The Organ:
A Dangerously Inexpressive Musical Instrument?

By Alan G. Woolley

Abstract

Whether mechanical organ actions allow organists to control the way in which they move the key and thus influence the transients has been discussed for many decades, and this is often given as their main advantage. However, some physical characteristics of mechanical actions, notably pluck, make it difficult for the player to control the key movement and thus vary the transient. This project looks primarily at how organists use rhythm and timing to play expressively, but also provides some evidence about whether transient variation is significant. Rhythmic variation can be through the use of deliberate "figures", or the player may be unaware that they are making such variations. These variations in style lead to clear groupings of the pressure rise profile under the pipe and thus limit the amount of transient control possible. This is supported by informal listening tests. It also considers other factors that might lead to transient variation that are outside the player's direct control.

Introduction

This paper presents results from a project funded by the UK Arts and Humanities Research Council at the University of Edinburgh and is based on papers presented at ISMA 2010 (International Symposium on Musical Acoustics) in Australia[1] and Acoustics 2012 in Nantes.[2] The organ has been described as a "dangerously inexpressive" musical instrument.[3] The project set out to investigate the extent to which organists use rhythm and timing to achieve expression on mechanical action pipe organs rather than varying the transient by the way in which they move the key, although it inevitably also considered the latter. Transient control is widely considered a basic factor of organ playing but this is not universal, and a number of prominent organists and builders, such as Robert Noehren,[4] disagree. However, there is little published research about this or whether other mechanisms may be important for expressive organ playing.

This project originally started because of the construction of a number of large organs in the UK that have dual mechanical and electric actions. The curators of these organs reported that the mechanical consoles were hardly ever used, suggesting that any advantage was not overwhelming. It also implied that there may be significant unnecessary expenditure and also the possibility that either or both of the actions were compromised.

The PhD work that preceded this project concluded that players did not vary the way in which they moved the key to the extent that they thought they did.[5]

Background

The bar (groove) and slider windchest has existed more or less unchanged for some 600 years even down to the materials generally used.

The one characteristic that defines the nature of the touch of a mechanical pipe organ action is **pluck** (being analogous with the feel of the plectrum plucking the string of a harpsichord. It is also called "top resistance"). Pluck is caused by the pressure difference across the closed pallet (H) in Figure 1, which is a modification of an illustration by Audsley of a cross section of a bar and slider windchest.[6] The bar is the channel on which all the pipes for one note are planted. The sliders (S) are movable strips, traditionally of wood, that determine which ranks of pipes receive air from the groove, by lining up holes in the slider with corresponding holes on the top of the groove. They move perpendicularly to the plane of the diagram. With the pallet closed, the pallet box (ABDH) contains pressurized air whereas the groove contains air at atmospheric pressure. The net force of the pressurized air on the bottom of the pallet has to be overcome in order for the pallet to start opening. As soon as the pallet starts opening as the tracker (attached to N) moves downwards, the pressures on either side of the pallet start to equalize and the additional force reduces very quickly (Figure 3). The feeling has been likened to pushing a finger through a thin layer of ice.

When a note is not sounding, the pallet is kept closed by the force exerted by the pallet spring (G) and the air pressure against its lower surface. As a force is applied to the key, the various action components bend (key levers, backfalls), twist (rollers), stretch (trackers) and compress (cloth bushes), etc., until sufficient energy is stored to overcome the force keeping the pallet shut. Figure 2 shows a 200g key weight on a key of the model organ in Edinburgh just before the pluck point, with the pallet still closed. The key is depressed by about 40% of its total travel. Any further movement will result in the pallet immediately opening by a similar amount before the key has moved significantly further—the pallet "catches up" with the rest of the action.

The need to keep the playing force and repetition rate within acceptable limits means that the action can never be made completely rigid, and it will always act like a spring to some extent. The basic characteristics of the movement of a key through to the sounding of the pipe are illustrated graphically in Figure 3.

The low frequency variation in the pressure at the beginning of the note is due to the delay of the pressure regulator, described more fully later, and the high-frequency component throughout is due to the pipe feeding back into the groove. The most important features of Figure 3 are:

- The key moves a significant distance before the pallet starts to open and catches up with the rest of the action ~ 40%

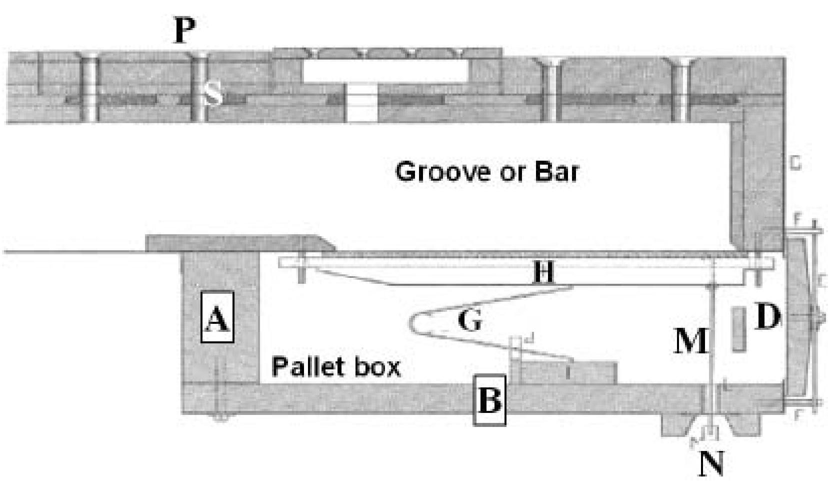

Figure 1. Cross section of a bar (groove) and slider windchest adapted from Audsley, Figure CLIX. The significant parts are: N connected to the tracker from the key and pulling open pallet H via tracker M, compass spring G providing the closing force on the pallet, pallet box containing pressurized air, bar connecting all pipes played with one key, slider S shown open so that the pipe, planted in tapered hole P, will speak when the pallet is opened.

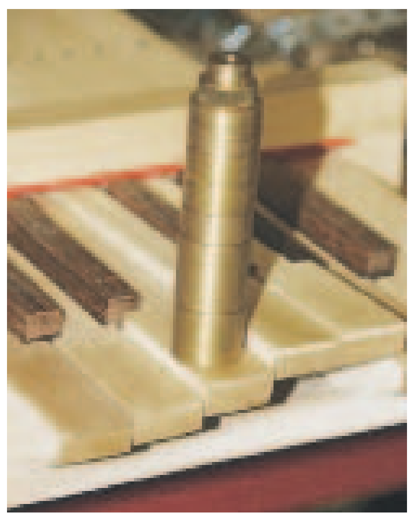

Figure 2. Flexibility in the action just before the pluck point demonstrated by placing a 200g key weight on the key head. Model organ, University of Edinburgh

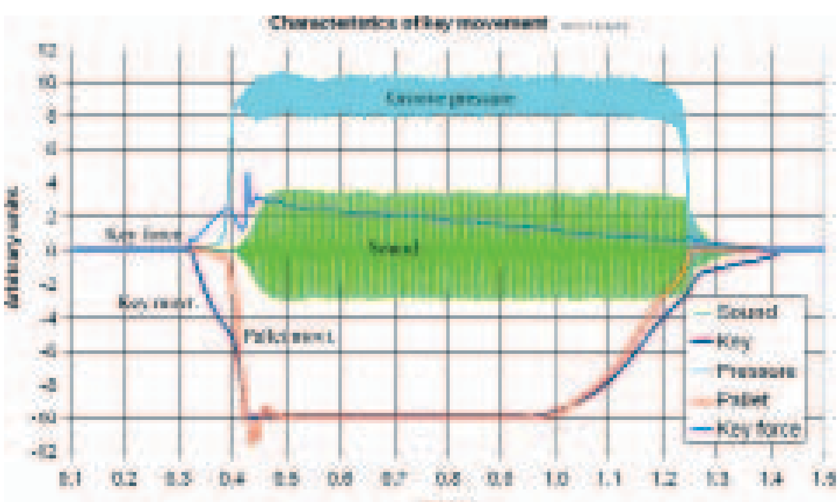

Figure 3. Graph showing key movement (dark blue), pallet movement (red), wind pressure immediately under the pipe foot (light blue), force applied to key head (mid blue) and sound recording (green) for a representative "slow" note on the model organ, University of Edinburgh. To a constant time scale, but arbitrary units of magnitude

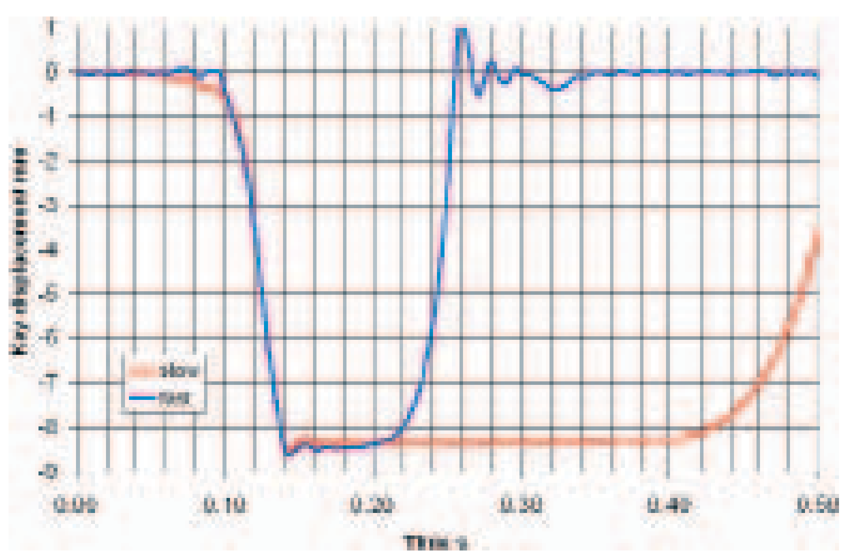

Figure 4. Key movement from two performances of the same theme. The player was asked to vary nothing but the speed of key depression, which he thought varied by a factor of five. Ahrend organ, Reid Concert Hall, University of Edinburgh

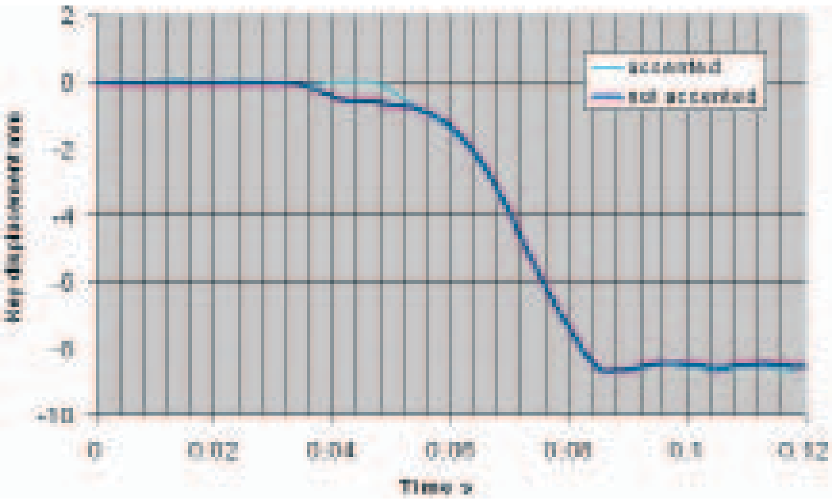

Figure 5. Graph comparing the same notes from two performances of the same sequence but with one accented by being "hit harder" (light blue). Ahrend organ, Reid Concert Hall, University of Edinburgh

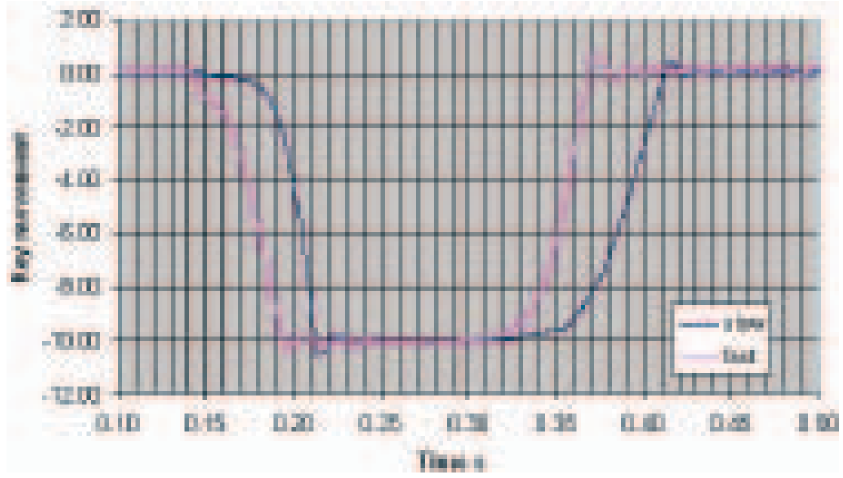

Figure 6. Two notes were played an octave apart, one with a "slow" (pink) and one with a "fast" (blue) key movement in order to establish the point at which the player perceived the note as starting. Ahrend organ, Reid Concert Hall, University of Edinburgh

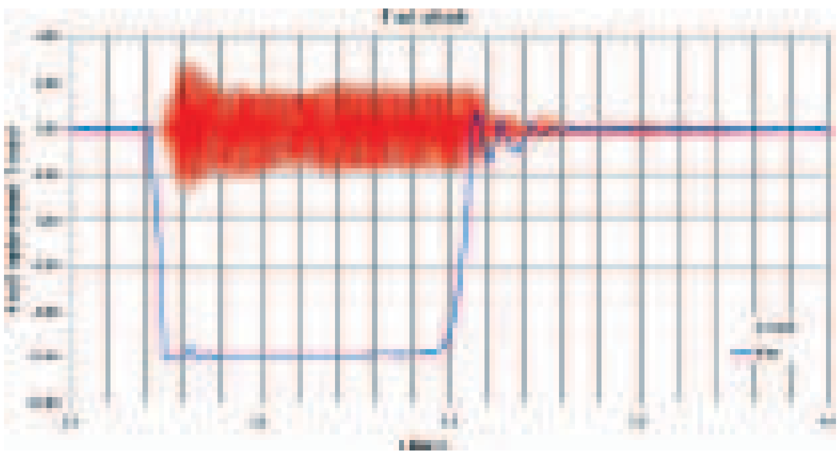

Figure 7. Canongate Kirk, Edinburgh. Key movement and sound recording for a "fast" key attack.

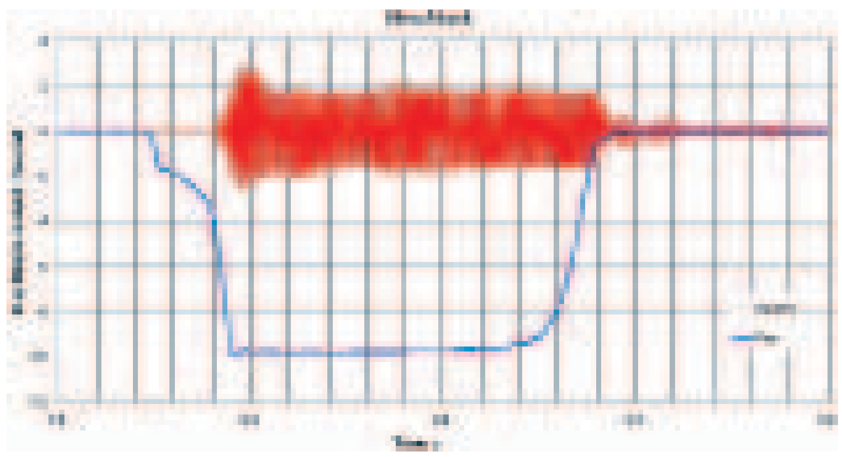

Figure 8. Canongate Kirk, Edinburgh. Key movement and sound recording for a "slow" key attack.

• The key slows down due to the increasing resistance as the action flexes (rollers twisting, washers compressing, levers bending, etc.)

• As the resistance due to pluck is overcome, the key increases in speed of movement, as it is not possible to reduce the force being applied by the finger in the time available

• The air pressure in the groove starts to rise at the same time as the pallet starts to open

• The force applied to the key increases until just after the pluck point, when it reduces, although not suddenly. This is probably due to the airflow through the pallet opening applying a closing force to the pallet

• The force increases suddenly as the key hits the key bed

• The air pressure reaches a peak early in the pallet movement (after about 45% pallet travel)

• The pallet starts to open at about 40% of key travel and the pressure in the groove reaches a maximum at about 57% key travel. This is the only part of the key movement that could affect the transient, but during this movement the pallet is out of control of the key because it is still catching up with it

• There is a delay before the pipe starts to speak

• The key is on the key bed and the pallet is fully open before the pipe has reached stable speech

• There is a delay before the pallet starts to close when the key is released (probably due to friction)

• Later in the release movement the pallet starts to close in advance of the key movement (due to air pressure)

• The pallet is firmly seated before the key has returned to its rest position (in this case the key has 23% travel to go)

• The sound envelope does not start to diminish until the point at which the pallet closes

• During the key release, the force is gradually reduced but the key does not start returning until the force due to the pallet spring is greater than the force applied by the finger

• There is slight increase in force as the pallet "snaps" shut due to the flow of air through the opening. This helps to reduce leaks around the closed pallet, but would also make it very difficult to control the pallet in the final stage of travel.

The time of travel of the pallet from starting to open to fully open is typically around 30ms (0.03 seconds). Reaction times in sporting events are generally around a best of 100ms.[7] This implies that the player is unlikely to be able to respond to pluck and reduce the force being applied by the finger.

These effects were noted in every organ measured, to a greater or lesser extent, depending on the size and rigidity of the action and the magnitude of pluck, and even on a light, suspended action the effect is significant.

Initial work

Some tests were carried out with the University of Edinburgh organist, Dr. John Kitchen, playing the 1978 Ahrend organ in the Reid Concert Hall. This has a very "light" suspended action (50g key force, 50g pluck, Hauptwerk, middle C Principal). In the first exercise he played an improvised theme and was then asked to repeat it, varying nothing but the speed of key movement. The measurements of the key movements are shown in Figure 4, in which the curves are superimposed on the main part of

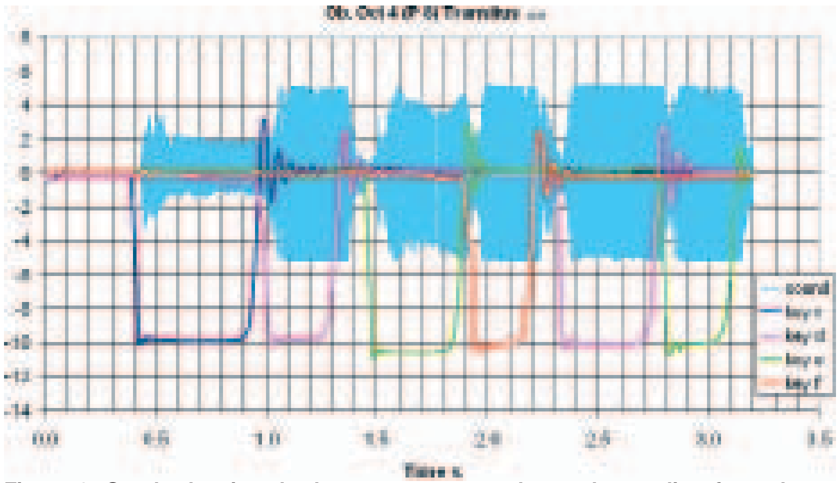

Figure 9. Graph showing the key movements and sound recording for a theme played using the Transitus Rhetorical Figure. Örgryte Church, Göteborg

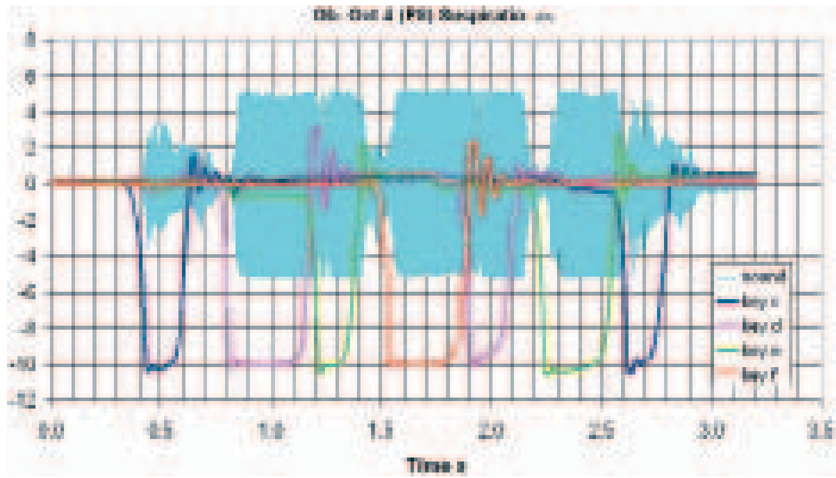

Figure 10. Graph showing the key movements and sound recording for a theme played using the Suspiratio Rhetorical Figure. Örgryte Church, Göteborg

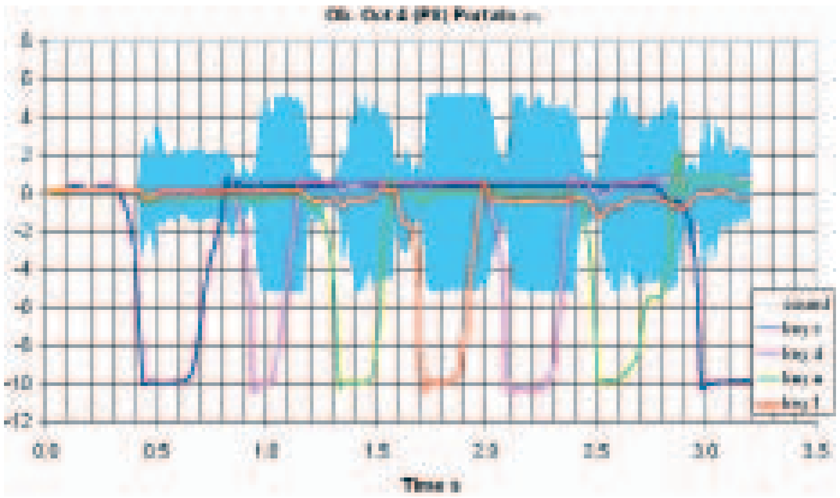

Figure 11. Graph showing the key movements and sound recording for a theme played using the *portato* rhetorical figure. Örgryte Church, Göteborg

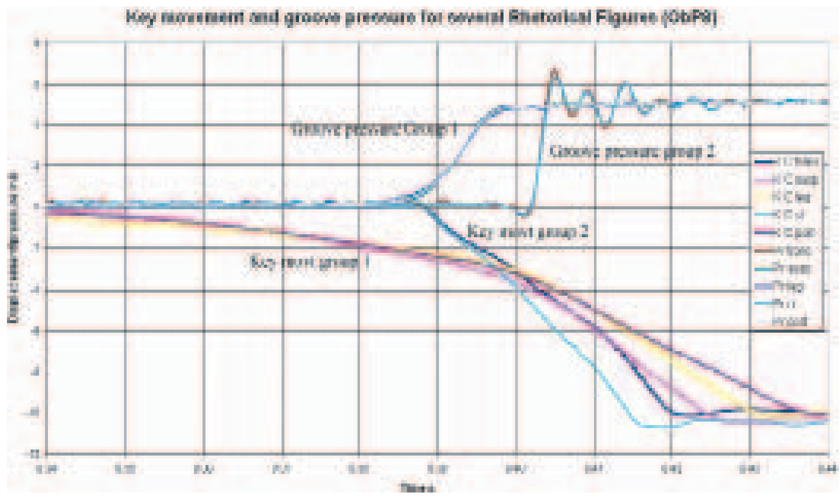

Figure 12. Graph showing key movements (K) and pressure in the groove (Pr) for the first note of a theme played with the rhetorical figures *suspiratio*, *legato*, and *portato* (Group 1) and *transitus* and *staccato* (Group 2). Pressure curves aligned to highlight similarity. Örgryte Church, Göteborg

the key movement rather than the pluck point.[5] Kitchen felt that he had moved the key "five times faster" the second time (black curve) and changed nothing else. In fact, the time from the key starting to move to hitting the key bed in the fast note was about half the length of the slow note, with all of the difference at the beginning. Figure 4 does not show that the overall tempo was also faster with the fast key movement, but it can clearly be seen that the fast attack has resulted in a significantly shorter note. Even on this relatively rigid action, the effect of pluck is apparent at the beginning of the key movement at about 0.8mm key travel.

In the next exercise Kitchen tried to accent a note by "hitting it harder." Figure 5 shows that again with the non-accented movement the effect of the flexibility of the action is apparent, but the majority of the movement is very similar in both cases.

In the two previous examples, the main part of the key movement has been superimposed. Since the relative timing of the pluck point varies, a further test was designed to indicate the point at which the player perceived the note to start. He was asked to play in the two manners from Figure 4 one octave apart simultaneously. Figure 6 shows the two notes to the same time reference and indicates that the player perceived the start of the note to be the point at which the key started to move. This introduces a timing difference between the two notes of approximately 30ms as the pipes will not start to speak until after the pluck point at a displacement of approximately 10% of travel. The "slow" note will sound after the "fast" note and is also slightly longer by about 10ms. The differences between the shapes of the beginnings of the key movements are discussed later. It is interesting that the notes do not end simultaneously.

A further exercise was carried out at the Canongate Kirk in Edinburgh (Frobenius 1998, IIP20). A simple visual examination (confirmed by informal listening tests) shows that distinctly different key movements are not reflected in the sound profiles. Figure 7 represents a "fast" attack and Figure 8 represents a "slow" attack as perceived by the player. As observed throughout, the "slow" attack also resulted in a longer note.

Rhetorical figures

A frequent comment by organists was that even if it were possible to vary the way that they moved the key at the start of a piece of music, it was not possible to maintain these variations throughout a piece. Dr. Joel Speerstra is studying rhetorical figures at the University of Göteborg, based on his research into clavichord technique. These are physical gestures that can be maintained throughout a performance and are based on rhetorical figures in German baroque music described by Dietrich Bartel.[9]

Examples of Speerstra's figures are listed below with his descriptions,[10] along with graphs of some of these showing the key movements, pallet movements, pressure rise in the groove, and sound recordings. The measurements taken showed that phrasings closely followed the descriptions given, and some examples are shown below.

Transitus (Figure 9)

"You are standing a certain amount of the weight of your arm on a stiffened finger with a relaxed elbow, and moving from the first finger to the second without completely engaging the muscles of your arm that would lift it off the keyboard. This technique makes it easy to control heavy actions, and you would expect this kind of paired fingering to have fast attacks for both notes and a

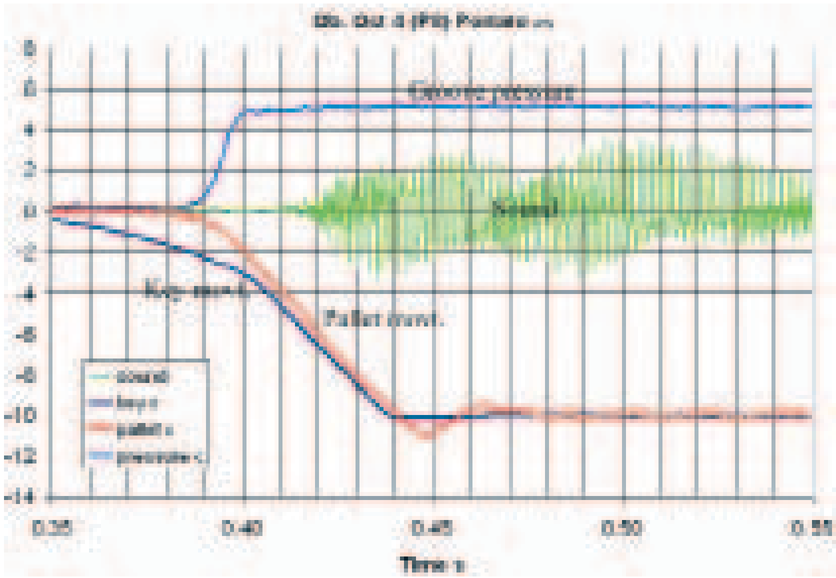

Figure 13. Key and pallet movements, pressure in groove and sound recording of a note played using the Portato Rhetorical Figure

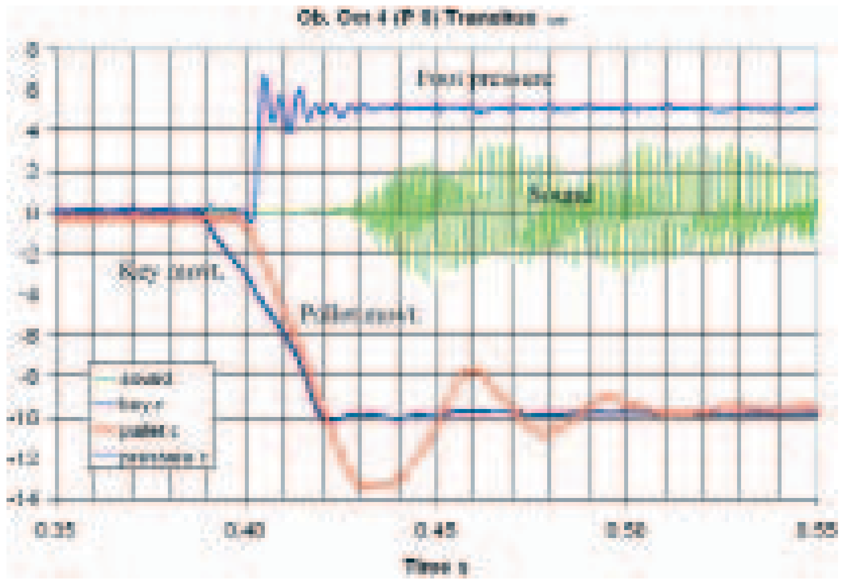

Figure 14. Key and pallet movements, pressure in groove and sound recording of a note played using the Transitus Rhetorical Figure

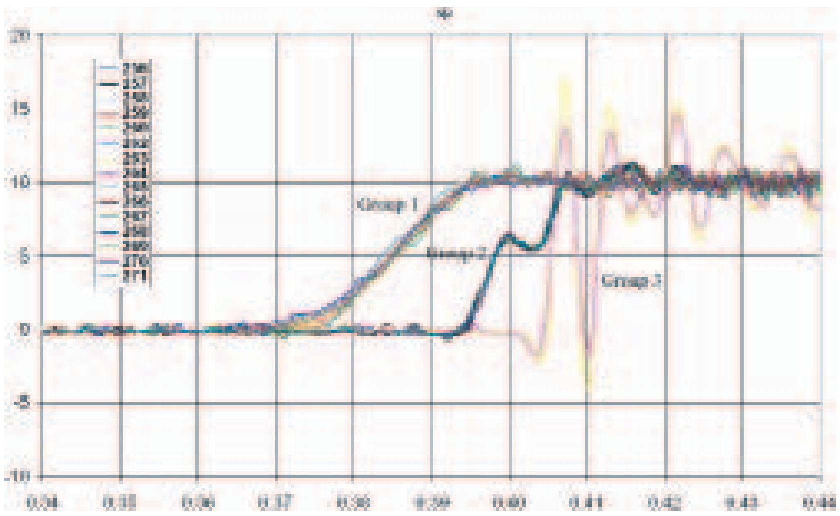

Figure 15. Graph to show groupings of the pressure rise immediately under the pipe foot of a theme played in a number of expressive styles as listed in Tables One to Three. Student CP on the Casparini copy in Christ Church, Rochester, NY

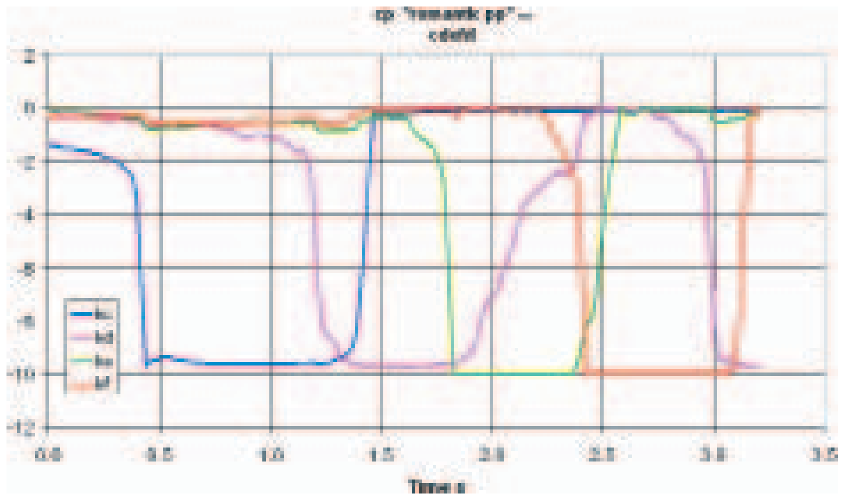

Figure 16. Graph showing the key movements of student CP playing in a style described as "Romantic *pp*." Casparini copy in Christ Church, Rochester, NY

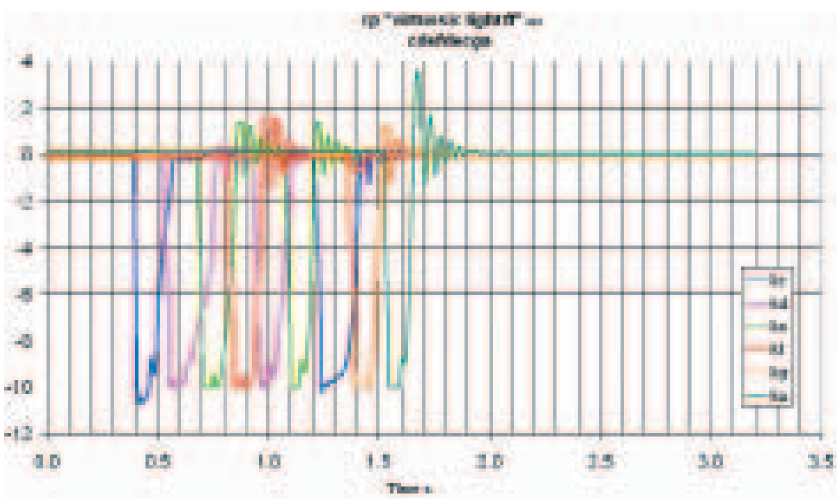

Figure 17. Graph showing the key movements of student CP playing in a style described as "Virtuosic Light *ff*." Casparini copy in Christ Church, Rochester, NY

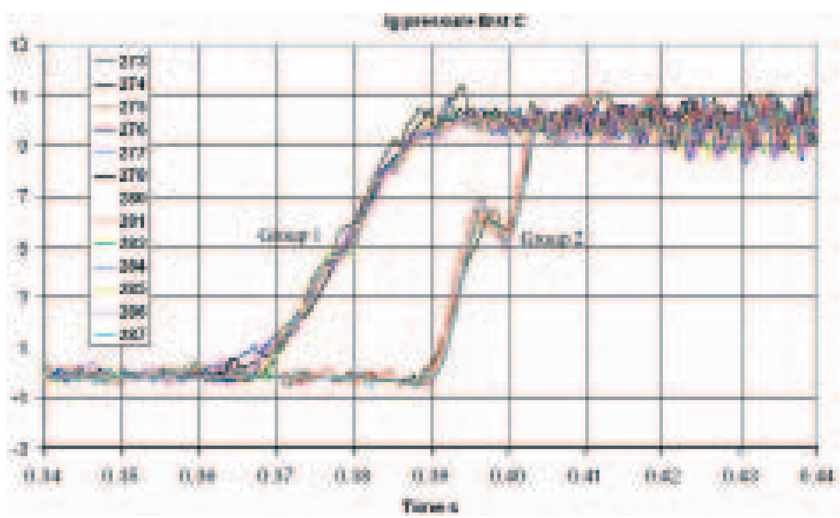

Figure 18. Graph to show groupings of the pressure rise immediately under the pipe foot of a theme played in a number of expressive styles as listed in Tables Four and Five. Student LG on the Casparini copy in Christ Church, Rochester, NY

longer first and third note a shorter second and fourth note and, hopefully, as slow a release as possible after the second and fourth note."

The releases of the second and fourth notes are not significantly different from the others.

Suspiratio (Figure 10)

"It is a figure that starts with a rest followed by three notes, so the first note is now an upbeat, and I would expect that there is a faster release after the first note, and the second and third would form a pair much like the first and second in the transitus example."

Portato (Figure 11)

"Portato [uses] separated notes but with slower attacks and releases."

To these can be added more familiar styles such as legato and staccato, although these may benefit from being more clearly defined. Whenever players were asked to play fast attacks, they also played shorter notes.

Measurements were made of Speerstra playing in these styles on the North German organ in the Örgryte Church in Göteborg (built in the style of Arp Schnitger by the Göteborg Organ Art Centre [GOArt] as a research instrument). The key movement (middle C, D, E, F), pallet movement (C, D) and pressure in the groove of middle C (measured by removing the Principal 8′ pipe) were measured, as well as sound recordings being made. All magnitudes are to an arbitrary scale.

Figure 12 shows all of the key movements and pressure profiles for the rhetorical figures described above. Despite the low number of data points, it can be seen that there are two groups of key movements and two very close groups of pressure rise profiles. The graph has been produced to show the two groups superimposed within the group but separated between the groups. If the player perceives the note starting at the point at which the key starts moving, there will also be time differences between the start of the notes as in Figure 6 above. There is an initial pressure drop in the "faster" group. Full listening tests have not been carried out, but initial tests across a wide range of musical levels did not indicate consistent differences in flue pipe transient between styles, although highly trained ears will detect subtle changes that others may not be able to. Reed pipes were not included in this study, although clear control of the final transient of some of the solo reeds was apparent when played in isolation.

This organ is unbushed and there is a considerable range of noise response from the action—from almost silent to distinctly audible in the church, depending on the performer's technique. This noise can mask the attack transient of the pipe, particularly close to the console. This issue was also encountered later in Rochester, and Speerstra considers that playing in a way that causes excessive noise is both undesirable and avoidable. John Kitchen also stated that he played in a style that minimizes the action noise on the Ahrend organ in Edinburgh. This avoidance of excessive action noise may limit variations in key and thus pallet movements.

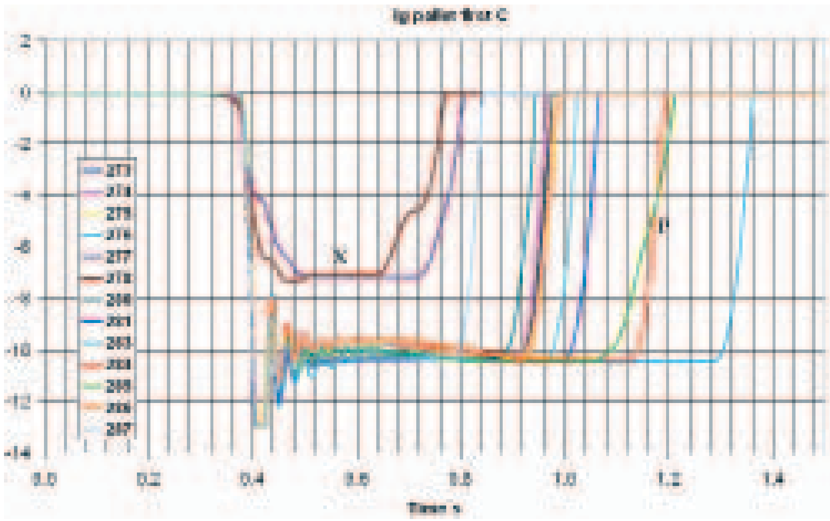

Figure 19. Pallet movements of the first note of a theme played by student LG in a number of expressive styles. There is considerable variation in the length of the note but little variation in the speed of movement during the critical phases just as the pallet opens and closes. Descriptions are given in Tables Four and Five. The curves marked with P were played on the plenum and not a single stop.

Excessive noise on key release may also mask the release transient.

An example from each group is shown in the following graphs. Figure 13 illustrates an example from Group 1 and shows a relatively gradual start of the key movement, the first in the sequence. The accent is on the second note of the sequence.

Figure 14 shows a comparable note from Group 2. The key initially accelerates quickly and shows a distinctly different form of movement from Figure 13. The accent is on this note.

The initial movement of the key is fundamentally different, and tests on the model at Edinburgh indicate that in the case of the portato playing style, the finger was in contact with the key at the start of the movement, whereas in the transitus example, the finger started its movement from above the key and thus was moving with significant speed when it contacted the key, causing a much greater acceleration of the key.

Measurements were also made on the copy of the Casparini organ of 1776 from Vilnius, Lithuania, built by GOArt in Christ Church, Rochester, New York, for the Eastman School of Music (ESM). A number of doctoral organ students played in styles of their choice that they considered resulted in variations of expression, including different transients. They used their own descriptions of these styles; some of these were long and descriptive and cannot be incorporated onto the graphs. The pressure was measured directly under the pipe foot using a device made by the ESM organ technician Rob Kerner, and is not directly comparable with the previous example. The groupings of pressure rise profile have again been superimposed to highlight the similarities, and the time scale does not represent a constant start point of the note. All recordings are of the same theme used in the previous exercise.

Figure 15 shows the measurements from the first student, CP. There appear to be three distinct groups. The initial gradient of the first group shows some variation, but again, initial listening tests did not consistently identify differences even between the two extremes. The other two groups are more closely matched. It is not clear why there is a pressure reversal in group 2. Note again the initial pressure drop in group 3 and the extreme pressure variation. It is not yet clear what differentiates group 3 from the others. There were significant variations in the overall tempo, length of individual notes, relative lengths of adjacent notes, and overlap of notes.

The student's description of each of the styles is shown in the following tables:

Table 1. Descriptions of playing styles in Group One, Figure 15. Student CP

259	Classical Mendelssohn
260	Romantic *pp*
262	Romantic *pp*
265	Baroque, two beats per measure
269	Bach 1st inversion suspiratio
270	Legato

Table 2. Descriptions of playing styles in Group Two, Figure 15. Student CP

256	One accent per measure
257	One accent per measure
258	Classical Mendelssohn
267	Baroque, one beat per measure
268	Baroque, two beats per measure
271	Harmonized

Table 3. Descriptions of playing styles in Group Three, Figure 15. Student CP

263	Virtuosic light *ff*
264	Virtuosic light *ff*

Two styles, 265 and 268—Baroque two beats per measure, and 258 and 259—Classical Mendelssohn, fall into both groups one and two, implying a fundamental difference between the two finger movements.

The key movements of the two extreme styles, Romantic *pp* and Virtuosic light *ff*, are shown on page 26. Figure 16 shows Romantic *pp* (262).

Figure 17 shows "Virtuosic Light *ff*" (263) to the same scale. It is unnecessary to state that the overall tempo is different.

Figure 18 shows the measurements of the first note in each sequence from student LG. Here there are two groups for the Principal 8′ alone, corresponding with groups one and two of CP's playing. The measurements from the plenum are not readily distinguishable from the Principal alone.

The descriptions of the styles are:

Table 4. Descriptions of playing styles in Group One, Figure 18. Student LG

274	Normal
277	Weight on 2nd
278	Weight on 2nd
283	Plenum equal accents
284	Plenum accent on 1st of pair
285	Plenum accent on 1st of pair
286	As 285 but faster tempo

Three of these are played on the plenum and not a single stop as with the others.

Table 5. Descriptions of playing styles in Group Two, Figure 18. Student LG

273	Normal
275	Paired notes with more weight on 1st
276	As 275
280	Weight on 2nd, 3rd and 4th finger
281	As 280
287	Fast, stronger on 1st

All of the pallet movements are shown in Figure 19. There is little difference in the initial movement, even though there were much wider variations in the key movements (Figures 20–22). There is very little difference in the key releases, but with two exceptions. In the case of examples 277 and 278, "Weight on 2nd" (marked with X on graph 17), there was a distinct elongation of the pre-pluck part of the key movement and the key, and thus the pallet did not reach full travel. As the pallet stopped at exactly the same point in each case (the key stopped at very slightly different points), it seems probable that there was high friction at this point. The attacks of these two key movements produced a shallower gradient at the start of the pressure rise, although informal listening tests did not indicate that this variation was sufficient to produce an audible difference with the single stop used in this test. The key and pallet movements for one of these are shown in Figure 20. The two "Normal" playings are split between the two groups, which again suggests a very distinct difference between them.

The curves are in sequence of time of closing and are from left to right, using the numbers in Tables 4 and 5, 278, 277, 287, 280, 274, 273, 286, 276, 281, 284, 285, 283. The consistency in speed of closure is worthy of note. The two curves at P are for the plenum and not a single pipe. It is possible that two non-accented notes marked with X would have closed similarly to the others had the pallet not stopped part way. There is a wide variation in the length of the notes and the overlap with following notes.

Two of the plenum notes in Figure 19 are marked with P at the point at which they cross. One of them shows a slower release of the pallet, whereas the other is similar to the rest of the movements. The key and pallet movements of the slower release are shown in Figure 21. This clearly shows that the pallet shuts before the key is fully released as shown in Figure 3. The key movement slows down when the pallet is no longer being pulled shut by the airflow round it.

Figure 22 is an example of a typical key and pallet movement, no. 275 "Paired notes with more weight on 1st." Note that in all of Figures 20–22 the pallet does not start closing until after the key has started moving, indicating a degree of friction in the action.

Comparing Figure 20 with Figure 22, the weak note in Figure 20 has resulted in an extended pre-pluck movement of the key compared with the strong note in Figure 22. This is not reflected in the pallet movements to the same extent and, as discussed above, may result in timing differences in the sounding of the pipe if the player perceives the note as starting when the key starts to move.

All of the six student subjects demonstrated significant groupings of pressure along the lines of the examples shown above.

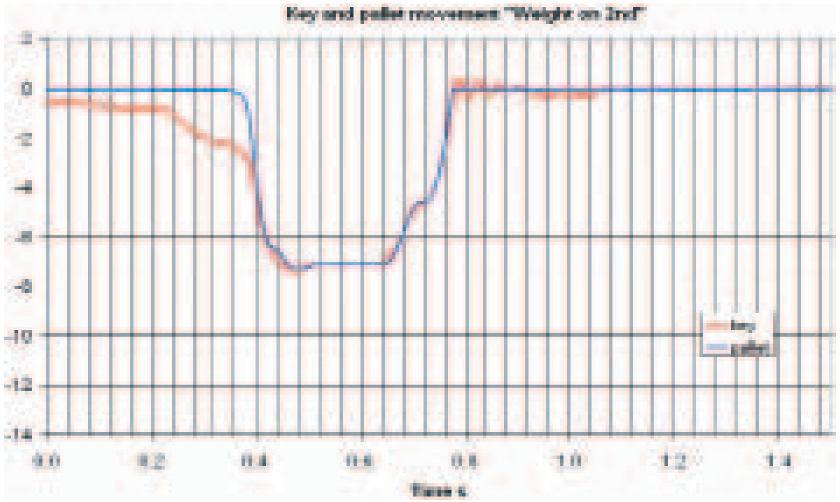

Figure 20. Key and pallets movements for recording 278 "Weight on 2nd": i.e., this is a weak note. This shows the distinctive curve in the key movement due to the increasing resistance of the flexing action before the pallet opens at about 0.26 seconds. The key and thus pallet have also stopped part way down. This also happened in the other recording of this style and it may be due to high friction at that point in the action.

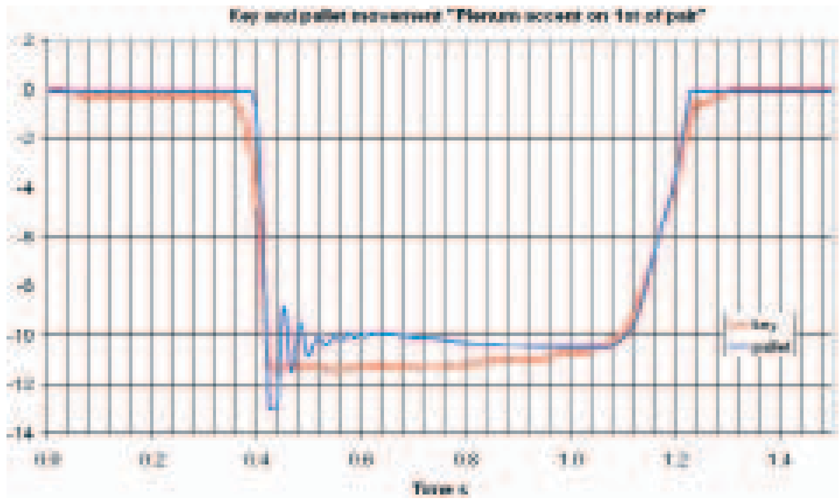

Figure 21. Key and pallet movements for recording 285 "Plenum accent on 1st of pair". The increased airflow due to the extra pipes speaking has caused the pallet to close before the key has fully returned.

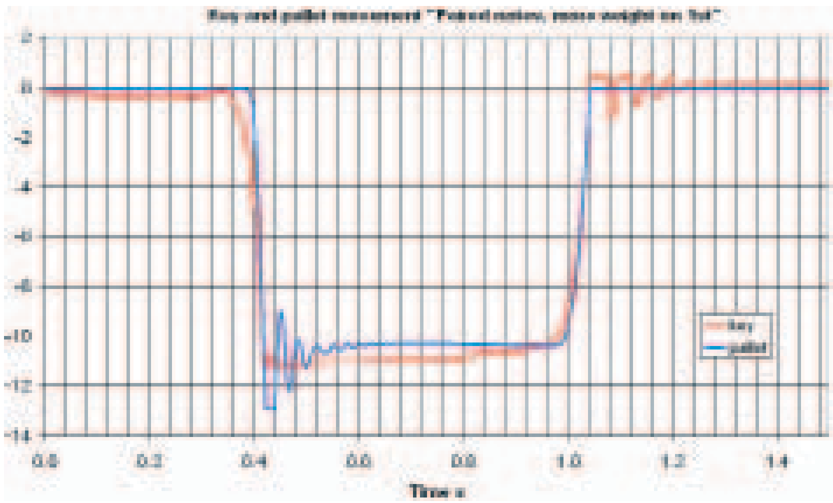

Figure 22. Key and pallet movements for recording 275 "Paired notes, more weight on first"

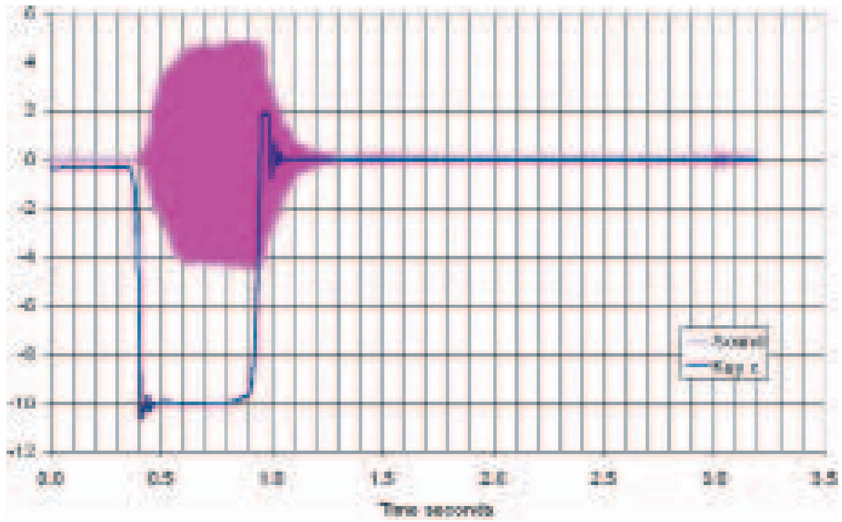

Figure 23. Fast key release. Blue line shows the key movement and pink line shows the sound recording. Örgryte Church, Göteborg

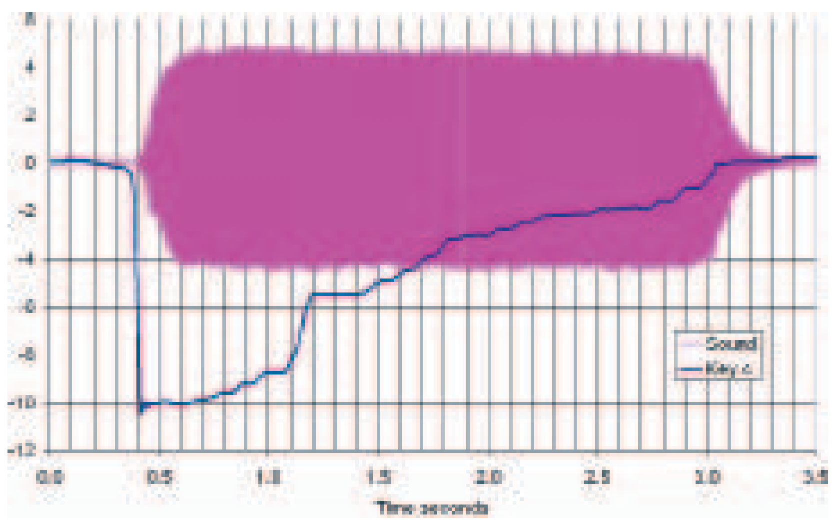

Figure 24. Slow key release. Blue line shows the key movement and pink line shows the sound recording. Örgryte Church, Göteborg

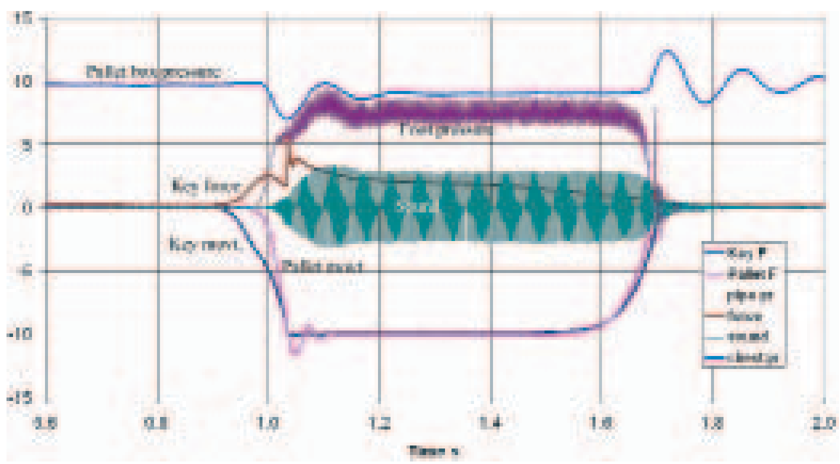

Figure 25. Effect of the variation on the pressure in the wind system due to the playing of a note

Key release

Throughout this project, players have stated that even if there may be reasons why the attack may be difficult to control, it is possible to control the release accurately. There seems little evidence that this is actually the case.

While it is possible to control the initial movement of the key during the release stage because there are no similar effects to pluck, this does not necessarily allow for control of the ending transient. In the same way that the pressure in the pipe foot reaches its peak very early in the pallet opening it starts to reduce very late in the pallet closure. The corollary of pluck is felt as the airflow around the nearly closed pallet starts to "suck" it shut. Due to the flexibility in the action, the pallet closes before the key has returned to its rest position. Also, because the key force reduces due to this effect it is very difficult for the player to control the last part of the key release.

Some key releases were recorded at Göteborg. A fast release is shown in Figure 23 and a slow release in Figure 24. The blue line is the key movement and the pink line the sound recording.

By editing the steady part of the slow movement out to make the notes the same length just leaving the transients, informal listening teats confirmed that there is no difference in the sound of the transients. The difference between the notes is that the slow release results in a longer note.

Pressure changes in the wind system

In most organs the pressure regulator is remote from the windchest. Any variation in the air supply, such as when a note is sounded, will not be immediately compensated for. There will therefore be an overall pressure reduction when a note is started and a pressure increase when it is released. This was investigated by Arvidsson and Bergsten at GOArt in 2009.[11] This has been extended at Edinburgh to consider how these pressure waves in the wind system might affect pipe speech. Figure 25 shows a single note being played, and it can clearly be seen that the pressure in the pallet box reduces as the pallet opens, oscillates for a few cycles, and then steadies. This is reflected in the pressure measured under the pipe foot and also in the sound envelope of the pipe speech. When the pallet closes there is a corresponding increase in pressure. The variations shown here are around 35% of the steady pressure. These measurements were made on the model organ in Edinburgh and, while the effect will occur in any organ, the magnitude of these effects may be greater than normally encountered. A schwimmer system will reduce these effects.

Figure 26 shows the effect of playing a note before the note being measured. The pipe of the first note, E, was removed so that its sound did not interfere with that of the pipe being investigated. It can be seen that the effect of the release of the first note and of the attack of the second, F, have resulted in an even greater variation in the pressure throughout the wind system, and this is reflected in the outline of the sound recording. Listening tests have not been carried out, but this may lead to an audible difference in the transient of the second pipe.

Many notes being played together will produce large and random pressure variations in the wind system. These effects are also apparent with electric actions.[12]

It should also be noted that since pluck is directly related to the pressure in the pallet box, it will vary in proportion to it. It is thus possible that a momentary change in the magnitude of pluck could influence the time at which a key is depressed—especially if the player is already applying some force to the key.

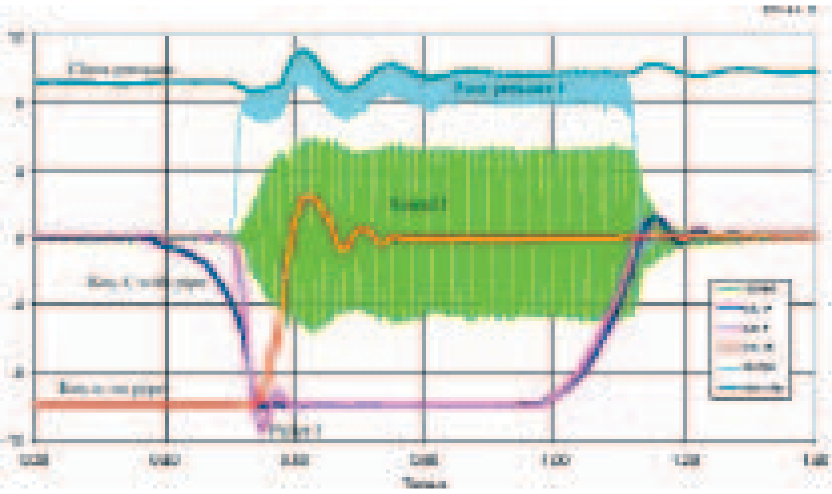

Figure 26. Effect of the variation on the pressure in the wind system due to the release of a note on a subsequent note

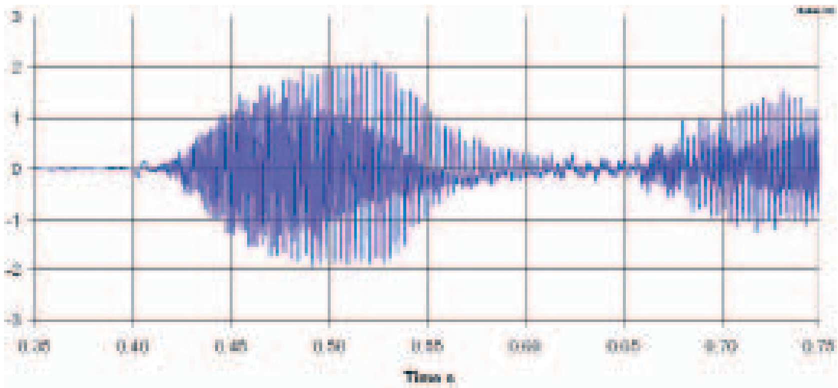

Figure 27. "Fast" attack, Italian organ, Museum of Art, Rochester NY

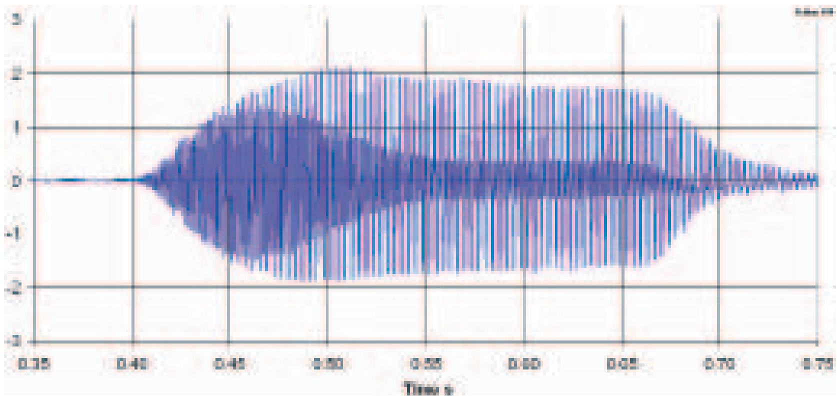

Figure 28. "Slow" attack, Italian organ, Museum of Art, Rochester, NY

Length of transient

In Figures 27 and 28, played on the ca. 1770 Italian organ in the Museum of Art, Rochester, New York, the pipe is slow to speak and starts at the octave and then breaks back to the fundamental.

If a short note is played, as when the player is asked to make a "fast" attack, most of the pipe speech will be at the octave and that is what the listener perceives as the pitch of the note. If a longer note is played, most of the pipe speech will be at the fundamental, and that is what the listener will hear. If the player is expecting a variation in transient, he may associate the different perceived sounds with what he believes are different key movements. In Figure 27, there is also evidence of initial mechanical noise. Note again that the nature of the attack has been reflected in the length of the note.

Conclusion

There is clear evidence that rhythm and timing are critical aspects of organ playing. In some cases they are the result of deliberate and systematic efforts by the player, as in the use of rhetorical figures, and in others the players may be unaware that they are making variations. Analysis of the various performances of the same sequence of notes showed wide variations in overall tempo, relative lengths of notes, and degree of overlap of notes, all of which will affect how it sounds to the listener. These and some other effects like variations of pressure in the wind system are independent of the type of action.

There is some evidence that transient control is difficult to achieve by the inherent design of the mechanical bar and slider windchest. Variations in key and thus, to some extent, pallet movement cause the pressure rise in the pipe foot to fall into distinct groups, the reason for which is still under investigation but would appear to be due to whether the finger starts in contact with the key or is already moving from above the key when it starts the note. Whether these differences result in audible changes is not clear and is likely to vary from organ to organ, and it is necessary to carry out properly controlled listening tests. Action noise may be a factor in informal listening tests. The player cannot react to pluck and any variations in key movement are predetermined.

Many of the characteristics of the bar and slider windchest work against transient control and this may have been one of its advantages—the aiding of clean consistent attacks due to the rapid opening of the pallet when pluck is overcome, but there is clear empirical evidence that players like mechanical actions. The immediate reason for this may be that it provides good tactile feedback. The organist can apply a certain force to the key in the certain knowledge that the note will not sound, but the force reduces to a comfortable level when the key has been depressed. It may also help reduce the risk of accidentally sounding a note if an adjacent key is brushed.

It is unlikely that the original builders of the first windchests applied theoretical fluid dynamics to the design, and other reasons for its endurance may include:

- Ease of construction
- Reliability
- Ease of repair
- Snap closing of the pallet to give a good seal.

Every organ is different and this project has been limited by the instruments available. While this work may suggest that direct transient control is difficult, this may not be the case on instruments with different characteristics. There are, however, other mechanisms in play that may explain different perceptions of the sound.

This project is continuing and, with the cooperation of our colleagues around the world, it is expected that a clearer understanding of these important issues will emerge. ■

Acknowledgements

My thanks to the Arts and Humanities Research Council, Professor Murray Campbell and Dr. John Kitchen at Edinburgh, the staff and students of GOArt and the Eastman School of Music, Joel Speerstra for his very helpful review of this article, Dr. Judit Angster and Professor Andras Miklos, Laurence Libin, John Bailey of Bishop and Sons in Ipswich, David Wylde of Henry Willis and Sons in Liverpool, and many others.

Notes

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Alan Woolley obtained a degree in applied physics from the Lanchester Polytechnic in 1976. In 1998 he decided that the organ was more interesting than his current job and was awarded an MA in Organ Historiography from the University of Reading in 2000. This led to researching for a PhD in Music at the University of Edinburgh looking at how organists actually moved the key. This was awarded in 2006. This work in turn resulted in a further project being funded by the Arts and Humanities Research Council to look primarily at the use of rhythm and timing as a means of expressive playing. This was based in the Musical Acoustics Group of the School of Physics at Edinburgh working with Prof. Murray Campbell and Dr. John Kitchen. He is currently an Honorary Fellow at Edinburgh where the work with Prof. Campbell on actions and airflow in the windchest is continuing.

All illustrations by Alan Woolley