

The Beethoven Question: Can Art Make Life Worth Living?

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TRANSCRIPT

Prof Age Smilde and Dr Edoardo Saccenti

Beethoven's deafness, his string quartets and his three styles

(with discussion and questions)

MICHAEL PUGH: Ladies and gentlemen, we are ready to restart and I am very pleased to ask you to welcome Professor Age Smilde and Dr. Edoardo Saccenti, from the University of Amsterdam, who are going to talk to us about Beethoven's quartet writing and deafness. [applause]

PROF. AGE SMILDE: Good morning. First of all I would like to thank the organisers for giving us this opportunity. It is an honour to be here, actually I feel a bit humble. Let me first introduce us to you. This is our daily life, this is what we do. And you see we are working in the area of systems biology, applying mathematical tools; we work with systems like this, this is the cell, a part of the human body and this is a set of equations we use to describe some of its behaviour. This is our daily life, so it's kind of a disclaimer - we are not Beethoven scholars. But - and that is I guess why we are here - we really love his music and we love mathematics we want to share some of these things with you today.

This is the big picture, this picture is going to appear again and again to give you a clue of what we are talking about. What we are interested in is to figure out relationships between Beethoven's music and life and composing style and composing activity. So those 3 facets if we want to combine those, find relationships between them, what we try to do, is we try to make, to quantify those kinds of things, we want to have numbers; we like maths, we want to study relationships using mathematics and in order to do so we have to put things in numbers, otherwise we cannot do mathematics. So that is what you see over here, you see we have to transform his music into numbers. We also have to take events of his life and put them into numbers and we also have to, some way or other, quantify his composing style - that is the hardest part actually.

What we are going to do today, is to present you with two examples of the scheme and how to use it, and how to distinguish between his 3 styles. The other one is whether we can say something about his composing activity and his deafness.

So the first part is about his music and his life. To what extent do his life events bear upon his music? That is what we are going to show, how to quantify it, how to use the big picture scheme in order to distinguish Beethoven's three styles.

DR EDOARDO SACCENTI: Hello. First of all I want to thank the organisers for giving me the opportunity of being here among such great speakers and big name veterans, I feel humble. But anyway, this slide is a pretty basic slide about Beethoven's three styles. It is probably a very crude approximation but that is actually what we do everyday, we make approximations. This is a quote about Beethoven's string quartets and we already know that music of Beethoven is divided into three styles - the so called first style, second style and third style, which actually summarise the three different phases of Beethoven's productions. So, the early years, the middle period and the later compositions - mostly the string quartets and the late piano sonatas.

The idea was: can we quantify these styles in a way that we can manipulate them mathematically and the idea came from looking at this picture. This is something that always fascinated me since when I was able to read the music and since my interest for Beethoven started. So this is the first of the quartets; it wasn't the first composed but it was the first that he chose to be the first in Opus 18, and this is the beginning of the last one. I have been always surprised by how different this style is. You don't really need to listen to see that they are different, it is just to look at how they are written and for me it is like, something like this, to go from this. So two valid approaches but completely different. But I mean, can you describe this? And yes, we can. Because like everybody knows, music is fundamental, it is mathematics and we today we have a bit lost these feelings because we think of music in very romantic terms, if I can say so. Music is related more to humanities, but in the Middle Ages it was pretty clear that it was a manifestation of mathematics. Music was put together with astronomy, geometry and mathematics, so it was clear to them that music was actually mathematics, and they left to the Trivium the grammar, rhetorical and electric.

Here you see this mathematical formula and this is the fundamental formula that relates intervals in Western music, so expresses each interval as the difference with this format as a power of the number 2 and which is nice, that when you change then you go, change this index and change this number you have got the different intervals and it is known that when the number that comes out from this formula, can be approximated with an exact ratio, we have consonant interval like a fourth or fifth, but when the number cannot be approximated as the ratio of the two integers, we have a dissonant interval, like for instance, the augmented fourth – the 'diabolus in musica'. This is a backbone of our tonal system.

How do we go from that formula to that music? There is a simple way introduced by these guys, he was a pretty peculiar guy, he made a lot of things in his life. He was a dancer, he was a composer, he was a psychologist, he did a lot of things but he came with this idea that now are called modern numbers, yes, well you seem to give one number to each of the notes on the scale

and then you encode your music with those numbers, so this is actually what we did. You put one to the lowest note, so it is the low G because it is the lowest note you can find in the violin part of the quartet. Then you go from one to 26 and then here is how you encode a piece of music, this is the opening of the quartet, opus 95 and in this way your piece of music became just a series of numbers.

So what we actually did, we took all the string quartets and well, let's be more precise, the violin part of the exposition of each quartet excluding the great fugue and we give a number to each number and from those numbers we calculate the intervals so we could actually get rid of the different tonalities and we counted the frequency with which intervals appear in the violin. Once we have the numbers, we put them in a big table, in statistics we call it a matrix, and you see that each row is a string quartet and each number is the frequency of intervals, so how many times an interval appears in the violin part. So each row is a different quartet.

What we do daily in our lives is to find the patterns in these data tables. So we say well, can you distinguish which rows are more similar to other rows or, in other terms, can we distinguish if some quartets are more similar to other quartets? This is pretty complicated to do by eye, and for doing this, methods have been developed. Now I will ask Age to explain how we analyse this kind of data.

PROF. AGE SMILDE: Yes, so I know this is a conference about music, but I will teach you a bit of maths, just 5 minutes, no equations actually.

So how do we deal with such a table? Think of it as the following problem: let's suppose I have little children and I measure the height of the children and their weight. So I have their age in months over here and their height. If I plot all the children, each child is a dot over here, this is a child 18 months old, with a certain weight etc etc then I have two variables which are age and height. So I was somewhere on the plot and Edoardo was also somewhere on the plot. What is the important information of the plot is the configuration, the configuration is how these points are related to each other, how these points are, let's say, graphically separated. That is like the string quartets later on. If we find it is a bit too complicated - the plot - then we try to fit a line through these points, and by fitting that line, we can try to summarise all this data with this one line. But obviously this line isn't very good, this line isn't very nice; it doesn't run nicely through the points.

If we do it better, then we have this line, and this line nicely summarises what is happening in the plot in terms of configuration of the points. This line is called the principle component, that is just a term, but that is the mathematical construct. Now, if we have this line and the dots originally, what we can do, is we can take those points and project them on the line, so we take the points, project them on the line and then the next step is we just take the line, we forget about the whole plot actually. So we have this line then we put it on a horizontal axis, we lose a little bit of

information, but you can see that I am still over here and Edoardo is still over here. We have lined up all the children on this line, and we reduced it from two dimensions to one dimension.

Now that's not so spectacular, but what we can also do, is we can start with lots of dimensions. So let's say for everyone in this audience we are going to measure your glucose, insulin and cholesterol in your blood. Each person is then a dot in this space, so think about this room as a space, each person is a dot and I am here and Edoardo is over here. The nice thing about this, is these dots are not randomly distributed - they are on a plane. If they are on a plane, we can do the same trick. We take all the points, project them on the plane and we lose a little bit of information, not much, then we simply take the plane and put it over here. Now we have a nice two-dimensional plot showing the configuration of the points. That is the trick we can use in this kind of research.

DR EDOARDO SACCENTI: Ok, we go from insulin glucose back to the string quartets and you get something like this. Ok, so you see, there are 4 different colours, so for instance I start from the green colour, these green colours are the string quartet Opus 59 so each point you see in this plot is a string quartet. And we have those principle components and actually it is a summary of the data we have seen before, extracted from the frequency. It means that in this case each quartet, instead of being described by many frequencies, it is just described by two numbers - one on this axis and one on the other axis.

What does it mean? It means that the points that are close together are more similar in their frequency content. Points that are far apart are more different in their frequency content. So you see that some sort of clustering appears because you see that the opus 59 stays here, that is this separate corner. Then you have the early string quartets are close here apart from this one, which I think is the Opus 18 number 6, but the other 5 are pretty concentrated. These dots actually mean that they share some similarities.

The blue ones are the late string quartets which are pretty spread. You can infer that there is a bit of variety in how intervals are used. It is a very nice thing that there are these two outliers, Opus 95 and Opus 74 which are particularly strange quartets, probably some leading bit of a score I can't explain why. But from what I have been reading and researching, those two quartets are particularly peculiar because they are the only two quartets from Beethoven, that didn't stem from a commission, they were just composed by Beethoven of his own will. They are pretty different apart in tone and character and you see this because they completely stand out in the opposite direction.

And another thing that I really found intriguing is that this is one of the later string quartets which is classed pretty close to the early quartet of opus 18. I don't know exactly the number, but, it is known that at the time that Beethoven was writing that quartet, he came back to study the C minor quartet by Mozart and he was studying the C minor quartet when he was actually composing Opus

18. I don't know if this is just anecdotal, but I like this idea that you can find this influence of Mozart, that you can trace back in this principle component analogies plot.

So, what I can show that with a simple mathematical analysis you can find patterns to distinguish Beethoven's three styles.

Now we move to deafness and I like to link to what John said before, that Beethoven's music, the late Beethoven's music is great because he was deaf and this actually was Wagner's idea, he wrote in his Beethoven essay where he claimed that Beethoven late music is great not despite his deafness but because of his deafness.

So the interesting question is: there is a relationship between Beethoven's styles and his deafness, so we go back to our big picture, so now we try to link music and life, and in this case I mean life with the onset of disease. What you want to see is that we can establish a link between the music that you have quantified numbers, some accounts of his life, in this case the deafness progression, and if you can match those two to get insight in the composing.

To do this, we actually need to introduce two concepts, which actually we found are very interesting: the auditory feedback versus the inner ear. So what is the auditory feedback that actually I picture? So, Beethoven has an idea, or any other composer can have a musical idea, that's put down on paper, then it can be performed or just the composer can just go to the piano, listen to it and then you have an auditory feedback, and then go back to the original idea and maybe do some adjustment, writing again and playing again, and doing this loop. So iterating this until he reaches perfection, or what he deems is perfection. This is opposed to what can be called the inner ear, in the term that you have a musical idea, then you write it on paper, then you can do some thinking about that, then go back to modify your idea, go back to a different version and - again and again. So we know it was typical in Beethoven where the same idea was worked and worked many, many times, as was mentioned. The beginning of the Fifth Symphony was worked something like 30 times. The beginning of Missa Solemnis - 53 different versions before Beethoven gets to the final one.

So our idea is: can we observe in the way Beethoven composes, there is a way that going from auditory feedback, supported composing to inner ear composing? Well, that could be interesting because it actually could relate to three different styles, because we know that especially for the string quartets it seems that there is a parallel between the deafness progression and the style change. So the first onset of disease is in the period when he was composing the Opus 18, then his hearing condition was worse at the time of Opus 59, the middle period, and then we can believe the last string quartets were composed when he was stone deaf. Anyway, we should now be trapped in the fact that correlation doesn't imply causation. [Laughter]. So there can be a correlation between deafness and style but it's not said that deafness caused the changed style. This is a just recently published paper on the New England Journal of Medicine where they show there is a really big correlation between chocolate consumption and number of Nobel Prizes. So you can imagine that

it's really difficult to believe that the more chocolate you eat, the higher the chance of you getting a Nobel Prize but this is one of the key paradoxes when working on correlation.

Anyway, our reasoning was that when we see a progressive hearing impairment in Beethoven, this actually turns out in a reduction of hearing high tones – Beethoven many times reported that he had a problem in hearing the woodwinds and the voices, and does it result in a reduction of using high notes? That's actually the line of reasoning and we were not the first to ask this ourselves. There was an earlier attempt in the 1980s, 1982, I think, where they analysed power spectre of recordings of Beethoven's symphonies to see if there were changes in the frequencies or at least a decrease of the high tones, but from this analysis they couldn't conclude that there was any reduction in the use of high notes. Anyway, they concluded that they had a pretty limited view because there were only nine symphonies and it was a 1977 recording of the symphonies.

We try and have an attempt which is actually simpler than this one, which looked at what he actually wrote. So it simply counted the high notes, so we set up a threshold to the high G, where we found a reasonable threshold to define a high note in the violin writing, and we tried to correlate the abundance of high notes to the deafness progression. What we got was something like this, so we saw a decrease in the first period and later an increase in high notes. While we speculated that you could actually have a shift between auditory feedback composing, then go to a sort of inner ear assisted composing, and at the point when Beethoven was not hearing, he just started using his inner ear in total freedom. That's actually what we could speculate on this. What I just said, okay, we could actually say that here he was probably relying on auditory feedback and here was just relying only on the inner ear, so it's a sort of speculation that we had, and of course this is a limited view because we only analyse a small fraction of the string quartets, so it's a limited view, but we think we have some insight in how Beethoven composed.

PROF AGE SMILDE: Okay, I will end this presentation by reminding you of the big picture, so what we have seen now, if we look at the composing style, that we can distinguish the inner ear and the auditory feedback, which is balanced some way or another which might have to do with his deafness. That's a hypothesis. We haven't proven it yet. But let's say that's part of the scheme, also a difficult part because if you want to think about creative process and composing style, it's very difficult to formalise it in equations and mathematics, of course. So this is the big picture again, and I hope that I've convinced you that we might have said something of the use of formalising musical life and composing, in terms of numbers and equations, etc, and so that ends our presentation actually but not before we mention what else we can do. Of course, we can take a look at the whole body of his string quartets, piano sonatas, symphonies, etc, and repeat this whole experiment, but that's one thing we can do. Another thing which I'm very interested in is can we have some way of formalisation of the creative process? Can we put numbers on that? That's very interesting, I think.

Okay, rounding off, we want to acknowledge some people. Wim Saris, a medical doctor who helped us write this paper that we published in the British Medical Journal; Henkjan Honing is Head of Music and Cognition at my University, and of course last but not least Beethoven for his beautiful music. Thank you for your attention. [Applause]

STEPHEN JOHNSON: Thank you, Age and Edoardo. We will be bringing in these lovely people in just a moment, if you are wondering why they are here, because we thought it might be rather interesting to hear some of the things that these two gentlemen were talking about, if that is the case.

First of all, could you just help if I try to summarise what you were saying, because I did find my head swimming a little bit at one or two parts in that, not being a mathematician myself, I am afraid to say. Are we saying, to put it very, very simply, that in his earlier years in the quartets, as Beethoven's hearing is reasonably functional, that he is able to hear because of the physical feedback, these very high notes, and therefore composes them; in the middle of the quartet output as he is beginning to experience severe deafness he is actually unable to get auditory confirmation of these high sounds and therefore we find the incidences far less in these middle quartets; then later in the last works as he learns almost by a miraculous process to trust that inner ear of his, the facility and ability to imagine and create these extreme high frequencies is therefore enhanced? Is that it in a nutshell? Have I got it right?

PROF AGE SMILDE: Can I give a short answer? Yes, that's the nutshell.

STEPHEN JOHNSON: Phew! That's such a relief. If you had said no I don't know what I would have done. We thought we might illustrate this. Here is the beginning of the first of those three Razumovsky quartets, right from the middle, as Beethoven is beginning to realise the fact of his own deafness and just how much damage it is doing to his ability to hear. The first quartet begins interestingly enough, very much with low sounds, with a glorious celebration of the sound of the cello and it's quite a while before we get any really high sounds in this, isn't it? So when you are ready, ladies and gentlemen, could we have the beginning of the first Razumovsky Quartet?

[Performance by the Sacconi Quartet]

Lovely, thank you. [Applause]. Thank you very much. Now, there's something immediately that strikes me subjectively about that, and that is that for the whole of the cello's tune there's nothing there that if you put a damper over the higher frequencies you couldn't hear. You would lose a few overtones, wouldn't you, but certainly you would get the point of it. The ascent to the height at the end is very slow and very deliberate, as though he is tentative at first, as though he is trying out these things. Am I being too interpretative here, or do you think there is something of what I'm saying, we are actually hearing possibly in that music Beethoven's process of trying to re-adjust the

way he envisages sound? Does that make sense?

DR EDOARDO SACCENTI: Well, that's a big question. In my opinion, I think that from a very practical point of view, I think that one could be more tempted to write music that he could actually listen to and trying to make effort to make his life easier. In contrast, when the point that you realise that there is no way you can hear, then you play everything you have, so you don't care anymore, so you get your imagination free.

STEPHEN JOHNSON: Yes. Well, maybe as another example we could have something from the late quartet that we are going to be hearing this evening, Opus 132, the trio section of the second movement, which has some magical high sounds, and again I think the contrast with what we've just heard is rather striking. This is a man who now has more or less, I think, completely lost the ability to hear and get auditory confirmation of what he has composed. This is the kind of sound he is now capable of creating.

[Performance by the Sacconi Quartet]

Lovely. Isn't that extraordinary? You feel like clapping Beethoven as well. I think I do after that. One has to remind oneself that the man who created those sounds, unprecedented in string quartet writing, was completely incapable of hearing them. It is a truly phenomenal thing, but there again we have not just the violin at the top of the register but every instrument high up in its register, very much aware of that, so he is cherishing those - not just the notes themselves, but as I said the overtones, the reverberations around them, which to me does seem almost miraculous. Yes, your feeling too?

PROF AGE SMILDE: Yes, I feel it too and especially because you talk about the overtones now, so actually although the whole colour, the whole timbre, he had to imagine that, so that is amazing.

STEPHEN JOHNSON: The other day, I heard for the umpteenth time a remark about the wonderful Hammerklavier sonata of the 1810s in which it was said his imagination was simulated very much by receiving a new Broadwood piano which had a much greater range. Maybe it was but he wouldn't have been able to hear the thing as he played it. He might have had some vibrations coming back through the keys and of course the piano is his own instrument so that sense of physical identification with it is something that's crucial. I've noticed playing late Beethoven that you sometimes become acutely aware of how it feels; he will space chords on the piano in such a way that it's almost as though the physical feeling of making them is heightened by the fact he is not getting the same auditory confirmation, or great long chains of syncopated chords where you are playing against the beat, there's nothing on the beat and you as a player know where the beat is but I sometimes wonder if the audience does. It's very easy to lose that sense

sometimes, and it's a reminder of something that the philosopher Ernst Bloch said, which I think is marvellous, if you are talking about authentic performance, he said that the authentic way to play Beethoven is in your own head because that is how he would have heard it and experienced it. But this medium that we are talking about, the string quartet, Beethoven could play string instruments but it is not his instrument in the way the piano is, so there's a further degree of remove here.

DR EDOARDO SACCENTI: It is what you said, it's to remember what Verdi was doing in his late years, he was keeping Beethoven's string quartets, and reading them before going to bed, not playing, not listening, just reading them.

STEPHEN JOHNSON: I don't know, but did Verdi's own hearing begin to go in later years? I've never heard that it did.

DR EDOARDO SACCENTI: No.

STEPHEN JOHNSON: So actually his hearing was perfect but he had a similar ear. It is not as ridiculous or astonishing as it sounds. You can eventually with time train yourself up to a point to hear music off the page. It's a skill that can be learnt like many others, so it's not maybe as absolutely miraculous, but there is something about hearing those sounds just there, and thinking the man has lost a long time ago the ability to confirm that he got it right. It is truly extraordinary. At this point maybe I think it's time again to bring in you, and a lady immediately puts her hand up. Thank you very much, this is going awfully well.

FROM THE FLOOR: I was in Bonn recently and heard a story that Beethoven in his late years, when he was deaf, could be found with his teeth embedded in the wood of his piano, I think the Broadwood. And the explanation was that he was composing via feeling the vibrations, and I wanted to ask you, you know, genuinely from a position of ignorance about hearing and the hearing apparatus, when we are talking about the inner ear, which seems in what you've been saying to be very much what you are talking about is imagination and presumably memory too of sound, are we also talking about the inner ear of the hearing apparatus and the vibration and presumably conduction of sound through those processes?

STEPHEN JOHNSON: That's interesting. I've heard that story too about Beethoven. In talking to the percussionist Evelyn Glennie who is deaf herself, she said that certainly would make sense to her, a great deal of her experience of music is conducted in a similar way. What would you say about this?

PROF AGE SMILDE: I would like to be a little bit strict over here. I think what you are mentioning, I would still pose that under the umbrella of physical feedback. So the inner ear we are talking about is pure - a conceptual thing. Pure imagination. Completely let's say cut off

from any physical realisation. At least that's my opinion.

PROF EDOARDO SACCENTI: I found an account in a book where somebody asked Beethoven how he was composing and he tried to explain in terms of geometry, not in terms of sound.

STEPHEN JOHNSON: Interesting point. Yes, a lady put her hand up here.

FROM THE FLOOR: Thank you. Janine Roebuck, I'm a severely deaf professional opera singer. I think from what I've heard today that I probably have exactly the same sort of progressive hearing loss that Beethoven himself had. It's the same period of onset. Mine is hereditary, goes back many generations in the family so perhaps a difference there. I could still continue to function because I have superb digital hearing aids, so when we were just hearing those rather wonderful examples, I removed my hearing aids completely, just to remind myself what it might have been like for him. I'm of an age - I'm a little older than he was when he died, so I think, you know, it's pretty appropriate - and I've got high frequency loss as well. I could scarcely hear anything at all, so I think the notion of him hearing his music at all - he could hear vague sounds, but you wouldn't take any pleasure in hearing them and you wouldn't make any sense of them so I feel really quite strongly that he would have relied on his musicality, his memory of what music sounded when he had perfect hearing loss to recreate and to compose. I hope that's helpful.

STEPHEN JOHNSON: Thank you for that authentication, very personal authentication, exactly the kind of thing we want today. That would appear to confirm what both of you were saying?

PROF AGE SMILDE: Yes, I am very happy with this comment, yes.

STEPHEN JOHNSON: [Laughing]. Somebody else, over there

FROM THE FLOOR: Hello I had a terrible double ear infection about 20 years ago and inner ear and middle ear infections simultaneously of different kinds. I would go through periods during this when I become quite deaf to outer sounds in that ear, but what turned on was a very high music. I talked with the doctor about this and I said did he know of other examples of this. He said he'd heard of people hearing sounds because of this effect. But when the high music was played by the quartet, it actually reminded me very much of the sounds that would come on when I went deaf in that ear, which I found very interesting.

STEPHEN JOHNSON: So you had some sort of auditory phenomenon inside your head, like tinnitus?

NEW SPEAKER: No it was the sound of stringed instruments.

STEPHEN JOHNSON: You heard this, as you lost your hearing you were almost hallucinating these sounds?

NEW SPEAKER: It was a combination of stringed instruments mostly quite high.

STEPHEN JOHNSON: And it was like that passage of Opus 132? How interesting.

NEW SPEAKER: Yes, I've talked to several doctors about it, but they'd not heard of that particular thing before. I actually, even though I was in considerable pain I actually looked forward to these times because it was as if I was creating this music in my head.

STEPHEN JOHNSON: Well you were. Yes.

NEW SPEAKER: I was somehow but it makes me think there might be more explanation for this.

STEPHEN JOHNSON: I think it is really fascinating. A lady put her hand up over here?

NEW SPEAKER: Hello, I am very interested listening to the people who have experienced some degree of hearing loss. Are there any examples with Beethoven where he may have used – the incident with the teeth - if you lose one sense, specifically hearing, then I have been told that other senses kick in. Could it be that he was developing a style of composing using touch and feel and touching the piano, maybe resting his face against the piano to feel the vibration? Is there any kind of evidence of that or is it just that people feel it was his memory of sound or hearing the sounds in his head rather than hearing them himself?

STEPHEN JOHNSON: As I tried to say earlier, I felt with that with the piano music myself, the sonata, Opus 101 in A major, the first movement this [sings] figure, and there are these syncopated chords ahead of the beat, dum dum dum dum. If you are listening in the audience, you feel that the dum is the beat, when you come out of that, it is a bit of a jolt. But if you are playing it, I've found you are almost leaning in at the point where the beat happened, and at that moment I felt like I was sharing something of the experience that Beethoven himself might have been having. I can see a big smile here, but do you find yourselves, members of the quartet, that there are moments when you feel that Beethoven's deafness or hearing impairment has sort of physical consequences for the way you play it or mental consequences for the way you play his music? Anybody care to say something here?

BEN HANCOX: Yes, it is quite hard to say really. I think you are always aware when you are playing Beethoven's music that it is unlike playing any other composer, but I think we are always sort of focussing on, I don't know, I am a bit stumped actually!

STEPHEN JOHNSON: What do you feel you are focussing on? It is important, this man must have had phenomenal - we have hit a problem with the term inner ear, seems to mean something different to medical practitioners and people like me. Maybe I shouldn't try to use it. There is a phenomenal sense in Beethoven's music of some inner strength isn't there, maybe what he called God? I don't know - do you feel you are sort of digging deep into the psyche in this music or is it just a question of musical problems?

BEN HANCOX: No, it's not just a question of musical problems, our first job is to try and untangle those. Personally for me, Opus 132 is one of my favourite pieces of music and having looked at it again and worked at it to play this weekend. I think what you're really focussing on the contrast that he begins to achieve later in his quartets and maybe, as you were talking about this morning, the fact that he was by then completely deaf allowed him to make the most shocking contrasts that I think even composers to this day would not dare to do. I think those give us very profound emotional feelings, whether they correlate with what he was wanting to achieve, I don't know.

STEPHEN JOHNSON: Certainly Opus 132 is full of the most extraordinary changes of direction and emotional extremes. Yes, you are all nodding here, but is there something you would like to say at this point.

NEW SPEAKER: I was just going to say, this music is kind of, I always feel that there is an immense struggle for everything somehow like Ben said for us to understand what is going on. I don't think we will ever completely understand what is going on but there is just, it is always like you say, it has got this immense strength but it is always changing and you kind of feel you have got one bit and you're on this journey, then it completely changes and you have no idea what is going on. It is like that all the time.

STEPHEN JOHNSON: I know exactly what you mean. Nigel Osborne, is there something you would like to say?

NIGEL OSBORNE: Just a very quick point on the lady who was hearing the strings. Oliver Sacks notes this in *Musicophilia*, there are several examples, and the explanation that he offers is that we are used to the idea of sensory information coming to our ears and our senses and then

travelling to centres in the brain, but there is a reverse process, the brain can send it out to your senses sometimes as well. So it is quite well documented, hearing music in that way.

The other thing about Beethoven biting the piano, there are two things that could have been happening there. We all hear by bone conduction. Our idea of what our voice sounds like comes from the vibrations of the bones in our head, and is not so much influenced by the air. We all have that. And it depends really on what was damaged in Beethoven's hearing apparatus, as to whether bone conduction might have been of use to him, even if the cochlear was not damaged, for example, the vibration of liquid in the cochlear could send the basilar membrane going and give pretty good pitch information.

And something more: the cutaneous senses when we touch, is also connected to listening. I don't know if neurophysiologists can correct me here - I know that our nearest human relatives, the macaques, for example, their ability to touch joins up to their auditory cortex quite low down, so the brain is sharing information about vibrating surfaces together with what the ear is saying as well. So this would explain there would be sense in Beethoven biting his Broadwood. It would suggest, probably because the teeth are connected to the jaw and the temple bone, he was hearing some bone conductors which means his cochlear was probably working.

STEPHEN JOHNSON: Thank you very much indeed for that Nigel. Extremely useful advice. Yes somebody over here would like to say something.

NEW SPEAKER: From the first lecture, I got the impression that he wanted to create and he was a very dominant person who knew he was clever and he could create. Surely that was the most dominant feature, whether he could hear or not, with memory and all that he has learned and his own ability to believe in himself he would create his beautiful music and the hearing was almost secondary? And the neuroscience, I am a neuroscientist, he has got a set of ideas, a set of numbers and results and he knows how to create a new paper if you like, from my point of view.

STEPHEN JOHNSON: That is an interesting point, has anybody any comments on that, gentleman at the back over there?

NEW SPEAKER: Not a comment on that actually. I was just interested that you talked about cause and effect on your study. I just wondered if you had applied that analysis to any other composers and whether actually this change in the use of high frequency notes was a feature of composers maturing or whether high notes just went out of fashion and came back again later on in life?

PROF. AGE SMILDE: That is a very good point. Let's say, to confirm all the results we should look also at composers without deafness and how the progress is there. And also another composer like Smetana, who also went deaf, to see if he had a similar kind of experience. So there is a lot of work to do indeed.

STEPHEN JOHNSON: Another name that would be worth mentioning here would be Fauré who, toward the end of his life, had a horrible form of hearing impairment, where notes as they got higher got flatter and as they got lower, got sharper. I can hear the groans of pains from the viola here on the right, it is a horrendous idea, and yet somehow or other he managed to navigate his way through that and create music of extraordinary harmonic adventurousness. There is such a rich field for exploration here and I hope we return to these themes later in the conference.

Ladies and gentlemen, will you join me in thanking these two wonderful people and these people here.

And thank you too for the quality of the comments that you are making, this is exactly what we hoped would happen. Really very moving and illuminating comments thank you very much indeed.