; because no plateau was perfectly stable, the lowest reading that was a part of that plateau was selected; finally, working backward from within the consistent descent, the selected plateau reading was reached; this was the beginning of the key strike. The end of the key strike was somewhat simpler to identify--this was defined as the lowest Z axis reading before an ascent or plateau. There was often a period of further descent following that initial ascent/plateau--that following period was defined as aftertouch. The key strike, then, is a period of consistent descent which excludes premature movements of the key as well as aftertouch.

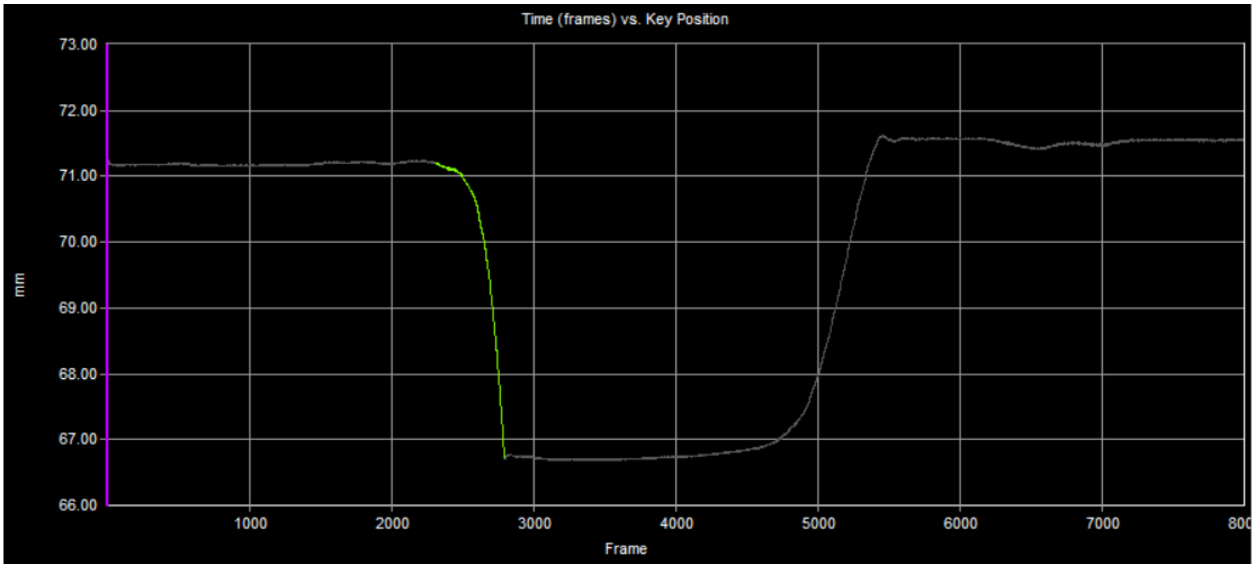

Image 15 – Example of Key Period (green highlight)

Once the beginning and end points of the key strike were selected, the frame numbers were recorded and the time of the key strike was translated to milliseconds. Finally, the "magnitude of distance traveled" function in QTM calculated the millimeters traveled, taking all three coordinates into account. This function uses a .2mm hysteresis, meaning that the distance traveled only increases when the marker moves more than .2mm. This reduces the risk of false movements contributing to the overall distance traveled but also means that the readings are not exact to frame.

Analysis of Video Recording – Hammer Head Travel

The beginning and end of the hammer strike were chosen from within the key strike period, but again it was a difficult to objectively select the beginning and end of movement. For this, the following paradigm was used: the movement of the hammer along the Z (vertical) axis was plotted in QTM; a plateau or smaller steady area was identified that was attached to the period of consistent ascent; because no plateau was perfectly stable, the highest reading that was a part of that plateau was selected; finally, working backward from within the consistent ascent, the selected plateau reading was reached; this was the beginning of the hammer strike. Additionally, fluctuations due to error at the beginning of a hammer strike period were eliminated as consistently as possible. The end of the hammer strike was defined as the last frame before the beginning of hammer descent.

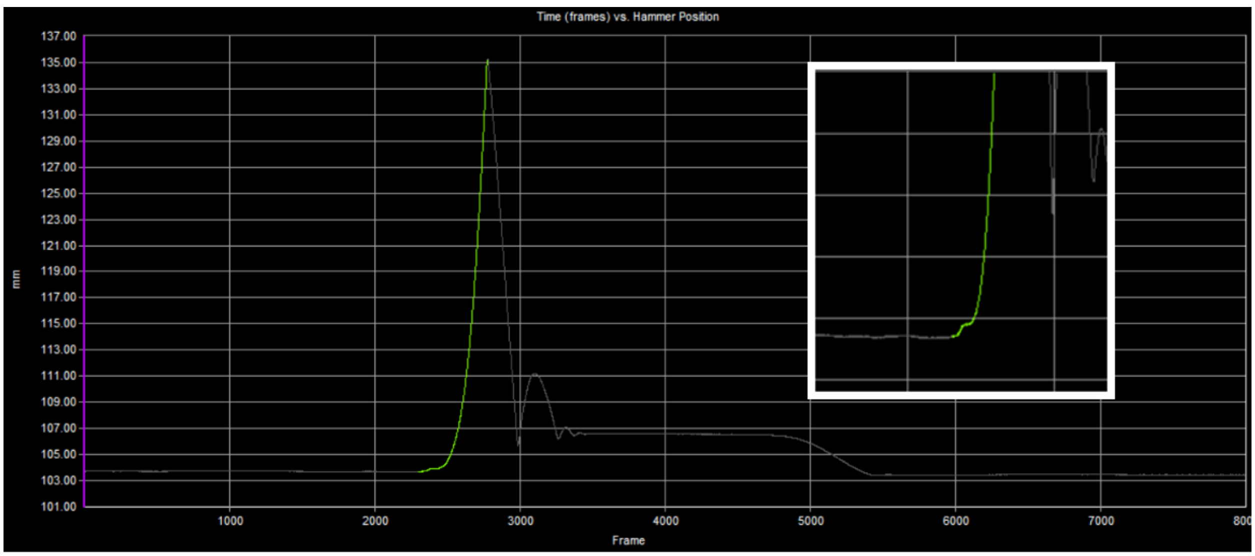

Image 16 – Example of Hammer Period with Inlay of Strike Beginning

Just as in the analysis of key depression, the “magnitude of distance traveled” function was used to calculate hammer travel. However, an additional analysis was conducted. The angle of the hammer head was calculated at the beginning and end of the hammer strike. This was done using the angle analysis function in QTM, which projects planes outward from the X, Y, and Z axes of the learned coordinate structure. The line created between the hammer head tip and base markers is measured against those planes. A filter was employed in the QTM analysis of hammer head angle. Every frame was considered within a surrounding window of 33 frames, and the software calculated the closest second-degree curve to fit each frame. This eliminated spikes in the data in the same way that the distance-traveled hysteresis eliminated unreal movements. A somewhat small 33-frame window was chosen because it serves to eliminate noise without drastically distorting the data.

Statistical Analyses

Statistical language is used throughout this chapter. Student t-tests and analyses of variance serve to determine whether the difference between sets of data is due to random chance or due to some significant difference between the scenarios or mechanisms that created those sets. A “p value” represents that determination: if p is less than or equal to .05, it means that there is a five percent or less chance that the differences are due to random circumstance. These differences are considered statistically significant. If p is greater than .05, it means that there is more than a five percent chance that the differences are due to random. The differences are then considered statistically insignificant. A regression analysis considers whether two factors are related proportionally to one another. For instance, if as the distance traveled of the piano key increases, the distance traveled of the hammer increases proportionally, this would be shown by a high “r^2 value.” If r^2 is around or above 90, then the relationship between the two factors is considered proportional. The lower the number, the less clearly linked the factors are, and vice versa.

In order to use these types of statistical analyses (called parametric analyses), the data sets should ideally be “normally distributed” – that is, contain a high concentration of data points around the mean and equally smaller concentrations of data points on either side of the mean. All data sets in this experiment were assessed for normality using the Shapiro-Wilks test. Some instances of non-normal distribution are noted in the results section, however the size of the data sets are large enough (15) to use parametric analyses as, at the very least, an estimate of statistical reality. Unpaired student t-tests, two-between analyses of variance with Bonferroni Post-hoc pairwise comparison, and regression analyses were used in the comparison of groups (specified below). $p \leq .05$ was considered significant.

Section 2. Results

Loudness

On each mechanism – *stoss* and *prell* – three dynamic levels were performed: piano, forte, and mezzo (literally in-between). The analysis of decibel range was the first step in order to investigate mechanical attributes of each mechanism at the same or similar dynamic levels. **Figure 2.1** demonstrates that the decibel range at each dynamic level was indeed similar between mechanisms.

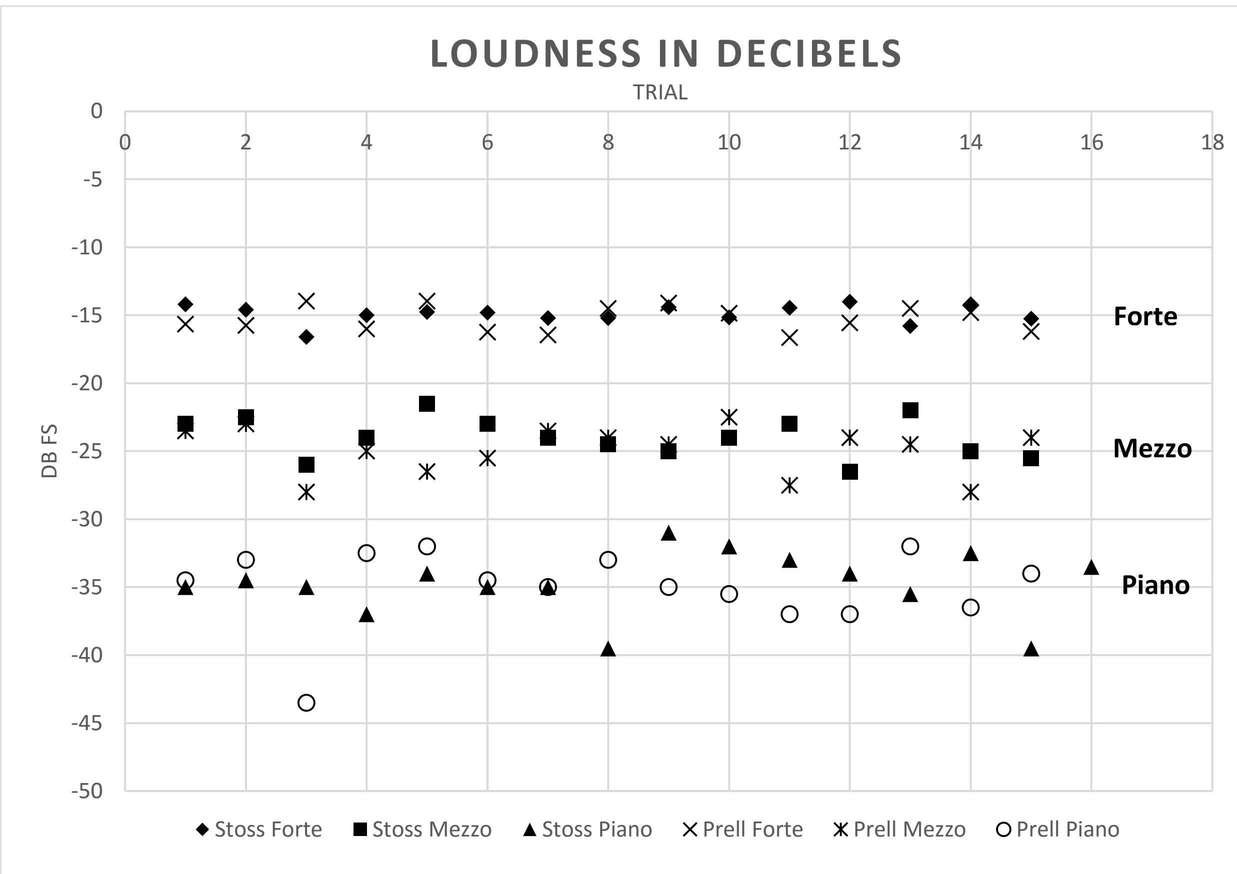

Figure 2.1

This was confirmed by unpaired student t-tests conducted on the *stoss* and *prell* decibel readings at each dynamic level. The decibel range was statistically the same ($p > .05$) for both mechanisms at all three dynamic levels.[75] T-tests were chosen over an analysis of variance (ANOVA) because dBFS is a logarithmic scale, and it is more accurate to compare only the decibel ranges within each dynamic level. Using targeted t-tests instead of the all-encompassing ANOVA served to minimize comparison across disparate areas of the scale.

Key Depression

The Qualisys motion capture camera system and the Qualisys Track Manager software were used to track a marker placed on the side of each mechanism's key. The distance traveled and period of time between the selected beginning and end of each key strike enabled the calculation of average key speed for strikes at each dynamic level.

A two-between ANOVA showed that the key speed at mezzo was statistically the same between mechanisms (See **Figure 2.2**).[76] The key speed at forte showed a trend of difference between mechanisms ($p = .05859$), however that trend is not obviously discernible in the data points of **Figure 2.3**. The key speed at piano was statistically different ($p < .05$) between mechanisms, and in **Figure 2.4**, it can be seen that piano strikes were consistently slower on *stoss* than on *prell*. It may be reminded that, in spite of this difference in speed of key depression, the same decibel range was achieved by both mechanisms at each dynamic level.

[75] The data set for *prell* piano was the only data set in the population that showed a non-normal distribution (Shapiro Wilks, $p = .0078$).

[76] The data set for *prell* mezzo was the only set in the population that showed a non-normal distribution (Shapiro-Wilks, $p = .0097$).

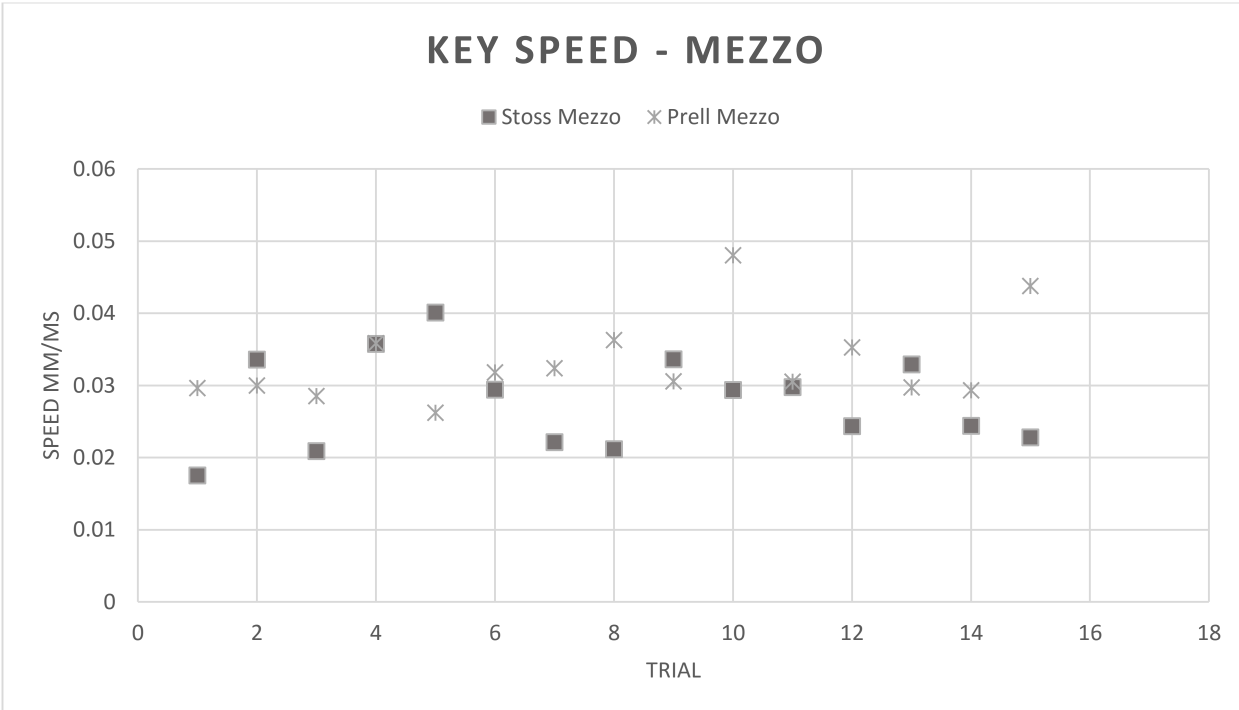

Figure 2.2

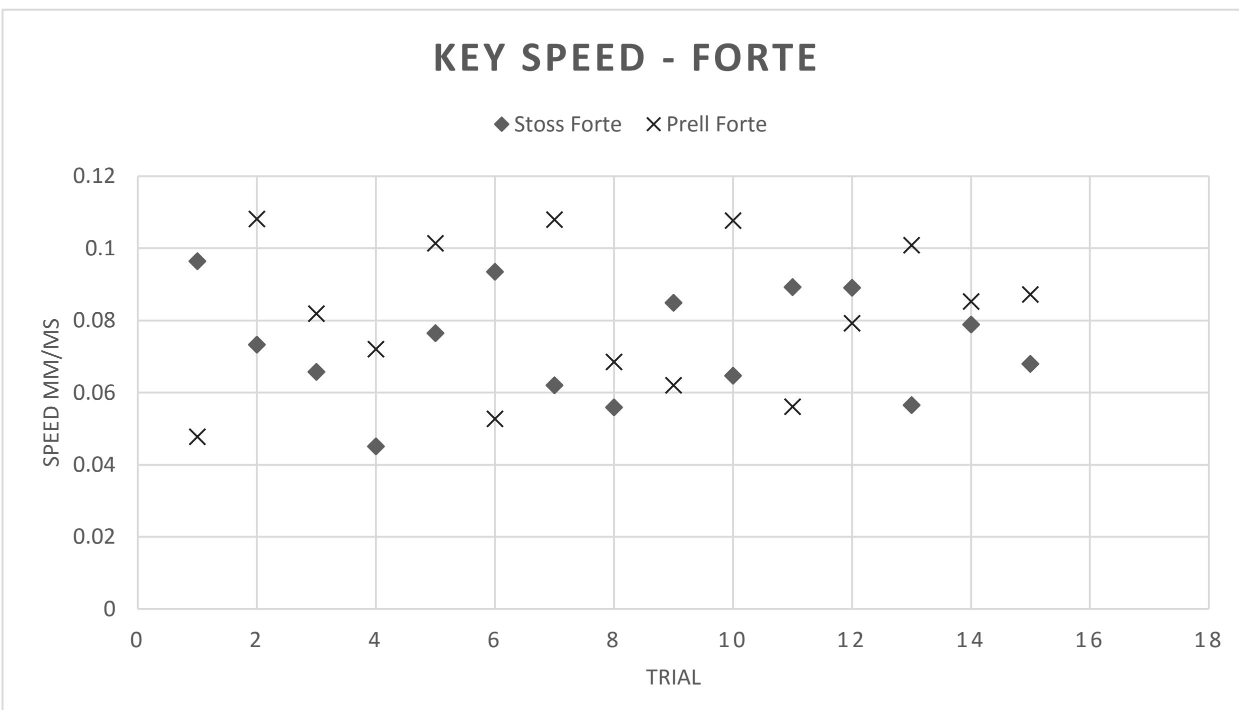

Figure 2.3

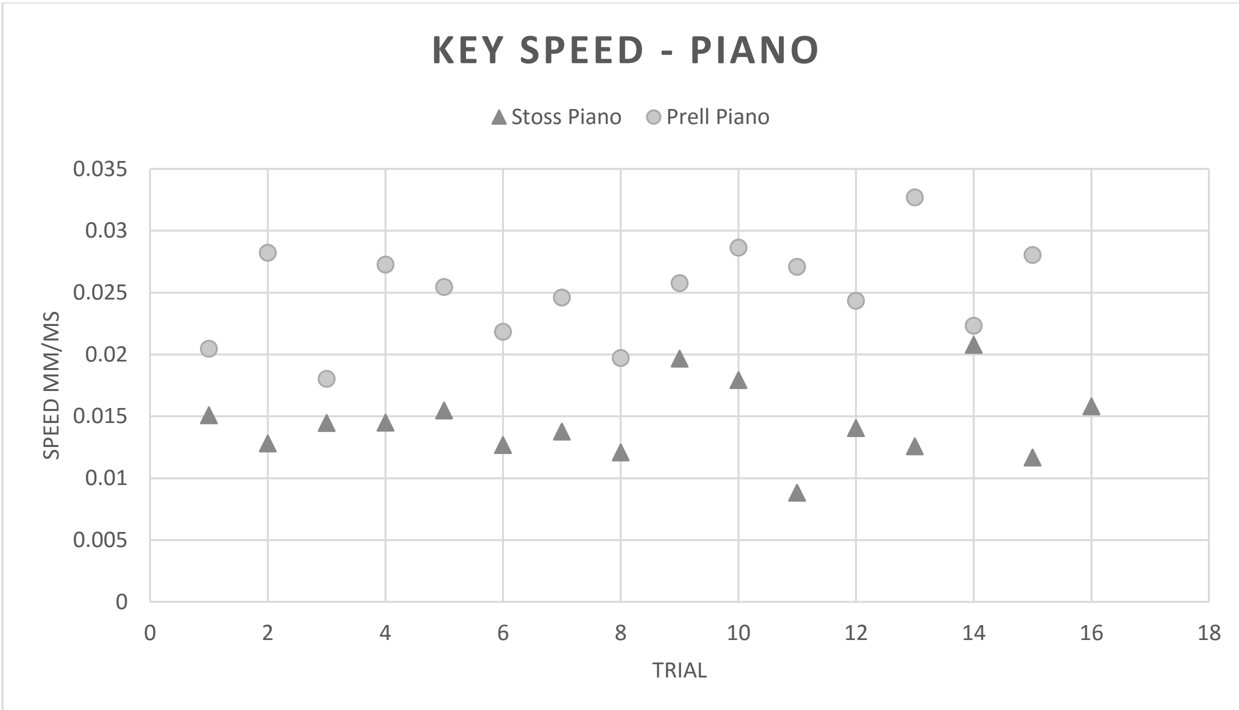

Figure 2.4

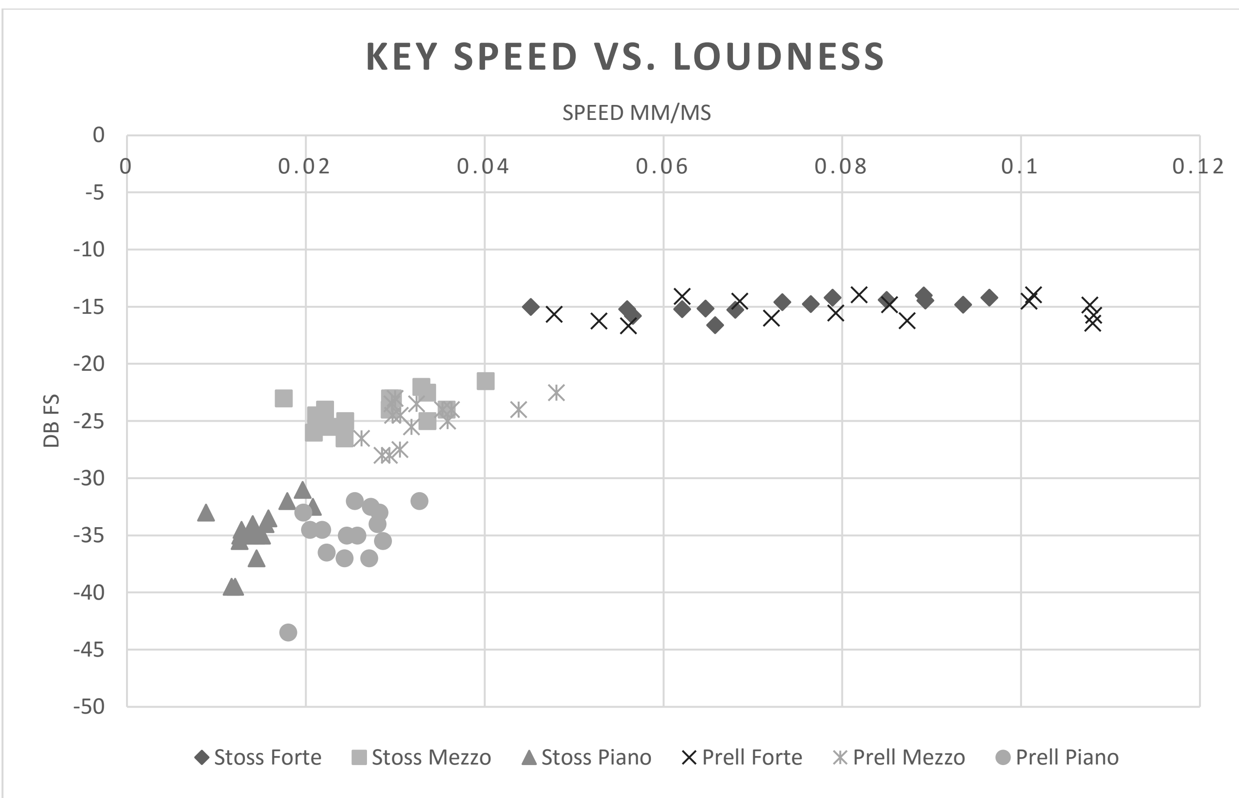

Figure 2.5

In **Figure 2.5**, the mechanism data sets are merged together, and key speed is plotted against loudness. The graph shows a fairly close relationship between key speed and loudness in both mechanisms, however a plateau at the forte dynamic level disrupts that relationship. This plateau could be the result of reaching the maximum achievable dynamic on the instrument, or it is possibly due to a greater ease of consistency at the louder dynamic level. A regression analysis shows that key speed and loudness are somewhat more closely linked in *stoss* ($r^2 = 78.30$) than in *prell* ($r^2 = 67.62$).

In **Figure 2.6**, the mechanism data sets are plotted on a graph of millimeters vs. milliseconds. The graph shows that the *prell* key traveled a consistently greater distance than the *stoss* key. This is confirmed by a two-between ANOVA that shows a significant difference in key travel between mechanisms at all three dynamic levels ($p < .001$).[77] Another two-between ANOVA calculated the mechanism effect on time. This analysis showed that the time of key depression was statistically the same ($p > .05$) between mechanisms at both mezzo and forte, but significantly different at piano ($p < .001$).[78] Therefore, it can be said that the greater distance traveled of the *prell* key is an isolated attribute of that mechanism in forte and mezzo strikes, while the greater distance traveled in *prell* piano strikes is perhaps due to the lesser amount of time taken.

[77] The data set for *prell* piano was the only set in the population that showed a non-normal distribution (Shapiro-Wilks, $p = .0149$)

[78] The data set for *stoss* forte was the only set in the population that showed a non-normal distribution (Shapiro-Wilks, $p = .0359$)

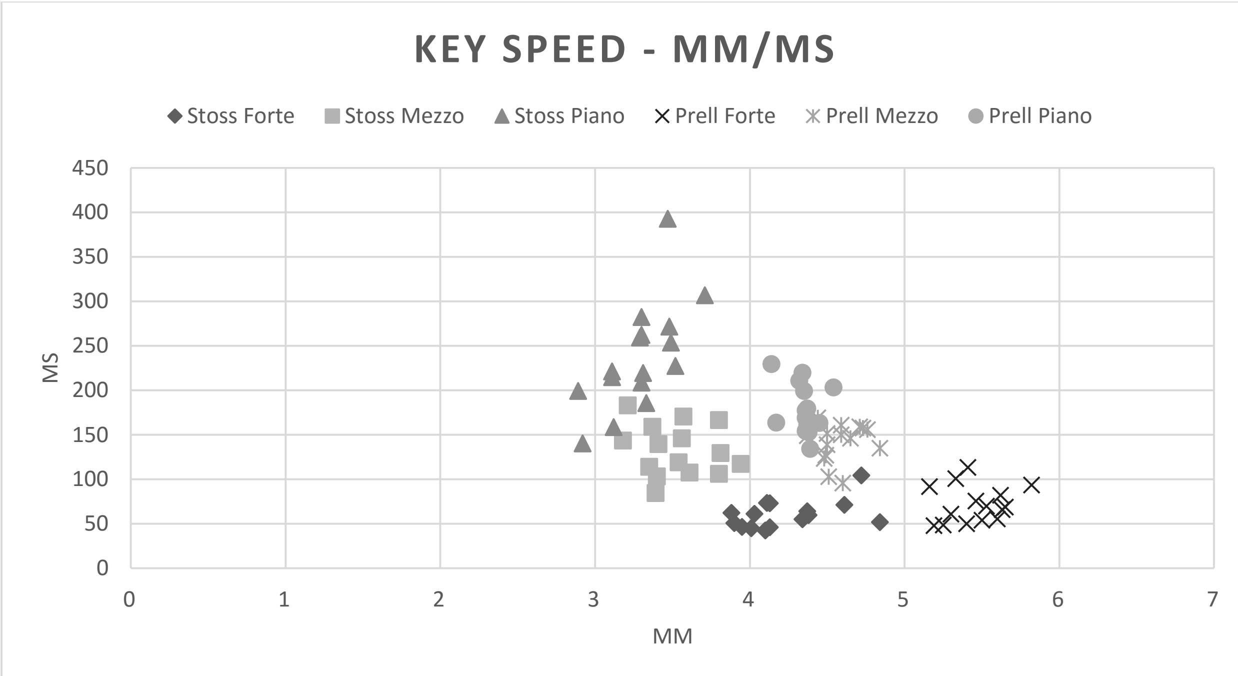

Figure 2.6

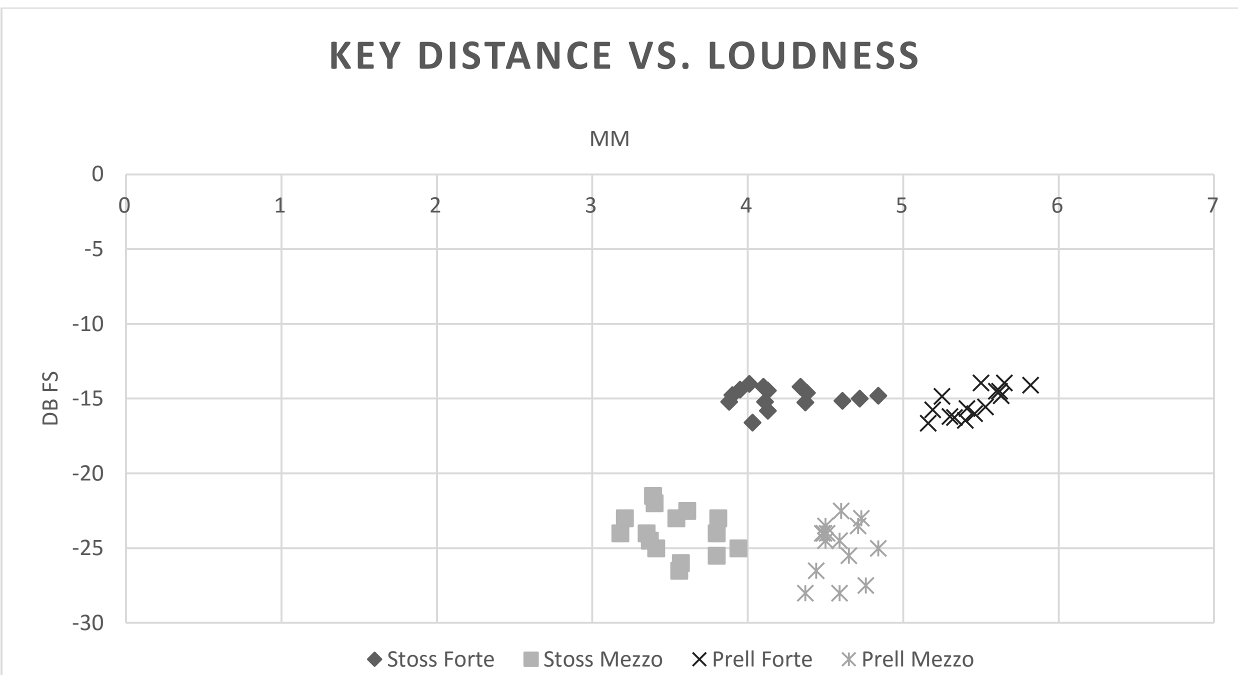

Figure 2.7

At the forte and mezzo dynamic levels, the key speed is statistically the same between mechanisms (as discussed above). This is due to the fact that the time of key depression is statistically the same between mechanisms, and the difference in distance traveled is not significant *enough* to affect the statistics of overall speed. However, the greater distance traveled in *prell* forte and mezzo strikes could still show an influence on other factors. **Figure 2.7** shows distance as isolated from time and plotted against decibel range. A regression analysis of the data points from each mechanism showed that key distance traveled is linearly related to loudness in *prell* (r^2 = 87.76) but not *stoss* (r^2 = 58.24). Thus, in *prell*, a change in key distance will likely lead to a change in loudness, while in *stoss*, the relationship is less clear.

Hammer Travel

The Qualisys camera system and QTM were also used to track two markers on each mechanism's hammer head: one placed on the tip and one on the base. These data again facilitated the calculation of speed at each dynamic level (see **Figures 2.8-10**). A two-between ANOVA showed that at all three dynamic levels the hammer speed was statistically the same between mechanisms ($p > .05$).

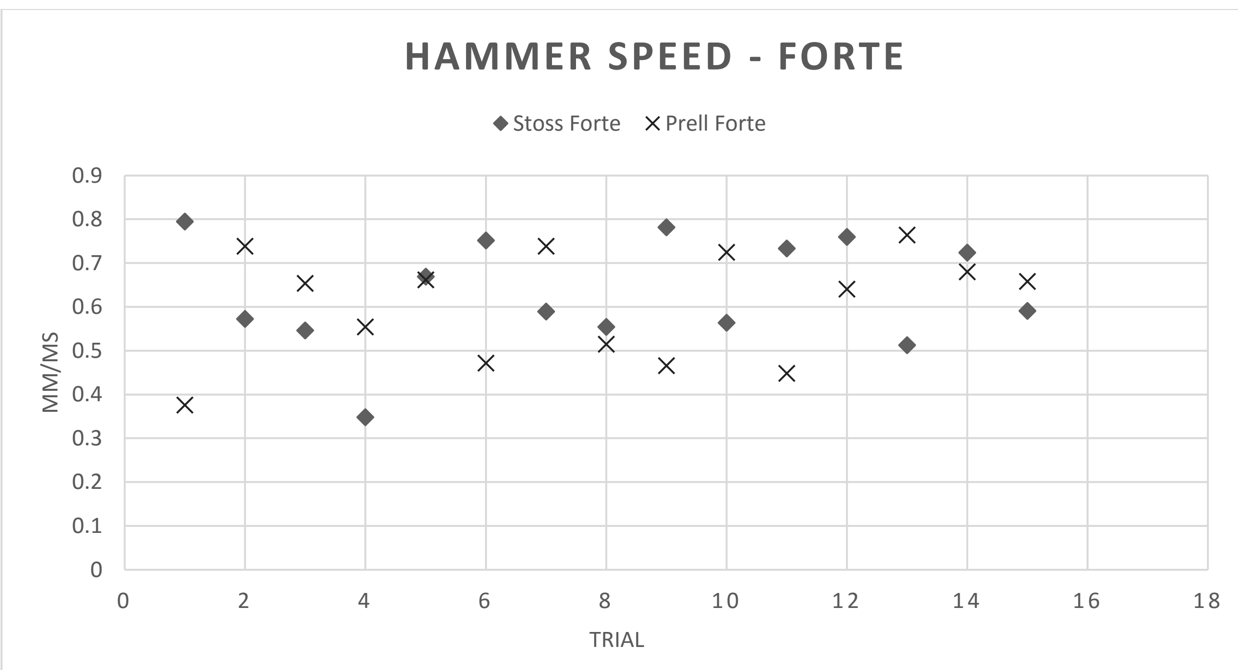

Figure 2.8

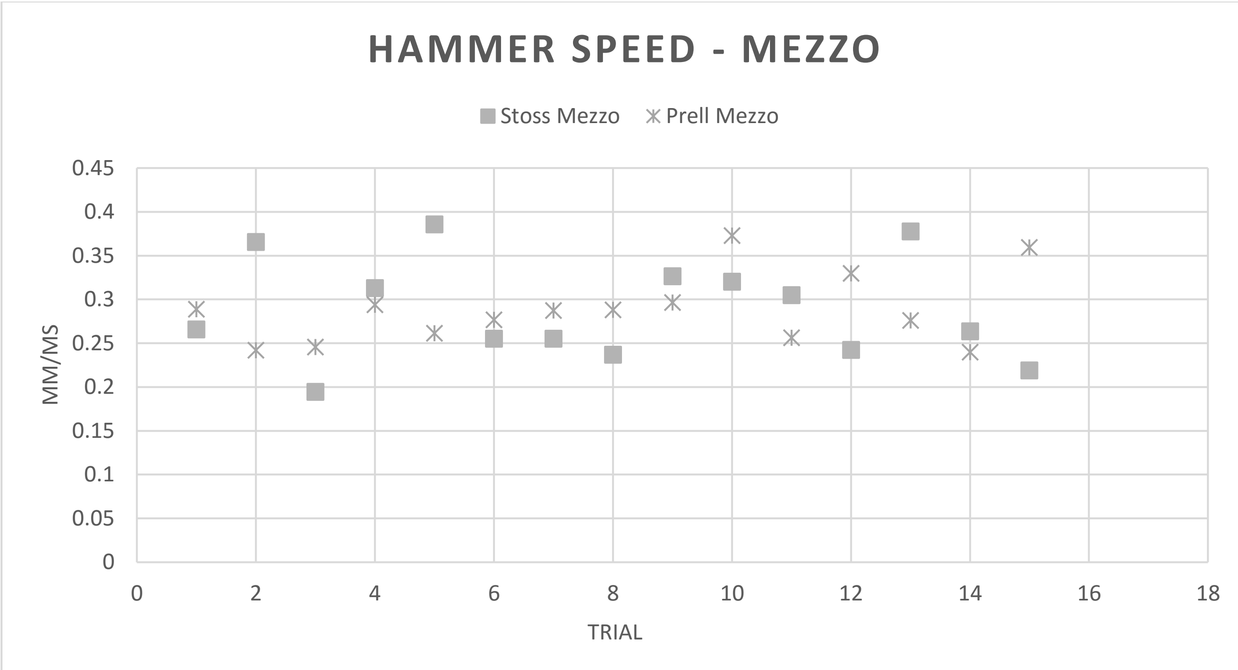

Figure 2.9

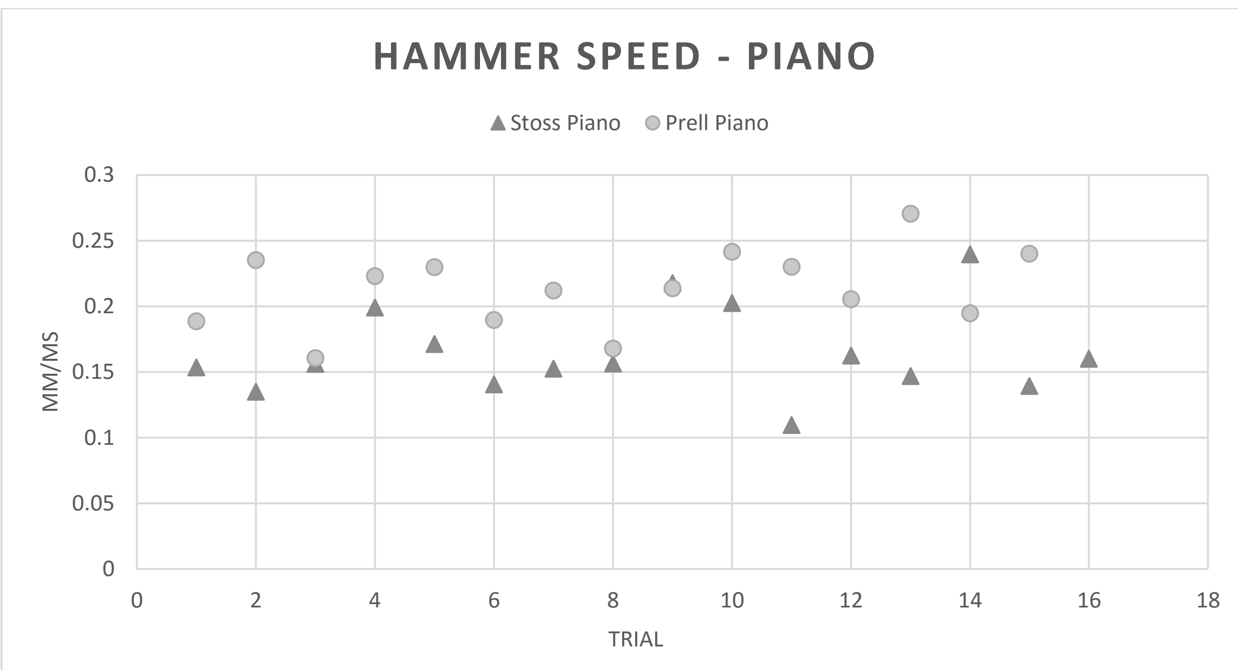

Figure 2.10

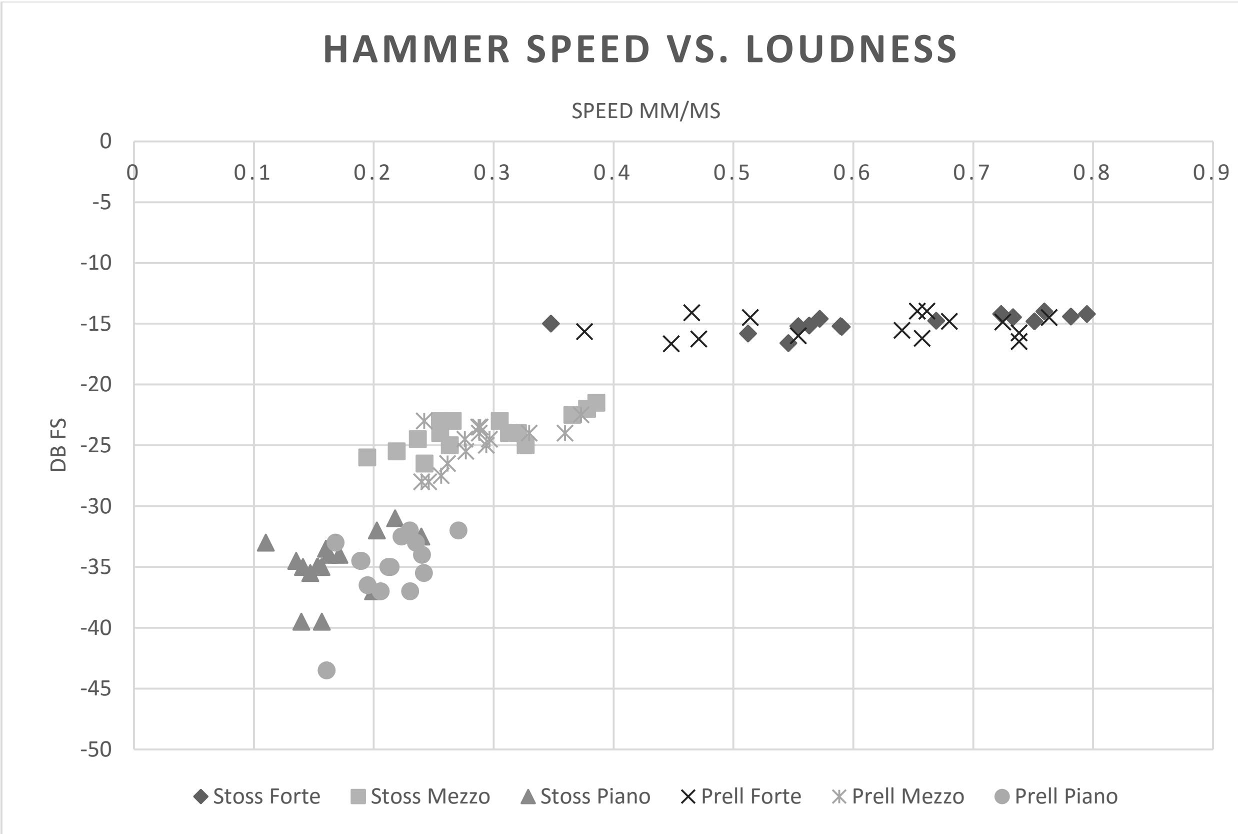

Figure 2.11

In **Figure 2.11**, the mechanism data sets are merged together, and hammer speed is plotted against loudness. Similarly to the analysis of key speed versus loudness, this graph shows a fairly close relationship between hammer speed and loudness. Again there is a plateau at the forte dynamic level which disrupts that relationship. A regression analysis shows that hammer speed and loudness are somewhat more closely linked in *stoss* ($r^2 = 79.74$) than in *prell* ($r^2 = 73.34$).

In **Figure 2.12**, the mechanism data sets are plotted on a graph of millimeters vs. milliseconds. This shows that the *prell* hammer traveled greater distances than the *stoss* at all dynamic levels. A two-between ANOVA confirms that the difference in distance traveled is significant between mechanisms at all dynamic levels ($p < .001$).[79] Another two-between

[79] The *stoss* piano data set is the only set that showed a non-normal distribution (Shapiro Wilks, p = .0004)

ANOVA showed that the time of hammer travel was statistically the same between mechanisms at forte and mezzo ($p > .05$), but significantly different at piano ($p < .001$).[80] Similarly to the key depression results, these data show that the greater distance traveled of the *prell* hammer is an isolated attribute of that mechanism in forte and mezzo strikes, while the greater distance traveled in *prell* piano strikes could be the result of different times traveled.

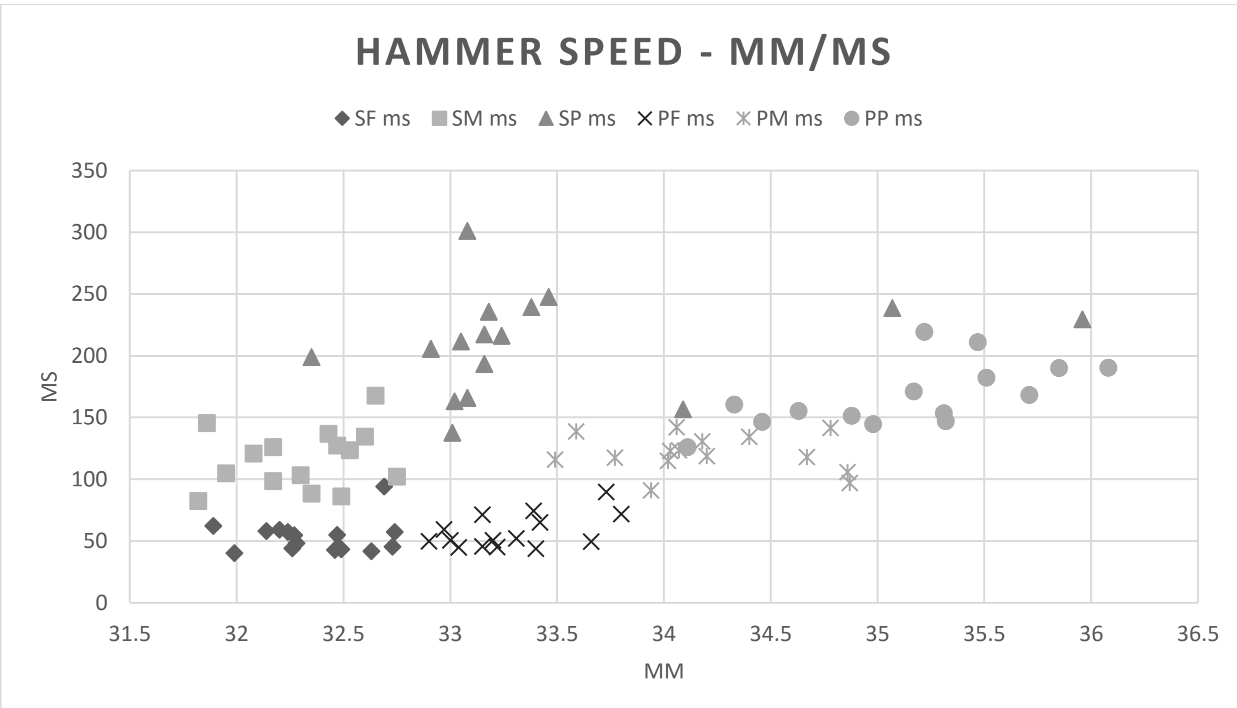

Figure 2.12

As was the case for the key depression results, the greater distance traveled of the *prell* hammer did not influence overall speed statistically, however it can be shown to influence other factors. **Figure 2.13** shows distance as isolated from time and plotted against loudness at the forte and mezzo dynamic levels. A regression analysis shows that hammer distance traveled has no real relationship with loudness in *stoss* ($r^2 = 0.57$), while hammer distance traveled is much

[80] The *stoss* and *prell* forte data sets were the only sets in the population to show a non-normal distribution (Shapiro Wilks, $p = .0023$ and $p = .0242$ respectively)

more closely related to loudness in *prell* (r^2 = 66.53). This means that a change in hammer travel is more likely to yield a change in loudness on *prell* than on *stoss*.

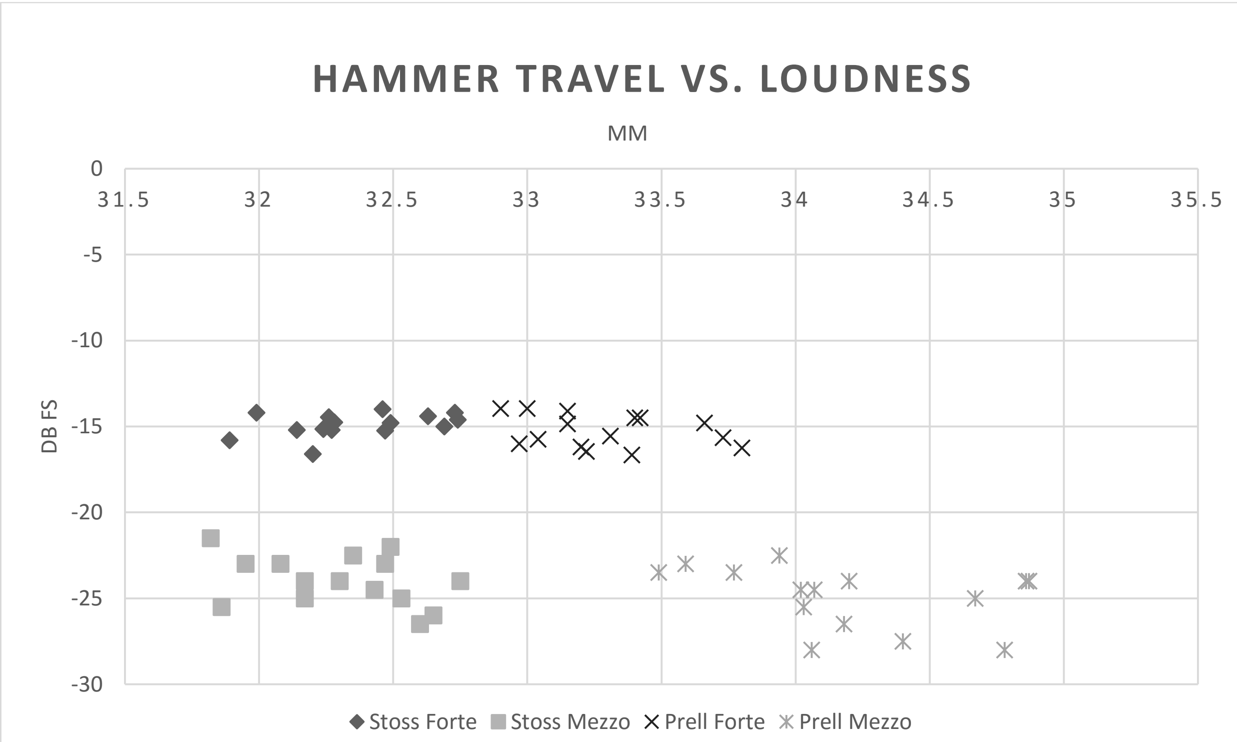

Figure 2.13

The pianist does not have direct control over the hammer distance traveled, but he does over the key distance traveled. **Figure 2.14** shows the relationship between key travel and hammer travel at the forte and mezzo dynamic levels (distance can be isolated at these dynamic levels because time is statistically the same for both hammer and key). A regression analysis shows that key and hammer travel are more closely linked in *prell* (r^2 = 56.43) than in *stoss* (r^2 = 3.53). Thus, a change in key distance is more likely to yield a change in hammer distance on *prell* than on *stoss*.

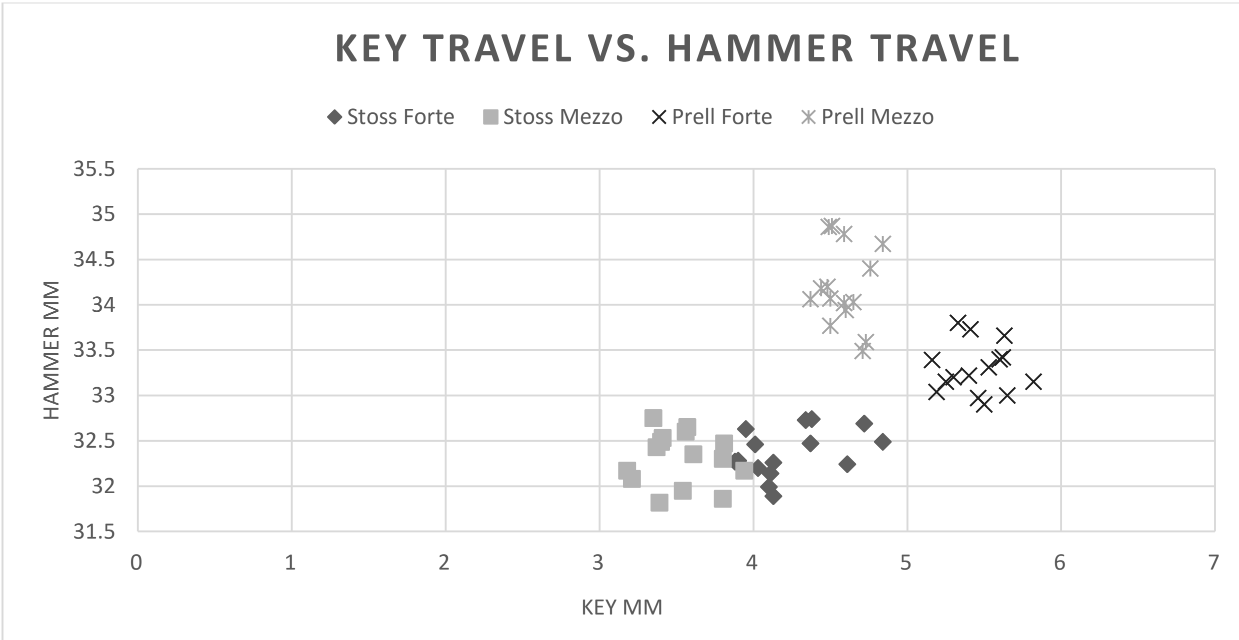

Figure 2.14

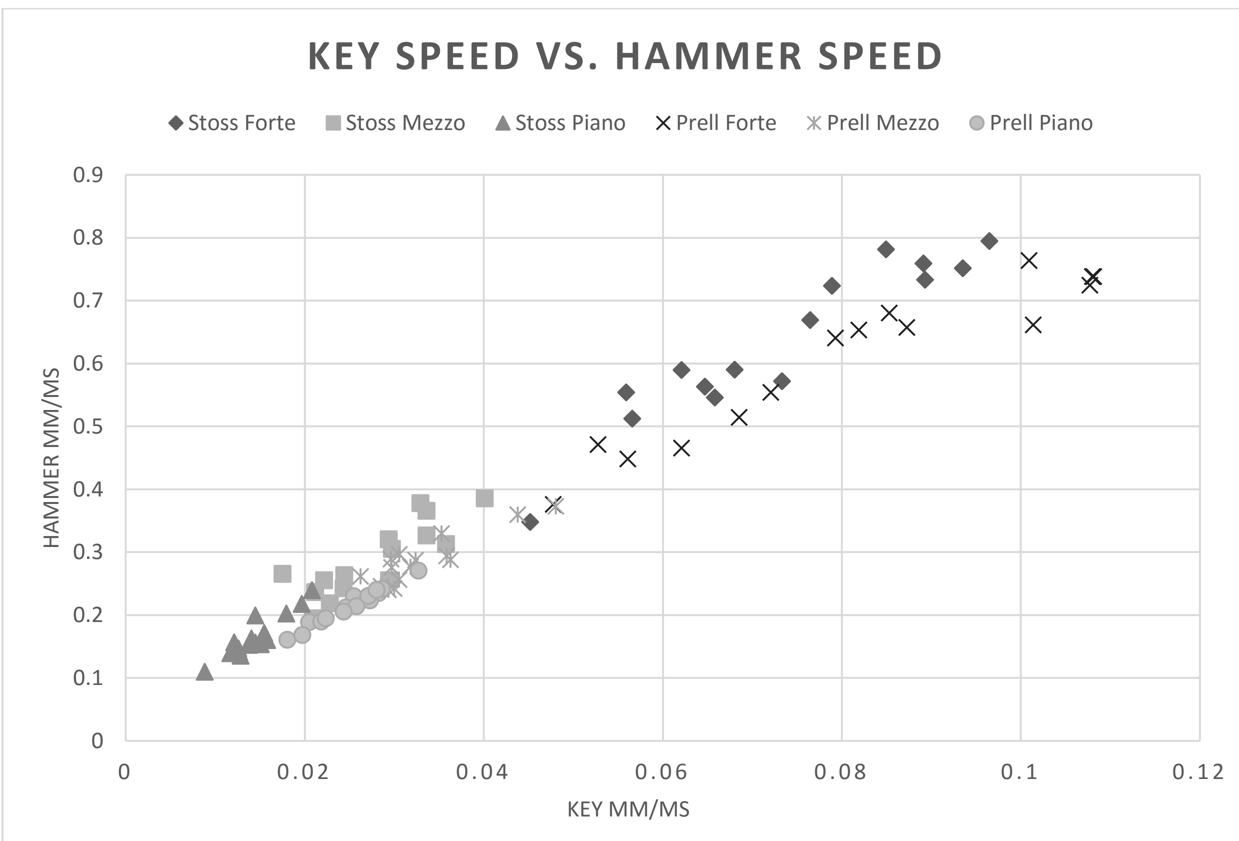

Figure 2.15

In **Figure 2.15**, key speed is plotted against hammer speed. The relationship appears linear with respect to both mechanisms, and indeed a regression analysis shows this to be true. The linearity is nearly the same in *stoss* (r^2 = 97.98) as in *prell* (r^2 = 97.87). However, the same analysis shows that the slopes are significantly different ($p < .01$). The *stoss* slope is slightly steeper, suggesting that a small change in key speed will yield a more significant change in hammer speed.

Angle of the Hammer Head

The angle analysis function in QTM was able to calculate the angle between the planes of the coordinate structure and the hammer head. **Figure 2.16** shows the change in hammer head angle against the XY plane (ground) as plotted against millimeters traveled by the hammer. **Figure 2.17** shows the same change against the YZ plane (right wall). A regression analysis shows that a change in hammer distance traveled is more likely to coincide with a different angle change in *prell* (r^2 = 66.61 against the XY plane and r^2 = 65.45 against the YZ plane) than in *stoss* (r^2 = 9.41 against the XY plane and r^2 = 0.32 against the YZ plane).[81]

[81] The *prell* forte and mezzo data sets for the YZ angle change showed a borderline non-normal distribution (Shapiro Wilks, p = .0527 and p = .0559 respectively).

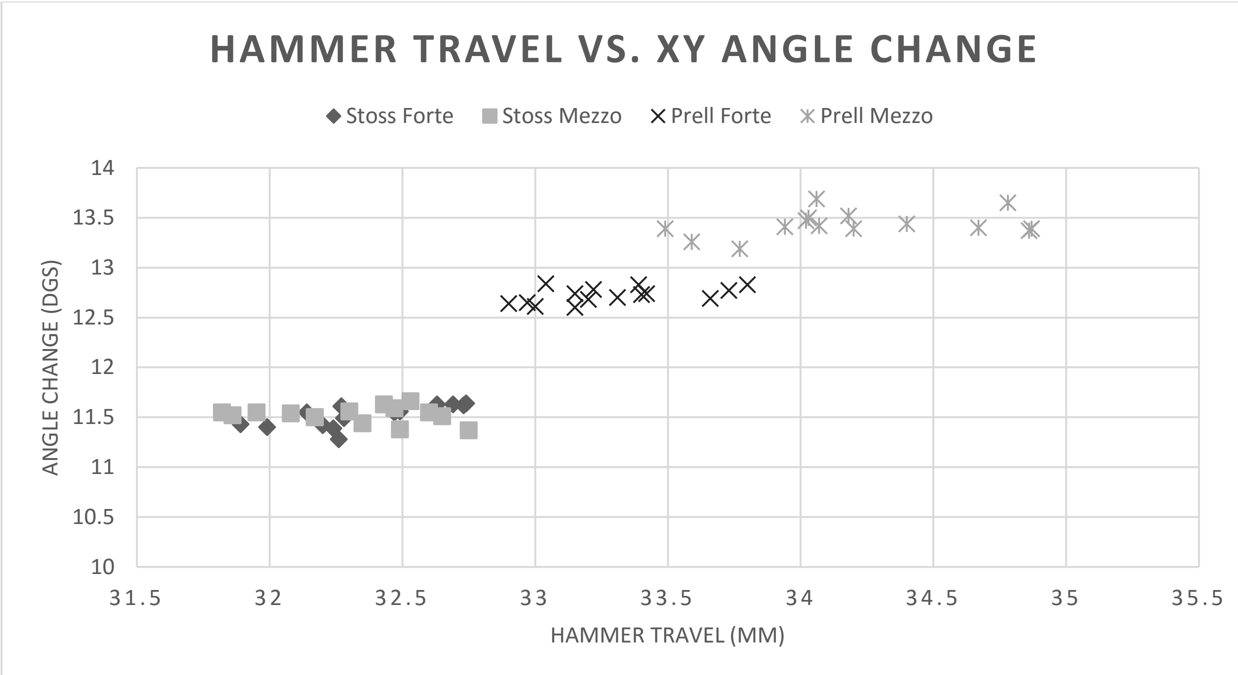

Figure 2.16

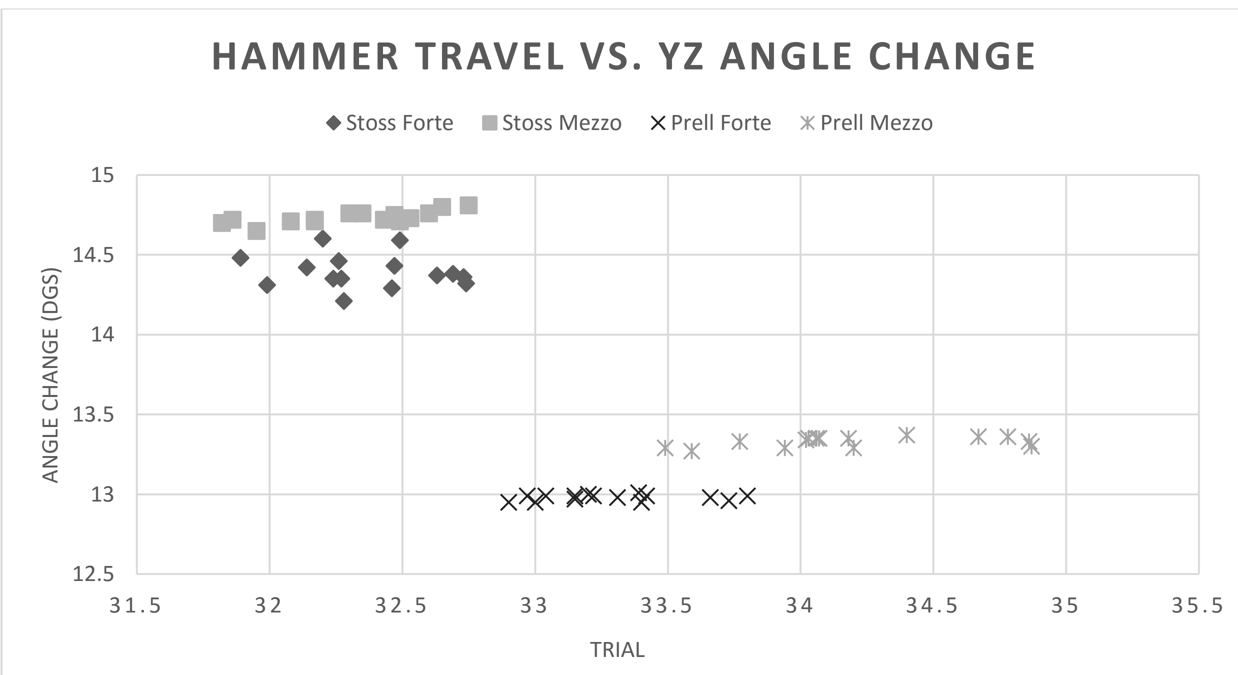

Figure 2.17

Summary

Each mechanism produced decibel ranges that were statistically the same at each dynamic level. Changes in both key and hammer speed were shown to be linked somewhat more clearly to changes in dynamic level in *stoss* (**Figures 2.5 and 2.11)**. The relationship between key speed and hammer speed, while linear with respect to both mechanisms, was represented by a steeper slope in *stoss*. This suggests that a small change in hammer speed will yield a more significant change in hammer speed (**Figure 2.15)**. However, changes in both key and hammer distance – a single constituent of speed – were shown to be linked much more clearly to changes in dynamic level in *prell* (**Figures 2.7** and **2.13**). Likewise, key distance traveled was shown to be more closely linked to hammer distance traveled in *prell* than in *stoss* (**Figure 2.14**). Finally, hammer distance traveled is more closely related to angle change in *prell* as compared to *stoss* (**Figures 2.16** and **2.17**).

Section 3. Discussion

Stoss *and* prell *use different means to modify loudness*

The key is the performer's conduit to the mechanism. It is only through manipulation of that simple lever that the pianist can control what occurs between hammer and strings. In the case of this experiment, the performance of "emphasis" through mechanical manipulation is tested on two mechanisms. In order to effect the many "shades" of loudness that Türk desires, the performer must have a close tactile relationship with the hammer as it rises to meet its strings. The results above concerning key depression represent a measure of that control.

First, in terms of average speed, the results concerning piano key strikes show that the *Stossmechanik* achieved the same dynamic level as the *prell*, but with a slower key depression. Bearing in mind that the *Stossmechanik* "constantly requires a certain minimum of finger pressure for the hammer to hit the string at all,"[82] it seems that it will reach its inoperable point (or at least an inconsistently operable point) sooner in the diminishing gradations of softness than the *Prellmechanik*.

In comparing key speed to loudness across all dynamic levels, the results show that the relationship is somewhat closer in *stoss* (r^2 = 78.30) than in *prell* (r^2 = 67.62). Likewise, this is the case in hammer speed and loudness, where the relationship is also somewhat closer in *stoss* (r^2 = 79.74) than in *prell* (r^2 = 73.34). Regarding key speed and hammer speed, both mechanisms show a linear relationship, but the slope of the *stoss* data is somewhat steeper. This means that a small change in key speed will effect a more significant change in hammer speed and ultimately, those changes are slightly more likely to effect a change in loudness. That the *stoss* mechanism relies more heavily on speed of the key/hammer to effect a change in loudness is understandable: the *stoss* hammer is propelled up to the strings when the tangent hits the butt of the hammer, and therefore the speed of the key has a more direct and singular effect on the force imparted to the hammer. In the *prell* mechanism, however, the constant and variable contact between key and hammer means that it is not as much the overall speed at which the key is struck, but rather the depth and manner of depression that influences how the hammer contacts the strings.

Isolating key distance traveled (in piano-technical terms, "key dip" – a tool in the pianist's manipulation of the key) serves to elucidate the relationship between touch and loudness. At forte and mezzo dynamic levels, the mechanisms performed key depressions that were statistically the same in time, but statistically different in distance. This provides an opportunity to discern how key dip, isolated from time, is related to achievable loudness on each mechanism. The data show that a change in key dip is more likely to yield a proportional change

[82] Beghin, "Playing Mozart's Piano," 21.

in loudness on the *Prellmechanik* (where r^2 = 87.76) than on the *Stossmechanik* (where r^2 = 58.24). This means that, on *prell*, a greater key dip will likely yield a louder tone and vice versa, while on *stoss* the relationship is less certain. The pianist, then, has more consistent control over loudness in *prell* through the distance he depresses the key.

How is it, though, that the performed key dip influences the action of the hammer on each mechanism? The data show that, where time is statistically the same, key dip is more closely linked to hammer distance traveled in *prell* (r^2 = 56.43) than in *stoss* (r^2 = 3.53). Furthermore, a change in hammer travel leads to a change in loudness somewhat consistently in *prell* (r^2 = 66.53), while virtually no relationship exists between those two parameters in *stoss* (r^2 = 0.57).

It seems, then, that the pianist has more control over loudness through key dip in *prell*. This could be due to the fact that, when the key dip is altered, there is more likely to be a concomitant change in hammer distance traveled, which is also associated with a change in loudness. It is interesting to note, however, that an increase in key dip is linked to a decrease in hammer distance traveled, both of which are linked to an increase in loudness (and vice versa). How can greater key dip be linked to lesser hammer travel? And how can lesser hammer travel be linked to a louder tone? It is possible that the change of the hammer head angle during the strike is involved in this connection.

Angle change is linked much more clearly to hammer distance traveled in *prell* (r^2 = 66.61/65.45) than in *stoss* (r^2 = 9.41/0.32). And furthermore, in *prell*, a lesser angle change is associated with lesser hammer travel, the latter of which is linked with a louder tone. That the angle of the hammer head changes less severely in forte strikes could suggest that the hammer strikes the string earlier in its curving trajectory. It is possible that shank deformation (more pronounced at the forte dynamic level) affects the trajectory of the hammer in such a way that angle change at the end of the strike is diminished and total distance traveled is decreased. This hypothesis, however, would require a more detailed investigation of angle change throughout the strike, as well as an in-depth modeling of the entire system (i.e. motion of the hammer on its axis as relative to the axis of the key lever and the position of the string).

Whatever the explanation for the clearer linkages between key depression, hammer travel, and loudness, it is shown by the results above that the *Prellmechanik* offers a definitive advantage in controlling dynamic level through manipulation of key dip. On the other hand, the *Stossmechanik* offers a slight advantage in controlling dynamic level through manipulation of overall key speed.

Controlled loudness facilitates prosodic musicality

As learned in the first chapter, prosody is the organization of sounds into time-functional patterns of pitch, duration, and loudness. According to the "built-from-within" definition of prosody, it is the nature of and relationship between segmentals – small individual units – that determines possibilities for prosodic stress. Additionally, it is the prerogative of the speaker to choose stress patterns that may alter the meaning of a message. The teachings of Türk parallel these linguistic concepts. Possibilities for emphasis are determined by the nature of and relationship between notes, and it is up to the keyboardist to determine how stress patterns could be altered in service of his intended message.

Control over loudness is a significant element in the performance of nuanced eighteenth-century phrases. In terms of mechanical clarity (or *pronunciation*) Türk explains that, "when the keys are struck too hard or soft, the execution can become unclear." He furthermore likens musical execution to the reading of poem, which is made "comprehensible" through the correct placement of emphasis. Regarding expression of a work's character, there are too many gradations in loudness for Türk to explain the application of every one, or for composers to label them in their scores. "To what an excess," Türk writes, "would these words have to be added if every note which required a special shading would be so indicated."

Türk's musical teachings were formulated with a comprehensive knowledge of eighteenth-century performance practice and theory in the German-Austrian realm, and as a proponent of the clavichord, he recognized the expressive potential inherent in dynamic shading. Thus, if the hypothesis of the first chapter is correct – that (1) Türk's lessons were representative of a musically intuitive mind from the German-Austrian realm and (2) that his lessons were applicable to the fortepiano – then it is understandable that his contemporaries would respond favorably to the tactile control of the *Prellmechanik*. Whereas it is only overall key speed and force imparted to the hammer that yields a connection to loudness in the *Stossmechanik*, it is a greater and nuanced flexibility in the manipulation of a constituent of speed – key dip – that adds a further measure of control in the *Prellmechanik*.

The Viennese selected prell *over* stoss *in grand pianos*

In 1794, Nannette Streicher (née Stein), along with her brother Matthäus Andreas Stein and her new husband Johann Andreas Streicher, established a piano-making firm in Vienna. She built a Stein-like *Prellmechanik*, retaining many of her father's mechanical designs through at least 1802.[83] In 1801, a manual was written by Johann Andreas, which provided owners of Streicher fortepianos with details of maintenance and tuning. The manual began, however, with an opinion on what exemplifies an artful touch, tone, and overall performance. Near the start of these remarks, is a summary of what a fortepiano should be capable of:

> Even if some believe that this instrument might be quite inferior *in expressive playing* to other instruments, this criticism can only apply to such fortepianos *that have little*

[83] Latcham, "The Development of the Streicher Firm," 55. See also n.53 above.

> *flexibility in tone, where the keyboard's touch is very stiff, and in which the action does not support the movement of the fingers*. Were one to hear a really sensitive performer on an instrument *that produced all degrees of loudness and softness of tone, even in the finest nuances, the keyboard of which was made in such a manner that the player didn't think of anything mechanical, and on which you could with the greatest of ease produce everything—play a fast staccato, sing, and allow the tone to simply fade away*—wouldn't the highest standards of art then be met?[84]

This opinion is descriptive not only of the Viennese building scene, but also of contemporary Viennese performance. Both Nannette and Johann Andreas were respected pianists--indeed, they were both included in Johann Ferdinand von Schönfeld's *Jahrbuch der Tonkunst von Wien und Prag 1796*. Nannette's skill was described thus:

> Under her fingers, tones increase in volume and become more mellow to each degree she desires and virtually vanish until they become inaudible. One who wants to acquaint himself about all characteristics of a good fortepiano must hear her.[85]

In both statements – that from the Streicher manual and that from Schönfeld's *Jahrbuch* – there is significance given to the idea of achieving every "degree" (*der Grad*) of softness and loudness. Furthermore, Schönfeld's proceeding statement – that the characteristics of a good fortepiano can be learned from Nannette's playing – implies not only that dynamic control is essential, but also that it is on her fortepianos that it can be best carried out.

Indeed, the Streicher manual includes dynamic control among the "two main things that are absolutely necessary for every fortepiano player to *know correctly: (1) How tone is produced (2) How tone must be formed, especially in its shadings of forte and piano*."[86] With the first, he refers to the mechanical production of tones, and he provides a detailed description of the Stein-type *Prellmechanik*, complete with diagram. Just as the linguistic concept of pronunciation is

---

[84] Preethi de Silva, *The Fortepiano Writings of Streicher, Dieudonné, and the Schiedmayers* (Lewiston NY: The Edwin Mellen Press, 2008), 41. Italics in this and the following quotes are from the Streicher manual, carried over into the English translation by de Silva.
[85] Ibid., 24-25.
[86] Ibid., 43.

linked to stress, and Türk's explanation of mechanical clarity is linked to emphasis, Streicher's description of the mechanical process for creating a tone is connected to a mechanical description of emphasis: "However strong or weak the falling [of the finger] is at *c* [the key], so also is the resulting tone."[87] This statement, though seemingly ordinary, can be connected with a line from the first quote above; there, Streicher discussed a substandard fortepiano "*in which the action does not support the movement of the fingers*." A good fortepiano, then, is one in which the action is supported by the movement of the fingers: the falling of the finger determines the volume of the tone.[88] Taken in the light of what our experiments revealed, these statements point directly to the advantage of the *Prellmechanik*: the key dip is proportionally related to loudness; the distance the finger falls directly impacts the volume of the tone. While the *Stossmechanik* is shown to have a slightly greater connection to loudness through "strong or weak falling of the finger" (i.e. overall key speed), the relationship between loudness and "the movement of the finger" (i.e. key dip) is much less clear.

Just as stress in speech can be altered by a speaker's freedom of choice, and emphasis in music can be chosen in accordance with the keyboardist's message, the Streicher manual explains that the effectiveness of an action is enhanced by the keyboardist's use of touch:

> But even the best [keyboard] action can surely do no more than *prepare* [the way for] *the good and proper stroke*. It can *only make it possible and easy for the player to strike* [the key] so that the tone is produced in precisely the manner that the music or the player's sensitivity demands. *Thus* it now depends *on him* to bring life into this action. *On him alone* rests the responsibility for the good or bad effect of his instrument.[89]

---

[87] de Silva, *The Fortepiano Writings of Striecher, Dieudonné, and the Schiedmayers*, 43. I have added the bracketed phrase [the key] because "c" refers to Streicher's diagram not included here.

[88] Latcham attributes a harpsichordist's technique to Andreas Streicher, pointing out similarities between his text and that of Jean-Philippe Rameau in 1724. He refers to Streicher's statement that "rather than by using the fist, the greatest volume is attained more easily and also more beautifully by placing the notes so close together that the ear hears no space between them." ("The Development of the Streicher Firm," 51-52) However, this view of Streicher's text fails to take into account the clearly outlined role of touch and key pressure discussed above.

[89] Ibid., 45.

By the time of this manual's publication, not just the Streichers but the whole community of Viennese builders and musicians had embraced the *Prellmechanik* in grand pianos, collectively recognizing that such a mechanism made it both "possible" and "easy" to adjust the emphasis of tones in the service of the music's message.

Bibliography

Beghin, Tom. "Playing Mozart's Piano: An Exercise in Reverse-Engineering." *Keyboard Perspectives* 1 (2007-2008): 1-35.

Bilson, Malcolm. "Keyboards." Chap. 11 in *The Norton/Grove Handbooks in Music: Performance Practice: Music after 1600*, edited by Howard Mayer Brown and Stanley Sadie. New York: W.W. Norton & Company, 1989.

Birkett, Stephen. "Observing the 18th-century *Prellzungenmechanik* through high-speed imaging." In *Bowed and Keyboard Instruments in the Age of Mozart,* edited by Thomas Steiner, 305-326. Berne: Peter Lang, 2010.

Bonds, Mark Evan. *Wordless Rhetoric: Musical Form and the Metaphor of the Oration*. Cambridge, MA: Harvard University Press, 1991.

Clark, John, Collin Yallop, and Janet Fletcher. *An Introduction to Phonetics and Phonology*. 3rd ed. Oxford: Blackwell Publishing, 2007.

Cole, Michael. *The Pianoforte in the Classical Era*. Oxford: Clarendon Press, 1998.

Connell, Bruce. Review of *An Introduction to Phonetics and Phonology,* 1st ed., by John Clark and Collin Yallop. *Phonology* 11 (1994): 196-199.

de Silva, Preethi. *The Fortepiano Writings of Streicher, Dieudonné, and the Schiedmayers*. Lewiston, NY: The Edwin Mellen Press, 2008.

Huber, Alfons. "Was the 'Viennese Action' Originally a Stossmechanik?" *The Galpin Society Journal* 55 (2002): 167, 169-182.

Komlós, Katalin. *Fortepianos and their Music: Germany, Austria, and England, 1760-1800*. Oxford: Clarendon Press, 1995.

Latcham, Michael. "Mozart and the Pianos of Gabriel Anton Walter." *Early Music* 25/3 (1997): 382-400.

———. "The Development of the Streicher firm of piano builders under the leadership of Nannette Streicer, 1792 to 1823." In *Das Wiener Klavier bis 1850*, edited by Beatrix Darmstädter, Alfons Huber, and Rudolf Hopfner, 43-71. Tutzing: Hans Schneider, 2007.

———. "Johann Andreas Stein and the search for the expressive *Clavier*." In *Bowed and Keyboard Instruments in the Age of Mozart*, edited by Thomas Steiner, 133-215. Berne: Peter Lang, 2010.

Maunder, Richard. *Keyboard Instruments in Eighteenth-Century Vienna*. Oxford: Clarendon Press, 1998.

Schmeiser, Benjamin. Review of *An Introduction to Phonetics and Phonology*, 3rd ed., by John Clark, Collin Yallop, and Janet Fletcher. *Journal of the International Phonetic Association* 41/3 (2011): 369-371.

Shattuck-Hufnagel, Stefanie and Alice E. Turk. "A Prosody Tutorial for Investigators of Auditory Sentence Processing." *Journal of Psycholinguistic Research* 25/2 (1996): 219-220.

Steblin, Rita. "Anton Walter's Difficult Early Years in Vienna: New Documents, 1772-1779." *Journal of the American Musical Instrument Society* 33 (2007): 42-83.

Türk, Daniel Gottlob. *Klavierschule: Anweisung zum Klavierspielen für Lehrer und Lernende, mit kritischen Anmerkungen*. Leipzig and Halle: Schwickert, Hemmerde and Schwetschke, 1789. IMSLP.

———. *School of Clavier Playing*. Translated by Raymond H. Haggh. Lincoln, NE: University of Nebraska Press, 1982.

Vial, Stephanie. *The Art of Musical Phrasing in the Eighteenth Century: Punctuating the Classical 'Period.'* Rochester, NY: University of Rochester Press, 2008.