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ABSTRACT Professional music journals frequently publish descriptions of newly registered patents concerning classical musical instruments. Only a few of the many proposals for innovation actually enter production. The large number of ideas for improving musical instruments such as the violin, the flute and the bassoon contrasts strikingly with the stability of the often age-old design of these instruments. Notably, the instruments of the symphony orchestra have basically retained their features since the mid-19th century. Compared with many other artefacts of Western culture, such stability in design and outlook is remarkable. Why is this? And what strategies do today's innovation-seeking instrument makers use to break into this world of perfection? How, in other words, do they innovate and sell in a tradition-bound field? Moreover, how could insights in such strategies be valid for fields of technology–development in which tradition and craft have a similar significance? To address these questions, we examined music journals and, based on interviews and promotional literature, we explored the views and opinions of 12 instrument makers and promoters of unusually constructed flutes, bassoons, saxophones, violas, guitars and oboe-reeds. To account for their work, we will focus on the role of attachment to technology, on the go-betweens whose creative marginality enables them to connect technological and musical cultures and on the relevance of recasting tradition so as to innovate and sustain tradition at the very same time.

Keywords attachment to technology, classical musical instrument making, creative marginality, innovation in tradition-bound fields, recasting tradition

Breaking into a World of Perfection:

Innovation in Today's Classical Musical Instruments

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> one renowned violinist, asked how he might feel if his beloved violin turned out to be made of carbon fibre, said it would be rather like discovering his wife were a robot. (Curtin, 1999a: 379)

Professional music journals frequently publish descriptions of newly registered patents for classical musical instruments.[1] Yet just a few of the many proposals for innovation actually enter production. The large number of ideas for improving musical instruments such as the violin, the flute and the bassoon is in striking contrast to the stability of the design of these often age-old instruments. Notably, the instruments of the symphony orchestra have retained their same basic features since the mid-19th century. Compared with many other artefacts of Western culture, such stability in design and outlook is remarkable indeed.

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The patents indicate that, contrary to what is often believed, the world of the classical musical instrument has a place for experiment and novelty. In their advertisements and pamphlets, instrument makers stress the handmade character of their instruments and their long tradition of craftsmanship. Such statements, however, are commonly followed by the claim that the workshops incorporate modern technology as well, and they refer to more than just manufacturing technique.[2] Educational programmes for musical instrument makers similarly underline the importance of combining artistic craftsmanship and hands-on apprenticeship with 'a qualification in modern science'.[3] Furthermore, some classical musical instruments, such as the organ, have recently undergone significant innovations (Randel, 2003: 610). Yet, as the London Centre for New Musical Instruments claims for mainstream orchestral instruments, '[i]t is commonly thought that little can be done to improve on existing models . . . in which instrument-makers over centuries have achieved great refinement'.[4]

Why is this? And what strategies do today's innovation-seeking instrument makers use to break into this world of perfection? How, in other words, do they innovate and sell in a tradition-bound field? And how can insights in their innovation-strategies be relevant to fields of technology–development in which tradition and craft have a similar significance? To answer these questions, we interviewed 12 Dutch, German and US instrument makers and promoters of unconventionally constructed flutes, bassoons, saxophones, violas and guitars, as well as an engineer–oboe player working on a synthetic oboe reed.[5] We studied the promotional literature these instrument makers produced, examined music journals[6] and visited the annual Frankfurter Musik Messe (a huge international fair at which instrument manufacturers, makers and customers meet).

For most of the interviews, we selected makers of orchestral instruments: flutes, bassoons, violas and oboe-reeds. For comparative purposes, we interviewed the saxophone and the guitar makers. Although guitars and saxophones are occasionally used as solo or ensemble instruments in a symphony orchestra, they do not belong in the mainstream orchestra. Therefore, in this paper, 'classical musical instruments' primarily include instruments of the Western symphony orchestra. We selected instrument makers from relatively small workshops instead of large-scale industries, because we wanted to 'trap' the makers close to the sites of their craftsmanship, since the small workshop is of great practical and symbolic importance to the musical instrument industry at large. Even some large-scale instrument manufacturers separate their factories from the workshops in which they receive their clients. The employees of these small ateliers only fine-tune the musical instruments. The setting, however, suggests craftsmanship rather than standardized manufacture.[7] As for the kinds of innovation involved, we searched for diversity.

Most of the makers we interviewed had received little or no formal education in their craft. Some of them, such as the two viola makers, entered the trade through apprenticeship in an existing workshop. In case of a flute maker, the workshop was her uncle's business.[8] All others, however, followed a gradual career path from being an orchestra player to a repairer–dealer, from a repairer to an instrument maker, or even from an amateur player or professional player–composer–music teacher to an instrument maker. One innovator is a recognized professional concert player who cooperates with a repairer. These makers learned their craft by trial and error, reading professional literature, incidentally taking a course and, in one case, interviewing instrument makers for a music journal.

We will start with a short review of the literature in the field known as organology – the study and knowledge of musical instruments. We will examine how mainstream organologists think about the factors that contribute to change and continuity in musical instruments. We then compare this work to two other strands of research: cultural histories of musical instruments and Science and Technology Studies (S&TS) work on music. We go on to discuss musical instrument makers' understanding of conservatism in classical musical instrument making, as we follow them in their attempts to innovate and sell their instruments. Finally, we aim to further understand the significance of the musical instrument makers' strategies by confronting our empirical findings with theories on creative marginality, on the role of recasting tradition in innovation and on the attachment to technology.

The Evolution of Musical Instruments: Organology, Cultural Histories, and Science and Technology Studies

In the late 19th century, many public museums began to collect and exhibit musical instruments. The field of organology originated from such activity. Traditionally, organology focused on classifying musical instruments with a logical system; for example, the physical basis of their sound-production. At the turn of the 20th century, the musicologists Curt Sachs and Erich Moritz von Hornbostel developed a system that discerned idiophones (such as bells) from membranophones (like drums), chordophones (like violins) and aerophones (like flutes) (Sadie, 1995: vol. 9, 237–38).[9]

According to organologist Laurence Libin, biological models, and notably the ideas of Charles Darwin, strongly influenced the organologists' view of the evolution of musical instruments:

> The concept of biological and technological evolution implicit in typical nineteenth-century classification systems and museum displays can be represented schematically by a tree whose branches ascend slowly through time toward increasing diversity, complexity, and sophistication. The primary force nurturing this growth, so far as instruments are concerned, was commonly thought to be the rise of music as an art form, culminating in the masterworks of Beethoven, Wagner, and the rest of the Romantic pantheon. Where such inspired geniuses led, many believed, instrument makers naturally followed. (Libin, 2000: 187–88)

Curt Sachs, for instance, gave 'imaginative composers the upper, even decisive, hand in shaping the development of orchestral instruments' (Libin, 2000: 189).

Many of the older books on the history of musical instruments read as catalogues that provide fascinating details of gradually changing technological characteristics such as pitch, volume, range, timbre, hammers, fingerboards, keys, bores, valves and decoration (Sachs, 1940; Geiringer, 1978; Remnant, 1989). Indeed, in such books the role of composition is often stressed. Such histories claim that as soon as composers wanted to enlarge the range of keys, to refine modulations, or to colour their compositions with new timbres, musical instruments changed in response (Scheck, 1975). Because Liszt was 'a hard hitter' on the pianoforte and his pupils even 'surpassed' him in that respect, 'manufacturers were forced to increase the weight of touch' (Clutton, 1961: 100). Inversely, when composers refused to change musical form in accordance with the possibilities of the new instruments, the instrument failed or received belated recognition. The 'early neglect' of the pianoforte, for instance, 'shows that when an instrument maker invents something before the composer is ready for it, his rewards will be slight' (Clutton, 1961: 88). Early organologists, therefore, considered composers as the source that fuelled as well as hampered technological development.

'[I]ncreasing chromaticism, longer phrases, or greater pitch range and dynamic contrast' form the impetus traditionally held responsible for driving musical instrument innovation (Libin, 2000: 197). In contrast, Libin, in a recent paper, claims that economic, technological, political and social forces have been far more important for musical instrument innovation than compositional demand. Although he acknowledges that 'performers faced with extreme demands on their techniques often look to instrument makers for help in surmounting these challenges' (2000: 197), the significance of other factors can no longer be ignored.

Among the innovation-inducing factors that Libin identifies are the aim to cater for visual fashion, to raise factory output, to lower costs, to substitute for wartime shortages and to respond to technological change, objectives that 'sometimes unwittingly open opportunities for idiom and style to develop' (Libin, 2000: 198). The lyre-shaped guitar, for instance, resulted from visual aesthetics; upright pianos were, because of their 'key levers of equal length', more efficient to manufacture than square models, and 20th-century theatre organs such as the Mighty Wurlitzers provided a more economical alternative to instrumental ensembles (Libin, 2000: 200). Due to a copper shortage during the war, steel replaced copper for winding piano bass strings, while the 'mechanically amplified' and therefore 'loud and highly directional' Stroh violin, patented in 1900, answered to the demands of the new acoustic recording studios (Clements, 1995; Libin, 2000: 199). Not only are these factors very different from the composer's genius, performers 'must gain experience with unfamiliar instruments before composers can fully exploit their potential' (Libin, 2000: 198).

Libin claims that innovation actually has been hampered by the medieval system of craft guilds, by political considerations such as the occasional suppression of drums, horns and bagpipes – instruments associated with public insurrections – and by large-scale production. Most instrument manufacturers focus 'on perfecting the products they are accustomed to making and resist radical redesign and costly retooling' (Libin, 2000: 203). Standardization, for practical reasons or industrial efficiency, may therefore reduce variety (see also Barrett, 1998). Although the 19th-century mass production of pianos led to innovations, the 20th-century black concert piano has 'achieved near-iconic status', and some innovations in the piano have been rejected just because they looked 'odd' (Libin, 2000: 207, 212). Moreover, social aspects have coloured the caution of performers vis-à-vis change. Many 'professional players have their hands full mastering the familiar instruments upon which their livelihoods depend' and only 'seldom initiate radical changes' (Libin, 2000: 211; see also Ahrens, 1996).[10]

A message similar to Libin's can be found in cultural histories of musical instruments as well as in recent work on music in S&TS. Such studies have increasingly broadened the relevant context of musical instrument history. Cultural histories have underlined the impact of cultural images such as the Victorian piano girl's influence on the popularity of the piano in the USA (Roell, 1989) or 'a melancholy longing for another world' among European romantic poets on the success of the Aeolian harp (Hankins & Silverman, 1995: 103). Others have stressed the importance of new advertising and selling strategies, such as artists' endorsements and manufacturer-subsidized concert tours on the rise of the piano or the role of popular music journals in the acceptance of the digital technology in musical instruments (Théberge, 1997). Moreover, the S&TS literature has extended its concepts to musical instrument development, using notions such as 'reverse salient' to explain the role of feedback in electric guitars (McSwain, 2000) and 'boundary shifter' to understand the success of the Moog synthesizer (Pinch & Trocco, 2002).

The Moog synthesizer was a notable success because Moog was able to embed his synthesizer in conventional musical culture by introducing a volt-per-octave standard and keyboard control, and thus was able to move between different contexts of use. He was an excellent boundary shifter, because he was able to cross the boundaries between the worlds of engineers and musicians, and transformed the synthesizer as well as norms about what counted as music, composing and performing. In contrast, the competing Buchla synthesizer remained part of a musical counterculture (Pinch & Trocco, 2002).

Equally important for the success of new musical instruments has been the ability of their makers to reconcile the instruments with the conventions of live performances and the rituals of concert life. In this respect, many electronic musical instruments have failed (Pennycook, 1997; Barrett, 1998; Pinch & Bijsterveld, 2003).[11] Finally, as Libin has shown, political circumstances have occasionally contributed to failures, such as the political suppression of European avant-garde music in the early 1930s, which may have accelerated the demise of the gramophone as a musical instrument (Katz, 2001).

As we elaborate later, the musical instrument makers we interviewed gave reasons for innovation similar to the factors that Libin and others have identified. The makers mentioned goals related to composition and musical performance, as well as to social, cultural and technical issues. As for traditionalism, however, they identified an even wider variety than expected from our review of the literature, presumably because many of them introduced novelties in today's orchestral instruments – the very instruments whose design has enjoyed such a long history of stability. In the orchestral context, more deeply than elsewhere, the introduction of new musical instruments challenges the conventions, norms and values of musical performance.

'There's a Sound in their Mind': Understanding Traditionalism

The simplest explanation for the traditionalism in the classical music world given by some of the interviewees referred to the fact that high quality musical instruments wear extremely well. 'A professional musician playing a good instrument', a bassoon repairer explained, 'can just play the thing until his retirement' (MV 1). 'Since we have several hundred years' worth of great, wonderfully aged string instruments around', a viola player observed, 'top players generally want to get hold of those. If there were few of these . . . I think there would be no problem [with innovation]' (JL 13).

Most instrument makers, however, understand the traditionalism as a consequence of a very particular attachment of players to their musical instruments. In the course of their musical life, musicians and their instruments become 'fused'. The people we spoke to, however, advanced different explanations for this phenomenon. According to a bassoon repairer and former player, bassoons are often structurally out of tune. Musicians have somehow learned to play the instrument by circumventing its difficulties and vices. If they subsequently try out a new one, however, it is out of tune by definition. 'It takes time to get used to it again . . . no one does so voluntarily' (MV 1). On stage, soloists and orchestra members 'try to avoid even the slightest insecurity' (JHo 3; see also KG 12). So anyone radically changing a design, such as new fingerings, 'has almost to supply a herd of psychiatrists' (EK 17). Such explanations clearly resound with Libin's point that players are reluctant to modify their technique since it is their means of subsistence. Yet professional pride is at stake as well. A well-known saxophone player, Michael Brecker, preferred a saxophone with traditional leather pads to a new, noiseless sealing system, 'since there is nothing left for me to do. I am used to working hard' (RS 23). The musicians know how to handle the peculiarities of their instruments and consider such a mastery to be part of their artistic and professional identity. They do not want to lose it.

This attachment between musician and instrument may also be the result of the traditions of musical education. Most members of orchestras, the bassoon repairer stated, prefer to play the classical repertoire and the associated instruments instead of new music, simply because the former have become 'implanted' into their body by education (MV 2). In contrast to the Renaissance and Baroque periods, 'methods of music making have become solidified and, along with those unfortunate developments, the players, too, have become increasingly rigid'.[12] Another innovator claimed that learning to play music is often based on 'imitating' the teacher rather than on making music (FB 1). A similar observation is that students usually play the same make of instrument as their teachers do (MV 3). Retail traders sometimes pay teachers a percentage of the instrument's price when they advise students to buy a particular brand (personal observation). And some manufacturers, like Yamaha, even own music schools (RS 14–15).

The recent literature on classical concert culture supports the view that the frozen repertoire of orchestra[13] and the imitation-oriented educational system in music are related. In late 18th- and 19th-century concert culture it gradually became the norm to show deep respect, and thus silence, for the genius of music. This was the result of both musical and social changes, such as the introduction of absolute music,[14] which aimed at stirring authentic emotions, and the rise of the bourgeoisie (Johnson, 1995). Playing the score *correctly* mirrored such respect for music – an attitude transmitted to amateur players by conservatory-trained teachers in search of professional status. These amateurs increasingly learned to play a standardized repertoire, often simplified versions of the works dominating the concert programmes. Amateurs visited the concerts, equipped with this score-oriented mindset (Smithuijsen, 2001). By the late 19th century, the art of orchestration had become increasingly dogmatic as well, as can be inferred from the instruction books addressing both the general student and the prospective composer. 'Certain ideals of blended sound and . . . of immutably defined instrumental characteristics passed into currency and thence to unquestioned supremacy' (Sadie, 1995: vol. 13, 698).

According to Christopher Small, concert performances are now 'ritual' celebrations of the 'sacred history' of culture, in which the conventions of dress and the spatial separation of players from the audience 'depersonalize the performers' and 'emphasize the universality and timelessness of the proceedings' (1987: 7, 11). The players' task is to play long-dead composers with 'minute variations in interpretation', closely listened to by audiences that have 'become extremely skilled in perceiving these variations and comparing them' (1987: 13–14) – a skill acquired through education and, more recently, through the many records available (Hennion, 2001: 4–5, 15). The players are equally closely watched by the conductor at a podium in the centre of the 'concentric rows' in which players and public are seated (Small, 1987: 9).

Over time, orchestral rehearsals have also become increasingly disciplined events (Smithuijsen, 2001). Today, the authority of conductors and lead players is highly important in producing an orderly and efficient rehearsal, even if the authority of conductors is never self-evident and is highly dependent on their communicative skills (Faulkner, 1973). Moreover, orchestral power relations are not only executed through verbal communication, but are shown and continuously reconstituted through bodily movements in which authoritative players demonstrate how the music should sound with help of their musical instruments (François, 2002). And, although the latter is even more important in rock music where scores are absent or less dominant (Gay, 1999), the classical orchestra is more stable in terms of the bearing of the musicians and their repertoire. All this has created a situation in which professional classical music players are tied to critical-attentive audiences, watchful conductors, ever-present colleagues and well-known scores that function as the final arbiters of playing. Amidst these high demands, the musical instruments are both the vehicles for coordination *among* the performers and, literally and metaphorically, important mainstays *for* the performers.

In line with this view, some of the instrument makers stress that professional players are more conservative regarding their choice of instrument than amateur players. Amateur players, at least, seem to be more apt to try out a new instrument. They are probably persuaded by dealers and makers more easily (MV 3). Other interviewees, however, claimed that hardly anything changes in the market of instruments of lower and average quality, such as those for students. In contrast, on occasions professionals, notably concert players, need an instrument that best responds to their demands – a well-projecting guitar, for instance – even if it is a novel one (JHi 9–10, 13). Several injured viola players accepted David Rivinus' asymmetrical and ergonomic viola, named the Pellegrina, because they were in pain and would have been forced to retire had they not shifted to this brand-new instrument (DR 5–7; JL 2).

Nevertheless, certain characteristics of a novel instrument may cause problems to musicians, notably its sound. The sound of particular instruments such as the Heckel bassoon has become the 'standard'. If it does not sound like a Heckel, it cannot be good, as the bassoon repairer expressed the mindset of his clients. Even if he offered high quality new instruments, clients still wanted an 'old corpse' of Heckel, twice as expensive (MV 4). Similarly, people have come to associate with the viola an 'endearing' and 'very dark kind of nasal, almost guttural sound' versus the 'more clear and more direct' sound of the Pellegrina (DR 3):

> The sound is the real tricky one. Because people had in mind a . . . there's a sound in their mind. And people have a really difficult time forgetting that sound . . .. There's only one kind of viola. That's what they grew up with. (JL 9–10)

The first time Rivinus introduced his viola 'at a rehearsal in a major symphony orchestra, one of the violists in the section took a look at it and screamed' (DR 12). The reason for the initial critique was that the players wanted 'to maintain the traditional viola sound in their section' (DR 11). Any deviations in the sound can similarly pose a problem to chamber music ensembles: 'In chamber music, there's always the discussion of how to make it balanced, how do you play it .. . . Is the tone colour alright?' (JL 8). In the case of a saxophone quartet, such a discussion led to a temporary disagreement about using Karsten Gloger's new saxophone neck (KG 6).

Despite its significance, the sound of an instrument is, at times, lower in the hierarchy of musicians' values than the appearance of the instrument. In case of the violin, the appearance of the instrument is a key feature (Alburger, 1978), which may, as Libin has claimed, arrest change:

> Violinmakers are sculpturing a work of art, according to a traditional design. . . . And if he makes a beautiful looking violin that has all the elements of a classic violin the way a fine painting has all the elements of a classical painting, then it doesn't even matter if it sounds good. If it sounds good, then perhaps a musician will buy it. But otherwise a collector might buy it. Just because it's beautiful. . . . That's the reason there's no innovation. (JL 5–6)

This tradition-based 'artistic' approach of violin-making puzzled Joseph Curtin, himself the maker of another unconventional viola: 'generally speaking, in art, it's considered important to do something new, so to the extent that we want to call violin making an art I think it's our responsibility to try to do something new' (JC 4). Curtin designed the Evia, a viola with a phenolic resin instead of ebony fingerboard, sloping shoulders and simplified corners, an adjustable neck, a different type of soundpost and a single-turned scroll (Curtin, 1996b). He is also experimenting with graphite or carbon-fibre tops and backs. Yet he admitted that innovation is difficult, since 'the violin is . . . something of a cultural icon' (JC 8; also see Curtin, 1999c).

Many interviewees claimed that instrument makers themselves are often the ones who resist innovation most fiercely (JL 7; JHi 15). Again, education is part of the explanation. In Germany, the master–apprentice model is still important, and apprentices are 'just allowed to scrub, file and polish' (MV 5). In the bassoon-making industry, new employees are granted access to the tricks of the trade to a limited extent only, out of fear that they will leave and start their own business. In such a workshop, 'only one or two persons really know how to build a bassoon', which is 'disastrous' for change (MV 6; see also FB 5). Instrument makers not only keep their secrets because of business practices, however. Violin makers, for instance, often decry a scientific approach to violin making, since that would 'take the mystery out of it, take the romance out of it . . . I felt that way years ago. I thought: "Boy, scientists should just keep their muddy footprints out of our arc"' (JC 8). Even repairers may hamper change. One interviewee stated that a saxophone repairer's criticism of the Toptone Disk® (see later) merely derived from fear of losing his job, since that brand of disk, according to its inventor, was far less prone to wear and tear than traditional leather pads.[15]

Some of the instrument makers claim that the patent system is unhelpful for change as well (JHi 19; JHo 7). Applying for a patent is a very costly affair, requiring thousands of dollars to begin with, and to secure the patent after it has been acknowledged may require another US$10,000–45,000 depending on the national system of patent law. Before a patent is accepted however, the applicant must prove that the innovation is really novel. So in order to receive the patent, the inventor has to claim as much novelty as possible. Often, though, a patent is rejected because the patent archives show examples of 19th- or early 20th-century instruments with similar innovations, whether or not these still survive.[16] Only two of the interviewees succeeded in acquiring a patent: flute maker Eva Kingma for the key-on-key C-flute (see later) in the USA and Rienk Smeding for the Toptone Disk® worldwide, the latter with the financial backing of an investor. Most instrument makers were short of time and money, or considered it pointless to apply for a patent (KG 6–7; AW, 17 June 2002; JL 5, 13; DR 13; JHi 16, 18).

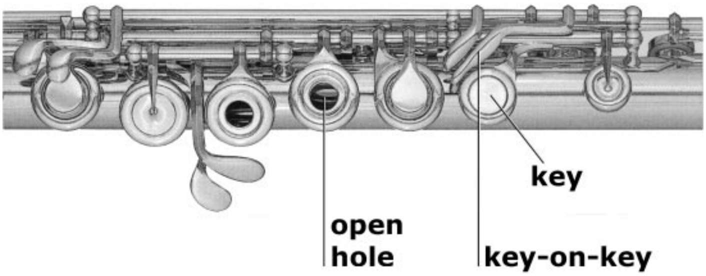
To sum up, traditionalism in today's world of classical musical instrument making, notably concerning the instruments of the symphony orchestra, is according to our respondents related to the patent system, the master–apprentice style of education in instrument making, and the 'iconography' of the appearance and sound of particular brands of instrument. The heart of traditionalism, however, lies in the attachment of players to specific musical instruments, itself related to the time-investment in and the pride of having mastered the often wilful instruments, the imitation-oriented system of music education, selling strategies that focus on teachers, and a rather rigid orchestral and concert culture.

Attempted Burglary and Strategies of Reconciliation

Despite these various difficulties, the instrument makers that we interviewed still sought novelty and stubbornly attempted to break into a world of perfection. As Curtin put it: 'The idea that the violin is perfect is such a ludicrous one that it is hard to believe that it's been so widely accepted for so long' (JC 4).

One instrument maker claimed he had started to experiment because he felt the need to distinguish his firm from other instrument makers in order to attract attention (JHi 10). He and others also made clear that they tested new things because they just loved to tinker with their instruments. It is 'the smell, the atmosphere, the metal, the machines . . .' (EK 6). Several of the instrument makers believed, as Libin does, that those who make their instruments one by one are more prone to experiment than manufacturers who employ standardized machines and techniques, since making new instruments often means one has to create new tools as well (JHi 16; EK 2, 4; JC 3). One instrument maker even claimed that his lack of formal knowledge had been his 'salvation' (JHo, notes 11). For this reason, a manufacturer had been reluctant to hire personnel with formal

FIGURE 1
Eva Kingma, Kingma System C-Flute (technical terms: authors).



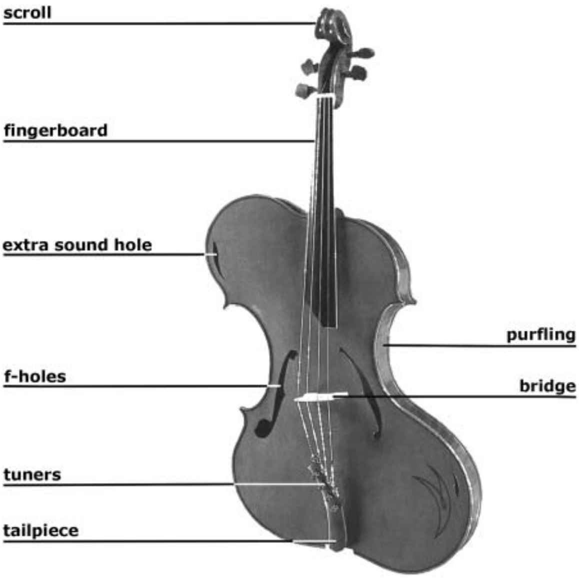
Source: *Pamphlet Kingma System Flute*, 2002. Reproduced by courtesy of Eva Kingma.

training and background in instrument making. Such training might only reduce their appropriateness for doing something new (RS, notes 11).

Notwithstanding the instrument makers' inclination to experiment, many of their innovations originated after musicians had pointed out to them particular problems or needs. Eva Kingma's first big challenge came when a modern music flautist–composer asked for an open-hole alto flute in order to play glissandi, quarter-tone scales and multiphonics. Until that moment, only C-flutes had open holes, which actually means open keys or keys with holes (see Figure 1). Yet designing an open-hole alto flute presented particular ergonomic problems. Since there is greater distance between the keys than with a C-flute, and since an open-hole flute forces the flautist to position fingers exactly on the keys in order to close them, it is difficult to reach *and* to close the keys. The flautist–composer himself had big hands, so it happened not to be a problem for him, but it nevertheless challenged Kingma to think of solutions (EK 2–3). The composer–flautist acquired grants from both state and private institutions to have Kingma make the flute and subsequently commissioned eight composers to compose for the newly built instrument (EK 3, 20). 'We put each other on the right track. And I can't do what I do without really listening to what flautists want . . .' (EK 3). Subsequently, the same flautist requested an open-key bass flute, which, in terms of ergonomics and mechanics, was ever more difficult to design. After 'nights without sleep', the so-called key-on-key system gradually came into being (EK 4). This system was meant to bridge the distances between the keys by superimposing a few extra keys upon already existing ones. These keys-on-keys correspond (with help of pinned mechanisms) with other keys that are not within reach. Other innovations, associated with tunings for instance, came along. Figure 1 shows part of the key-on-key system for the C-flute, which Kingma would develop afterwards.

In the case of David Rivinus, it all started with a petite female viola player in a Canadian symphony orchestra. She requested a small viola with a big sound, since she was the associate principal player. 'I'm not injured yet', she said to Rivinus, 'but I can't play your little viola in the symphony; it doesn't make enough sound. And if I play the big one, I can see the

FIGURE 2
David Rivinus, Pellegrina (technical terms: authors).



Reproduced by courtesy of David Rivinus.

handwriting on the wall that within a few years I am going to be injured, and isn't there anything you can do about it? And that's how the project began' (DR 1). Viola players get injured because they have to stretch their left arm in a very unnatural position (supination) in order to get around the upper right bout and reach the higher positions on the strings. Rivinus therefore made the shape of his viola asymmetrical (see Figure 2), so as to make it more ergonomic. This forced him to create several other innovations, simply to get the sound back. One was to take more mass off the bridge, by cutting away some wood there. Another was to pull the tailpiece out of the centre of the instrument (DR 2). He also created two extra sound holes and decided to employ lime wood with a veneer of phenolic resin, instead of the much heavier ebony, on top of his fingerboards (brochure *David Lloyd Rivinus*; DR 5).

In Rivinus' design process, players not only inspired him to experiment, as in Kingma's story, but also actively contributed to the innovation. Violist Joel Lipton, for instance, talked about a 'symbiosis' of maker and player.[17] Lipton suggested to redesign the tailpiece in such a way that his preferred type of tuners would fit, as well as to change the shape of the fingerboard so that it would match other curves already on the instrument. Players also repeatedly urged Rivinus to shrink the upper right shoulder (JL 4).[18] Such suggestions were detailed recommendations, although most of the time Rivinus would seek solutions for problems that players just hinted at. Thus, in response to the complaint of a player that she couldn't reach the C string, Rivinus created a fingerboard 'banked' into a more comfortable angle. And because someone had problems with putting a mute on the instrument, he redesigned the tailpiece again. 'So from the very beginning this whole idea has been driven by the desires and needs of the players. And that's one of the reasons why it is successful by the way . . .' (DR 6).

The same happened to guitar maker Jeroen Hilhorst. When clients requested louder tones for the higher frequencies, longer tones and extra frets, he built his guitars accordingly (JHi 11, 18). And although he claimed that clients only rarely brought forward technical ideas that made sense (JHi 12), it happened at least once. One client wanted both a classical and a 19th-century guitar, tuned one third higher, all in one instrument. After Hilhorst had shown her a guitar with a cut-away[19] that he had once built, she came up with an idea herself. With such a cut-away guitar, she only had to put a capo[20] on the third fret in order to construct a 19th-century guitar for the time she needed one (JHi 20). In the case of Frank van den Berg, the oboe player–engineer, consumer and producer are embodied in one person. His quest for a synthetic oboe reed resulted from his personal irritation with the instability and time-consuming construction of 'cane' reeds (FB 2).

So players – in some cases as player–composer, player–instrument maker or player–engineer–instrument maker – had a remarkable influence on many of the innovations, as our examples later will also underscore. Listening to consumers was not enough to sell instruments, however. First, the instrument makers had to create a 'setting' around the musical instruments: that is, a musical practice within the instrument could survive. Such settings came into existence in the course of and through developing these instruments. In doing so, breaking with as well as building upon and slightly shifting long-standing traditions were important.

A good example of this is the story of flute maker Jelle Hogenhuis. His idea was to build polyvinylchloride (PVC) bass flutes. This idea originated from his experiences as a music teacher. In the mid-1980s he established a flute orchestra at his music school, one of the first in the Netherlands. To add bass to the 'peeping' mass of his C-flute orchestra, he needed bass flutes (JHo 13). Yet Hogenhuis did not like the two silver bass flutes his director allowed him to buy. They were not loud enough, did not speak well and were expensive. As music schools are usually in need of money and Hogenhuis described himself as 'unbelievably thrifty', he decided to create a cheaper as well as louder alternative (JHo 11, 8). He found a used piece of PVC tube and just tried to make a flute out of it. Initially, he employed a baroque key system, but since players refused to relearn fingerings and since the hands of his students in the flute orchestra were not big enough to play it, he returned to the traditional Boehm system[21] (JHo 8). What's more, he used big holes so as to create loudness.

It was this loudness as well as a particular context that led to the 'discovery' of the PVC bass flute by his colleagues. At a flute competition, his colleagues arrived too late and were not allowed to enter the concert hall to *see* the orchestra. Thus they only *heard* the PVC flute, and were not bothered by its peculiar, privy-tube appearance that usually made people giggle. In contrast, they were so enthusiastic about the flute's sound, and its cheapness, that they commissioned Hogenhuis to build the unconventional instruments for them as well. Equally unusual, though, was the fact that a flute orchestra had been allowed to participate at a flute competition at all. Until then, only flute soloists had been admitted. It had been Hogenhuis himself who had successfully appealed for the extension of the competition to include flute orchestras (JHo 9–10). Moreover, he had to 'cultivate' the importance of the lower voices in his music-school orchestra. The players were inclined to see the highest voices as the leading ones. But he convinced them that only the best players were allowed to play the bass flutes: they made up the foundation upon which the others leaned, musically speaking (JHo 10). Today, Hogenhuis makes 12 PVC bass flutes per year, mostly commissioned by flute orchestras, and has built contrabass (see Figure 3) and even sub-contrabass flutes (JHo 11–12).

Eva Kingma had increasing success with her key-on-key system flutes after she followed the advice of the alto and bass flautist to attend fairs, as

FIGURE 3
Jelle Hogenhuis, black PVC contrabass flute.

Reproduced by courtesy of Jelle Hogenhuis.

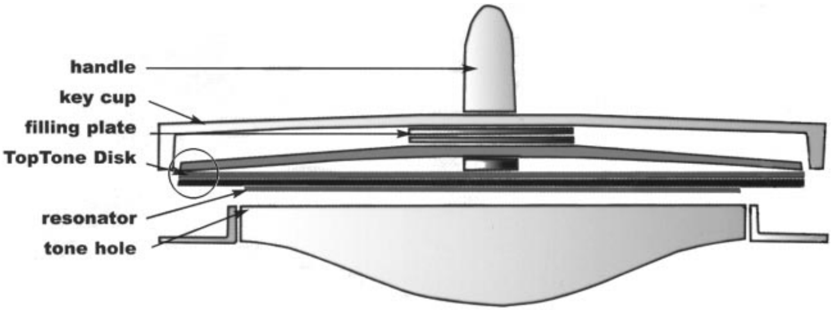
well as to contact Robert Dick, a prominent US concert flautist and new music composer. He happened to be greatly interested in using modern technology (EK 10). Out of this contact a very intense cooperation developed. He would request another open hole, she would offer even more, which he would immediately use artistically. He gave concerts and demonstrations, at times together with Kingma. He travelled to Europe and composed for the Kingma flutes, after which students and other musicians began to play and order the instruments (EK 10).

In a later phase of her career, Kingma developed the key-on-key C-flute (see Figure 1), which offered a full quarter-tone scale and multiphonic venting. She patented it, and sought a close working relationship with an established manufacturer Bickford W. Brannen of Brannen Brothers Flutemakers, USA. A year of highly intense and secret email contact followed. They managed to simplify the design into a manufacturable flute (EK 12–14).

Subsequently, Kingma organized presentations, demonstrations and forums for flautists and composers in Europe and the USA. Since Brannen had earlier only sold standard flutes, Kingma's approach to experimental flutes was new to him. To his surprise, Kingma did not want to sell their first flutes, but to lend these US$13,000-instruments to the players for one month, to listen to their comments and to change the instrument accordingly (EK 15–17). It was her conviction that if she offered flautists 'something they can work with, something that inspires them', the composers would 'naturally come along as well' (EK 9). Indeed, many of the performers also composed music: all but one of the six musicians mentioned on the Brannen Brothers' website who perform with the Kingma flutes are flautists–composers.[22] Moreover, flautists frequently took the initiative to contact composers themselves after they had bought a Kingma flute (EK 21). To guitar player John Schneider, composing was similarly important. In order to play the just-intonation[23] music of Harry Partch, a composer of the 1930s, he had his luthier build an adapted guitar (JS 5). Thereupon, Schneider commissioned people to compose for it and wrote music for it himself (JS 8).

For Rivinus, the player–instrument connection remained highly significant in creating a setting around his instruments. Since he has none of his 26 Pellegrinas in stock, he asks people who bought the instruments to help him out in demonstrating them. Violist Joel Lipton, for instance, frequently had 'someone come over here to have lunch and play the instrument' (JL 3). More intriguing is that Rivinus is 'repaying the trust' of the players by taking back the instruments or sending out new parts whenever he makes a new improvement: '. . . it's also from a marketing point of view. If you want to sell something this radical, you have to offer some extra guarantees' (JL 3, see also DR 5). Consciously or not, he seemed to translate the Microsoft-style of upgrading software to the craft of violin-making. In other words, he used a strategy similar to Microsoft's practice of providing customers with upgraded software in order to maintain a 'loyal' business relationship.

FIGURE 4
Rienk Smeding, Toptone Disk® in cross section.



Source: *Pamphlet Toptone Systems.* Reproduced by courtesy of Rienk Smeding.

Rienk Smeding's Toptone® idea for sealing saxophones, however, needed manufacturers and repairers, as well as performers. Aided partly by feedback from a saxophone player, Smeding developed the Toptone Disk® – a new sealing system for saxophones (see Figure 4). Instead of using traditional leather pads that easily leak, Smeding created key cups with slightly movable disks made out of a metal resonating plates, rubber and synthetics that 'perfectly seal the flat tone holes' (pamphlet *Toptone*, RS 2–3). These disks change the saxophone, as the website claims, into a less noisy and more responsive instrument with a rich tone colour.[24]

Being an amateur player and former engineering teacher, and expert on bridges and locks, Smeding wanted to systematize the frustrating and unpredictable process of inserting and tuning traditional pads (RS 5). The Toptone Disk® was his final answer. A search for a saxophone factory willing to apply the disks, and later, for a factory able to provide him with half-fabricated saxophones, turned into a worldwide odyssey in which he was repeatedly confronted with people who tried to run off with his innovation. Far more helpful was the Saxophone Shop, a renowned repair shop that decided to employ Toptone Disks® because they took less time to install and, as the shop claimed, they were of good quality. The shop repaired saxophones with Toptone Disks® without telling the clients. The shop owners only mentioned the price of the repair and added that if clients *really* wanted leather pads, they could get them. Implicitly, however, they discouraged using leather. It worked, as almost all customers accepted Toptone Disks® (RS 7).

So, in creating new 'settings' around their instruments, the makers broke with tradition, often in close contact with players and player–composers, but they also made use of, were helped by, or intriguingly readjusted these traditions. The bass flutes of Hogenhuis were listened to thanks to the tradition of keeping concerts and music competitions absolutely undisturbed by late arrivals. He himself turned upside down the notion that the higher pitched wind instruments were the leading ones – yet implicitly sustained the idea of a hierarchy in musical instruments – and expanded flute competitions with flute orchestras. Rivinus and Kingma employed the rather common approach of having virtuosi-performers demonstrating their instruments. At the same time, Rivinus clearly transformed the selling process by introducing 'upgrading'.

Instrument makers were not the only participants in the process of endorsing the acceptance of the newly constructed instruments. Joel Lipton, a lead viola player of the Netherlands Philharmonic Orchestra who started to play a Pellegrina after an operation failed to solve his bursitis, claimed that he had made the orchestra's acceptance of the instrument easier by simply discouraging any jokes and teasing (JL 8). In his case, the orchestra management had been 'enlightened' enough to encourage him to try out a Pellegrina. In the USA, similar examples of orchestras adapting to the new instrument were not without self-interest (DR 10): 'orchestra managers think it's a great excuse for a newspaper article' (JL 6). The manager of the San Francisco Symphony Orchestra even decided to introduce the Pellegrina of violist Don Ehrlich:

> . . . the way they always introduce a new player in the orchestra.[25]. . . The manager came out on stage and made the introduction, and I raised the instrument. And from then on everybody, *everybody*, has had something to say. . . . Isaac Stern came in very shortly after that and said that it looked like I'd left it in the sun too long. (Simpson, 2000: 3)

Eventually, however, the orchestra accepted the instrument and let Ehrlich play front row at a Carnegie Hall performance. Notably, the orchestra management had deployed an orchestral tradition in order to facilitate a smooth reception of the innovation.

After achieving the appropriate setting, the makers began to employ strategies for endorsing the public acceptance of the instruments they had already sold in order to reach a wider circle of customers. When using such strategies, the innovators once again – and now explicitly – intended to *reconcile* innovation and tradition, so as to prevent or overcome resistance.

The *strategies of reconciliation* used by the instrument makers themselves were of two kinds. One was to change the *design* of the instrument so as to bring the innovation closer to tradition (innovation→tradition). The other was to rely on *rhetoric* such that the tradition appeared closer to the innovation (innovation←tradition). An example of the first kind involved 're-conventionalizing' the appearance of the instrument. Jelle Hogenhuis, for instance, first employed grey PVC for his bass flutes but shifted to yellow, blue and finally black PVC, the colour that most resembles ebony (JHo 10, 12, 18). Furthermore, he came to use silver instead of copper for the key mechanisms in order to please the many flautists who handle their instruments as 'trinkets': that is, like shining jewels in boxes with velvet lining (JHo 16, 10). Rivinus similarly refined the Pellegrina so as to make it more graceful (DR 4), and Jeroen Hilhorst readily conventionalized his designs: 'They play a guitar and want a guitar that looks like a guitar' (JHi 12). A slightly different, yet related version of this same strategy involves Curtin's emphasis on the reversibility of his Evia necks and soundposts.

They took away initial reservations of clients. 'They just want to know that they're not going to be stuck with something that doesn't work' (JC 7).

At the same time, several instrument makers experienced the advantages of an instrument with an unfamiliar appearance. A yellow bass flute that Hogenhuis sold to a Venezuelan national flute orchestra attracted a lot of press attention exactly because of its strange exterior (JHo 14). Rivinus 'wasn't getting anywhere with this project until the *New York Times* did the article' (JL 10). According to him, the newspaper chose to write about the Pellegrina partly because of its striking appearance. If it had only sounded new, reporters wouldn't have been nearly as interested. Rivinus even deliberately used a lightly coloured varnish and did not 'antique' the instrument. 'You know, that would be something ridiculous, on something that looks so radically new. . . . So it looks a little like a Picasso stuck in the middle of a bunch of Rembrandts' (DR 10–11).

Another strategy of reconciliation of the *design*-kind was to bridge the gap between traditional and novel ways of performing. Eva Kingma constructed the key-on-key system in accordance with the known Boehm system, because she deliberately wanted to ensure continuity with the classical music world, while she also wanted to make a flute that allowed for detailed pitch control rather than for revolutionary quarter-tone music. An advertising leaflet for the key-on-key-flute supported this rhetorically by claiming that the flute, despite its new music potential, is:

> in all respects, a Boehm system flute. All of the normal touch pieces and fingerings are where you would expect them to be. When playing this flute for the first time, it feels similar to the usual C flute. The extended possibilities are to be discovered in the course of time . . .

And indeed, the 40–50 flutes that have been sold are now played by members of symphony orchestras as well as by performers of jazz, modern music and world music (EK 17–19).

Reconciliation strategies of the second, *rhetorical* kind, did not change the actual innovation, but readjusted tradition so as to couch the innovation in a familiar frame. Rivinus, for instance, claimed that violin-makers wrongly justify the use of solid ebony in fingerboards by referring to tradition. 'The first fingerboards were maple, often inlaid with purfling, ivory or other elaborate designs. And when ebony was introduced, it was used as veneer. Only much later were whole, solid pieces of this wood made into fingerboards' (Rivinus, 2000: 2). The continuity of an asymmetrical appearance was a similar theme. 'In fact, almost all stringed instruments, bowed or not, are asymmetrical in their acoustics, and for a very good reason. . . . If anything, the Pellegrina's break from visual tradition enhances its acoustics' (brochure *David Lloyd Rivinus*: 13). Rivinus also underlined that his Pellegrina, unlike other violas, blended 'seamlessly with both the violin and the cello' in a string quartet (RV 3), thus favouring the tradition of a homogeneous ensemble sound over the traditional dark viola sound. And Curtin supplied a familiar frame by underlining that his Evia 'looks back to the Gamba, while retaining . . . some sense of modern simplicity' (Curtin, 1999b: 1).

Given their inclination to bridge tradition and innovation, it is no surprise that only a few of the instrument makers referred to science in order to legitimate their innovations. Several makers consulted physicists or scientific literature (EK 8; RS 15–16; JC 4), and engineer–oboe player van den Berg employed various sophisticated measuring techniques in order to create detailed graphs of the thickness of traditional reeds (FB 4). Yet only one instrument maker used scientific diagrams to convince his clients (KG 5). In contrast, all innovators endorsed the view that having famous performers play their instruments greatly helped to advertise their instruments, even though this concern conflicted with their complaints about imitation in the music world. 'If you can get a few of these very good players', Curtin expected, 'who are secure about their sense of their identity without their needing to have a Stradivarius to support it, and they'll play something innovative, well, that'll do a huge amount to make it acceptable' (JC 3).

Theorizing on Go-Betweens, Recasting Tradition, and Attachment

In the stories of the musical instrument makers, people who exclusively compose played hardly any role in the innovation process, whereas performer–composers and other people who found themselves at the crossroads of professions – such as performer–instrument makers, engineer–instrument makers and even a performer–composer–music teacher–instrument maker – proved highly significant. Such 'go-betweens' stimulated instrument makers to experiment when they did not do so already because of their own multiple stakes in the world of music.

A phenomenon well known in S&TS and related fields is that individuals who operate with 'creative marginality', that is, at the margins or intersections of disciplines and traditions, are often most inclined to innovate (Dogan & Pahre, 1990). These people transfer and 'translate' methods of analysis from one discipline to the problems of other disciplines. As Latour described the success of Louis Pasteur, such translation was a strange 'mixture of audacity and traditionalism' that innovated 'by linking together' (Latour, 1988: 69, 267). Such a 'return of novelty from the known', as sociologist of innovation Ingo Schultz-Schaeffer (2002: 233) noted, probably occurred as engineer–amateur player–instrument maker Smeding applied the systematic approach and concepts of building bridges to the completely different field of constructing saxophones. Using measurement techniques to understand oboe-reeds and software upgrading to improve violin-making are similar examples of introducing engineering notions in musical instrument making. In turn, 'boundary shifters' (Pinch & Trocco, 2002) may insert known musical values in an experimental context. So did Kingma, when she combined the quarter-tone flute with a Boehm-system through her key-on-key-construction, or Hogenhuis, when he made his loud PVC flutes look like old ebony-and-silver instruments again.

Less well-known than the importance of the creative marginality of 'go-betweens' in innovation, however, is the significance of the makers' and promoters' abilities to readjust tradition, such as introducing the Pellegrina as a new *player*, stressing the importance of bass-lines in PVC music or underlining the asymmetry of violin acoustics and the traditional dominance of ebony veneer. At times, the makers and promoters readjusted tradition with the same kind of virtuosity as the performers played their instruments. Marketing new technologies by associating novelties with familiar technologies is a well-known rhetorical trick used to promote innovations (Lipartito, 2003). The same holds for conventionalizing design. Enfolding early television with traditional cabinetry, for instance, enabled the domestication of the television in the US home (Tichi, 1991). Yet, recasting the tradition and history of the innovative technology itself is not a commonly discussed innovation strategy. Instead of bringing the innovation closer to tradition, as is the case in the television example as well as in the examples of the instrument makers who re-conventionalized the design of their instruments, recasting tradition implies pushing the tradition closer to the innovation. Employing this strategy may be specific to people innovating in fields in which craft and tradition are key values. And it is probably no coincidence that the strategy of recasting tradition in musical instrument making resembles the way in which the promoters of new academic disciplines rephrase the history and concepts of 'forerunners' within the long-established disciplines so as to legitimize the content and status of the new one (De Wilde, 1992).

In the case of the classical musical instruments, reconciliation strategies were necessary so as to disassociate performers from particular attachments to their instruments. As we have seen, the instrument makers' and promoters' understanding of such attachments varied. The view that the musicians' inaccessible mastery of whimsical instruments contributed to the attachment hints at the role of 'tacit knowledge', 'the ability to perform skills without being able to articulate how we do them'. This notion partly explains why musicians hold on to skills that have been 'a matter of trying over and over again until the skill has been mastered' (Collins, 1985: 56). Equally understandable is that fingerings, acquired after a lifetime of daily practice, are far from easy to re-adapt, given the overloaded schedules of today's musicians. Yet a deep dependence on technology based on lifelong training also holds for several sports such as car-racing or skating. These fields seem to be far more prone to innovation, however. How can we explain this? The easiest way to do so is to stress that it is often unclear to musicians which goal will be brought closer by the innovation, since it is not speed that is the issue here, but sound, musical style and aesthetics. Yet, the emotional attachment of musicians to individual instruments still needs a better explanation than the reference to tacit knowledge can provide.

Here, the philosophy of technology has something intriguing to contribute. The fact that it is highly complicated to control a musical instrument, while it also offers a kind of resistance to control, makes the instrument into an 'engaging technology'. This notion refers to artefacts with which people have an enduring relation *because* they need to take great pains to control them, in contrast to artefacts that can be easily and fully controlled, *and* because the artefact opens the door to a 'unity of performance and pleasure' or 'flow' (Verbeek, 2000: 205, 248). It is an attachment actively sought for by musicians, as Emily Gomart and Antoine Hennion claim from an actor-network perspective. They argue that musical effect – playing without fighting the instrument – '"arrives" with repetition' (1999: 240). Moreover, technologies can enhance the 'engagement', and thus the enduring love, of their users through the process of wearing out. In the case of a leather bench, for instance, owners can deduce the history of its use from how it changes, which enhances their personal engagement with the bench (Verbeek, 2000: 258). Once again, musical instruments – especially the ones used in classical symphonic repertoire – are perfect examples. Silver, brass and wooden musical instruments clearly show the signs of wear and tear and thus contribute to memories of personal use. The sound of string and wooden wind instruments even improves over time as a result of processes of drying within the wood. That is why Joel Lipton, despite his endorsement of the Pellegrina, still felt a special love for his old viola: it had 'history' (JL 9).

Conclusions

It is, indeed, 'history', in many forms, that today's musical instrument makers have to cope with when seeking to innovate with classical musical instruments, notably those of the symphony orchestra. Such histories encompass orchestral culture, including its visual icons and 'frozen' ideals of sound, the patents of times past, the longstanding master–apprenticeship model of teaching, the individual histories of time-consuming practice leading to tacit knowledge; and the *engaging* character of the musical instruments, partly constituted by their wear and tear. Further research into the views of players who resist specific innovations may further enhance our understanding of traditionalism in the classical musical world.

Given the conventions indicated, it is understandable that go-betweens with multiple stakes in the worlds of music-making and engineering play a crucial role in the innovations described. These people are able to cross the boundaries of different fields and to bring off *creative marginality*. Similarly, the motivations behind the innovations often are not simply 'musical' *or* 'extra-musical' (social, cultural, technical). Kingma's original alto-flute project aimed to fulfil a musical wish to play quarter-tones and to solve an ergonomic problem. Rivinus' viola had to be loud and playable without causing pain. To give two other examples, Hogenhuis wanted both a cheap and a loud flute for his newly established flute orchestra, and Smeding sought pads that were more easy to insert and more predictable to tune.

The fact that all the makers we interviewed had relatively small workshops facilitated their innovations: mass manufacturing, as organology indicates, usually promotes standardization rather than innovation. At the same time, however, it is clear that scaling-up, as with the production of Kingma's flutes and especially Smeding's Toptone® saxophones, can be necessary to pay for the costly patents, and thus, to transform an invention into a commercial innovation. In the highly specialized market of classical musical instruments, however, this is no 'law' – PVC flute maker Hogenhuis and viola maker Rivinus could do without it.

Probably because musical instrument makers had to fight against the history of their craft and the conventions surrounding the symphony orchestra, their most unique strategy of innovation – next to creating new settings for or reducing the spectacle of their instruments – was the one we coined *recasting tradition*. This strategy may also apply to other tradition-bound fields of industry, such as the beer, wine and chocolate industries. A brand of beer, *Grolsch*, once underlined its tradition and craft by associating itself with musical instruments. One of its advertisements showed a still life displaying a glass of beer upon a violin makers' workbench, saying: 'Craftsmanship is excellence'.

Notes

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1. See for instance, 'Internationale Patentnachrichten' in *Das Instrument*.
2. See for instance, pamphlet Bernd Moosmann, Frankfurter Musik Messe 2002, and pamphlet Rudolf Walter & Co, Frankfurter Musik Messe 2002.
3. <http://www.fh-zwickau.de/aks/musikinstrumentenbau/index.htm>, 5 June 2002.
4. <http://www.c21-orch-instrus.demon.co.uk>, 6 June 2002.
5. These interviews were semi-structured. Tape recordings, typescripts and email records of all but one of the interviews are available. With an eye to a future patent, one of the respondents did not allow tape-recording. References to the interviews refer to the pages of the typescripts of the interviews: 'MV 1' thus refers to the first page of the transcript of the interview with Maarten Vonk. References to 'notes' refer to the pages of the field notes taken during the interviews.
6. The following journals have been analysed (issues of 1998–1999 and/or 1999–2000): *American Lutherie*, *Catgut Acoustical Society*, *Das Instrument*, *Die Viola*, *Double Bassist*, *Fluit*, *Gitarre and Laute*, *Instrumentenbau Report*, *Journal of the American Musical Instrument Society*, *Journal of the International Double Reed Society*, *Musica Instrumentalis*, *Newsletter of the American Musical Instrument Society*, *Rohrblatt*, *Scrapes*, *Strad*, *Clarinet*, *Double Reed*, *The Galpin Society Journal*, *Woodwind Quarterly*.
7. Personal communication, Hans Cuypers, Maastricht, 7 April 2002.
8. She is the only woman among the interviewees, which 'accurately' reflects the fact that men currently dominate the world of musical instrument making.
9. In idiophones, for instance, vibrations 'are produced without stretching the basic material, by striking either one portion of the instrument against another . . . or another object against the instrument . . .' (Randel, 2003: 410).

10. Moreover, performers can influence the design of musical instrument through testing. Composer–performer Johann Sebastian Bach, for instance, frequently tested organs and, at times, fortepianos, suggested improvements in design and even modified instruments himself (Wolff, 2000: 142–45, 412–15).
11. Difficulty of playing likewise hampered a positive response toward some new instruments. This happened to be relevant in case of the Theremin, an instrument controlled by moving the hands within the electric field near two antennas without touching anything in particular (Théberge, 1997; Braun, 2002). Other instruments, such as the huge Telharmonium that had to pipe music to restaurants, failed 'because it was too big to transport, too expensive and produced too much crosstalk on telephone wires running through the same conduits' (Pinch & Bijsterveld, 2003: 10).
12. Personal communication David Rivinus, 28 May 2002.
13. The 'frozen repertoire' encompasses the works of famous 18th-century composers such as Mozart and Haydn, as well as – and even more so – those of 19th-century composers such as Beethoven, Brahms, Schubert, Dvořák and Mahler. According to *The New Grove Dictionary of Music and Musicians*, the orchestra owes its institutional stability basically to 'its role in the furtherance of 19th century music and traditions' (Sadie, 1995: vol. 13, 699).
14. Absolute music is: 'Instrumental music that is "free of" [Lat. *absolutus*] any explicit or implied connection with, or reference to, extramusical reality' (Randel, 2003: 1).
15. Personal communication Rienk Smeding, 13 December 1999.
16. See for instance: Archives Jelle Hogenhuis, letter 25 February 1986, Rijksnijverheidsdienst, Afdeling Octrooivoorlichting to J. Hogenhuis.
17. This symbiosis is reminiscent of the 'telepathic' relationship between engineer Robert Moog and musician Wendy Carlos in the design of the Moog synthesizer (Pinch & Trocco, 2002).
18. Personal communication David Rivinus, 28 May 2002.
19. A cut-away is a recess in the body of a guitar that enables the guitarist to reach the highest frets, or those closest to the sound hole of the instrument.
20. A 'capo' is a device for the fingerboard of a fretted stringed instrument that can stop 'all strings at a desired fret' and that can raise 'the pitch by a desired number of semitones without requiring a change in fingering' (Randel, 2003: 148).
21. The Boehm system is a 'system of fingering for woodwind instruments', encompassing 'the rational placement of tone holes' as well as a 'mechanized key system' so as to cover these holes, developed by Theobald Boehm in the 1830s (Randel, 2003: 105).
22. <http://www.brannenflutes.com/kingma.htm>, 6 January 2001.
23. Just intonation is any system of tuning with simple-ratio intervals, such as well-temperament, medieval mean tone and Pythagorean.
24. <http://www.toptone.nl>, 8 March 2002.
25. It is a peculiar and immovable orchestral habit to tap the bows on the desks softly and approvingly after a new player has been introduced.

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Appendix

List of People Interviewed

Jelle Hogenhuis (JHo; flute): Marssum, The Netherlands, 3 March 2000
Eva Kingma (EK; flute): Grolloo, The Netherlands, 22 March 2002
Karsten Gloger (KG; saxophone): Groningen, The Netherlands, 22 March 2002
Rienk Smeding (RS; saxophone): Meppel, The Netherlands, 21 March 2002
Maarten Vonk (MV; bassoon): Amersfoort, The Netherlands, 22 November 2000
Arthur Weisberg (AW; bassoon): Boca Raton, FL, USA, by email, 22 May and 17 June 2002
Frank van den Berg (FB; oboe): Delft, The Netherlands, 4 April 2002
Joseph Curtin (JC; viola): Ann Arbor, MI, USA, by telephone, 9 April 2002

Joel Lipton (JL; viola): Heemstede, The Netherlands, 15 May 2002
David Rivinus (DR; viola): Newberg, OR, USA, by telephone, 23 April 2002
Jeroen Hilhorst (JHi; guitar): Amsterdam, The Netherlands, 23 May 2002
John Schneider (JS; guitar): Venice, CA, USA, by telephone, 4 June 2002