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Human Instruments—(Maybe Not So) Radical Inclusion
Human Instruments – Inclusion (peut-être pas si) radicale

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See table of contents

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Article abstract

Human Instruments has its roots in experimental music and interaction. The company creates beautifully made, professional, accessible music technologies to level the playing field of music performance for disabled musicians. This article focuses on the need for growth and change in this field, as well as the history, present and future of the organisation.

Human Instruments—(Maybe Not So) Radical Inclusion

Vahakn Gehlhaar-Matossian and Zoe Cormier

Footsteps in the concert hall

Jaehyun Kang shifts in his seat, flattens a crease in his shirt, and gets comfortable—he'll be here for some time. His ears prick and he turns his head slightly to hear soft, familiar footsteps approaching. The hall is thickly quiet with the gentle sound of a hundred people whispering and settling in. A delicate wave of vibration sweeps over Jaehyun's left wrist, and then his right. He moves his fingertips from his trumpet keys to adjust one of the bracelets, moving it a little higher and little snugger. That's better.

The footsteps belong to the conductor, Sol Chin. Ready and poised, she lifts her baton and another wave of vibration flows over all the blind musicians on stage. As she strikes her baton downward, the musicians feel a punchier buzz through their skin, and in perfectly-timed synchrony, all launch into the first movement of Stravinsky's *The Soldier's Tale*.

This unique and powerful event—which took place in Seoul, Korea, on November 21st 2021—was a classical orchestral performance featuring two visually impaired musicians playing alongside five sighted players, one hearing impaired dancer alongside two non-impaired dancers, all taking expressive cues from a single conductor wielding the Haptic Baton System, also known as 'Buzz Beat' in Asia. But how has this happened? How did we get here? At every level, visually impaired musicians face huge barriers when attempting to play in traditional orchestras. If they are allowed in, the ways for them to receive musical guidance from a conductor can be incredibly limited. "I have to listen for a single 'sniff' inhalation from the conductor to mark the beat before the music starts" says trumpeter Kang. Often, this barely perceptible sound is inaudible once the hall is full of bodies: with the

audience seated, shuffling and breathing, the acoustics of the room have changed completely. And once the music is underway, Kang must listen hyper-carefully and intuit tempo and expression changes as best he can. An assistant may be asked to sit beside him to tap out the trickier timing cues on his arm or leg—a cumbersome and undesired musical chaperone.

Visually impaired pianist Yeji Kim explains that every time she plays a new piece, she has to learn the music completely by heart. Blind players cannot sight-read the score as sighted musicians can. "A pianist cannot touch a braille score and play at the same time," she explains. And during rehearsals, the conductor may make such demands as, "Ok everyone, going from bar 68…" Sighted players can simply turn the page and find the bar to locate their cue. A blind player has to know all the composition's parts intimately. Not only the melodies, but in what bar they reside. (To put this into perspective—Beethoven's Fifth contains over 900 bars with over 20 musical parts). Hearing impaired dancers face similar barriers when responding to music during performances. They must rely on counting beats and visual cues—or alternatively, they can lead the musicians.

A magic baton

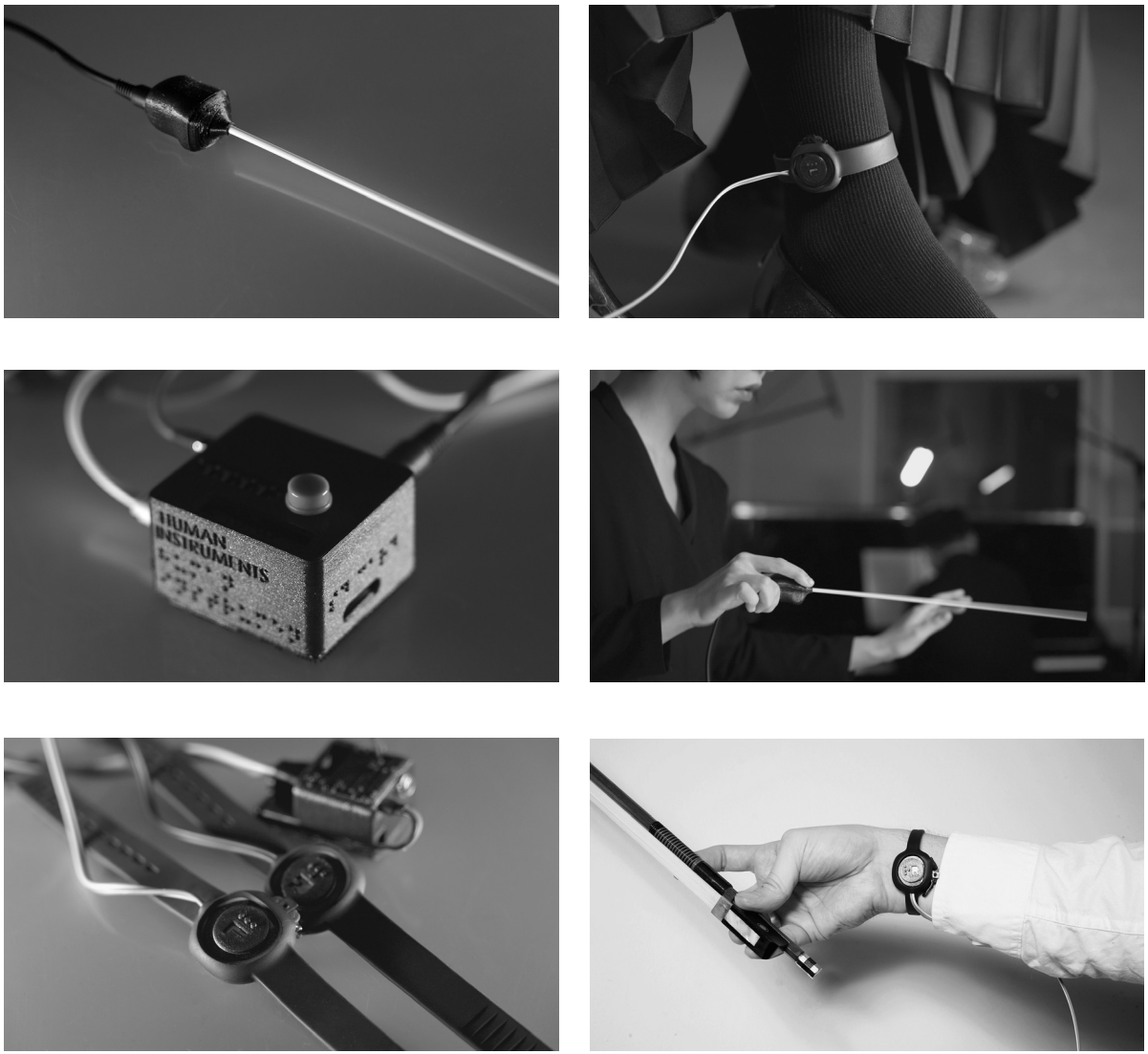
The Haptic Baton (Figure 1) made by Human Instruments[1] "is a total game changer," says Music Tech Fest founder and Member of President von Der Leyen's High Level Round Table for the New European Bauhaus, Michela Magas. The lightweight baton, which contains motion sensors and meticulously written software, tracks the movements of the conductor's hand and transmits it to elegant bands worn by the musicians and by the conductor themselves. Players wearing the bands on their wrists, ankles—or anywhere they choose—can feel precisely what the conductor is doing in real time. The vibrations are like waves. Some are *legato*, soft and flowing, while others are *staccato*, punchy and tight. They are felt on both sides of the body, sweeping left to right in sympathy with the conductor's hand. This is 'high-definition stereo vibro-haptics.'

Every move the conductor makes is felt by the musicians, initially on the surface, at skin level, but the more the players wear the Haptic Bands, the deeper the feeling is perceived in the limbs and body. Players can also adjust the intensity of their Haptic Bands. "I decreased the power throughout the day as I became more sensitive to it… it's weird, it feels good!" says Paraorchestra Pianist Kevin Satizabal.

The Haptic Baton has now been used in six different performances by the British Paraorchestra and the Army of Generals and Dominant Agency

1. See www.humaninstruments.co.uk (accessed September 1st, 2022). Human Instruments works internationally but is based in London, UK.

FIGURE 1 The Haptic Baton/Buzz Beat System by Human Instruments. Photo: Jongwon Choi and Polly Rothwell.



ensembles in a variety of formations. Since the first concert test in Bristol in 2018, concerts have occurred yearly in Seoul, including covid-sensitive non-contact concerts which were live streamed, as well as split screen studio recordings.[2]

The power of the technology's potential was demonstrated at a performance of *The Soldier's Tale* by Igor Stravinsky in Seoul in 2021. It was yet another world's first, in which conductor Sol Chin and visually impaired and sighted musicians were joined by hearing impaired and hearing dancers. International dance star Ara Gho and two others all wore the Haptic Bands and received music timing cues from Chin wielding the Haptic Baton. This performance has defined a new reality for hearing impaired dancers to take the stage with real-time cues alongside visually impaired musicians, from a single conductor.

SOUND=SPACE: dancing in music and non-verbal children

The Haptic Baton is an invention created for disabled musicians by Human Instruments, a company co-founded by me, Vahakn Gehlhaar-Matossian, and my father, the late Rolf Gehlhaar (1943-2019).

After finishing his degree in science and philosophy at Yale in 1961, Rolf Gehlhaar began studying music composition at Berkeley, University of California. Karlheinz Stockhausen, who was a visiting professor, invited Gehlhaar to return to Germany with him as his personal assistant and took him to the electro-acoustic music hub of Cologne. Gehlhaar performed in the Stockhausen Ensemble, directing works and administrating at the Osaka World Fair, and then shifted to the field of interactive and experimental music installation in 1972. Over his career he created 60 orchestral and electro-acoustic works while researching and experimenting with computer-aided composition and the use of digital technology in music.

In 1985 Gehlhaar created SOUND=SPACE[3], a pioneering and technically innovative interactive environment where people create music by moving or dancing (Figure 2). An array of gently clicking sensors pick up their motions and convert them into an array of tones, notes and noises. It was installed at the Centre Pompidou in Paris as part of the show *Les Immatériaux* in 1985.[4]

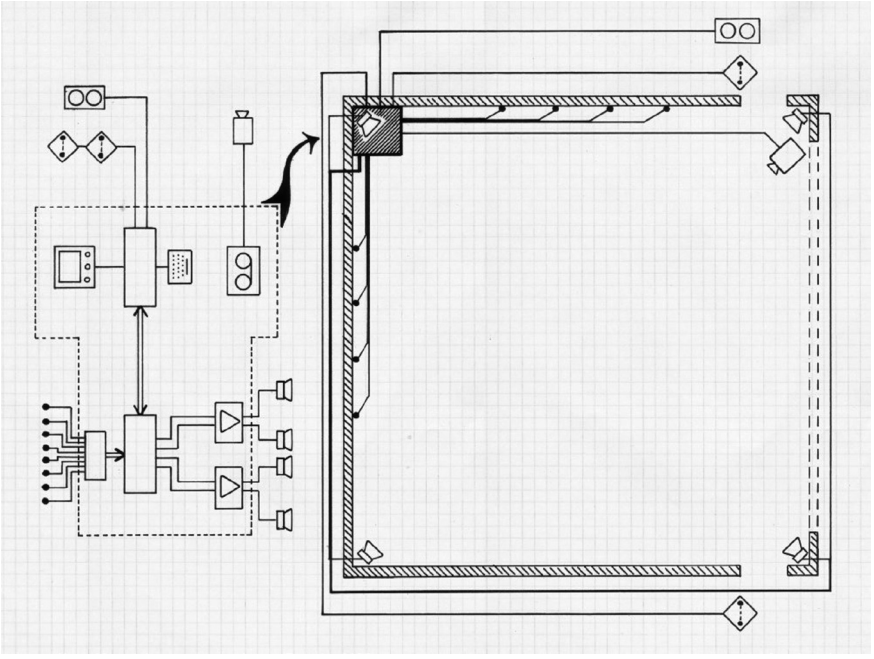
It functions through an ultrasonic echo-location system, similar to the ones used by dolphins and bats, that continuously surveys its surroundings. It can measure the positions of up to 20 people at a time. The system's measurements are used to synthesize and play musical "topologies" throughout the space over eight or more speakers. **SOUND=SPACE** doesn't simply fire notes from an imaginary keyboard, it launches complex algorithms of generative

2. Performance list:
   1. St George's Studio, Bristol 2018, Beethoven's 5th Symphony, Movements II & III, Sanggeun Choi's *Arirang Fantasy*, performed by the British Paraorchestra and the Army of Generals and Dominant Agency ensemble.
   2. Habit School, Seoul 2019, Bach's Concerto for Two Violins performed by Seoul Philharmonic.
   3. Heart Orchestra Studio, Seoul 2020, split screen studio recording Sanggeun Choi's *Arirang Fantasy* performed by Dominant Agency Players, recorded by Jaeyoung Lim, www.youtube.com/watch?v=BFV3Q3OVetk&t=636s (accessed September 1st, 2022).
   4. S-Plex Hall, Seoul 2021, Non-contact performance recording Sanggeun Choi's *Arirang Fantasy* performed by Dominant Agency Players, www.youtube.com/watch?v=sQ95uIWz2d8 (accessed September 1st, 2022).
   5. Seongsu Art Hall, Seoul 2022, Stravisky's *Soldier's Tale* performed by Dominant Agency Ensemble.
   6. Jangcheon Hall, Seoul 2022, Mozart's *Magic Flute* overture and Symphony No. 40 performed by Dominant Agency and Hearts of vision players.

3. Further reading can be done on SOUND=SPACE at www.gehlhaar.org/music/soundspace and essays found at https://www.gehlhaar.org/publication (accessed September 1st, 2022).

4. See www.centrepompidou.fr/fr/programme/agenda/evenement/cRyd8q (accessed September 1st, 2022).

FIGURE 2 SOUND=SPACE installation and diagram.



melodies based on the movements it detects. If participants run and spin the music becomes energetic and radical; if they walk slowly or lie down, the notes become calm in energy and in timbre.

Initially SOUND=SPACE was conceived of as a way for professional dancers to "dance to the music they are creating,"[5] but Gehlhaar discovered a new use for the technology in 1986 in Lisbon, when disabled school children were invited to explore the installation. "It was a music festival, so people who were attending would come down… I was a little bit disappointed at how blasé they were," Gehlhaar recalled to the BBC World Service radio in 2019.[6]

> This was something that was completely new, nobody had ever done it before, it was precise, you could play it, you could find a sound, choose it and play it… My wife Nouritza had found out that the Gulbenkian in Lisbon supports schools for disabled children, and so I asked the director of the festival to bring some kids down to see it… they went nuts. It still touches me when I remember it. They loved it. They would throw themselves out of their wheelchairs, throw their crutches in the air, crawl around on the floor—they just loved it. And it changed my life, because I realized I had made something that they needed.[7]

In 1998 specially dedicated workshops with SOUND=SPACE were held for autistic children at the University of New England in New South Wales, Australia. The children who took part not only enjoyed it, they also displayed new behaviors, new social interactions, and new curiosities, noted by their mothers or carers who had experience in the music therapy fields:

> After initial reluctance to participate, my son, who is normally quite aloof from other children, tried to initiate contact with an unknown peer, stating he wanted to be friends. He was able to use the child's name without having been told it, i.e. picking it up from incidental conversation. He also actively sought out his sister to play, using full sentences. He also was able to respond to a request to dance like a butterfly and horse. His communication continued for some hours after, to be greater in quantity and clarity. In all, a remarkable experience. […] To have access to such an avenue is wonderful. The experience was enriching. It confirmed much of the research I had done into music therapy. Best of all, it helped to open another window of opportunity for my son to experience the world.[8]

As the young son of the inventor, I was present at most of these workshops. I helped by running cables, unfolding tripod stands and guarding equipment. Gehlhaar's and my own experiences with "motion in space" to create music was formative and meaningful, inspiring in us both a desire to break open the possibilities of music making for people who truly wish to make it but are excluded by design.

5. Gehlhaar, 1998.

6. Listen Zoe Cormier's podcast "The Haptic Baton," In the Studio, 2019, www.bbc.co.uk/programmes/w3csww8h (accessed September 1st, 2022).

7. *Ibid*.

8. Gehlhaar, 1998.

HeadSpace: Clarence and the machine

Gehlhaar continued to push his work with music technology in new directions, which led him to create new musical devices for musicians who had been "designed out of the system."

In 2000 he created HeadSpace, a musical instrument for ex-trumpeter Clarence Adoo, who was paralysed from the neck down in a car accident in 1998, rendered quadriplegic. John Kenny[9]—a trombonist and musical archaeologist—approached Gelhaar about creating a new instrument for somebody who desperately needed one—something that did not yet exist. After his accident Adoo was unable to play the trumpet—or any instrument. In 2016, he told *The Guardian*, "I would rather play music than walk again."[10]

Gehlhaar devised a solution: an interface on a computer screen which Adoo could control by moving his head and blowing into a tube. It was a computer-aided instrument that used his head position for the mouse position, and his breath pressure for the click function.

The HeadSpace software is two musical instruments in one. The sounds of traditional instruments—from the viola to the piano—are available, stretched across a virtual keyboard. The software allows players to create timbrally unique sounds, loops and sonic textures which can be chosen and triggered with volume control. It is not a traditional instrument, but an instrument controller with an extensive, user-expandable palette. Adoo has performed in the HeadSpace Ensemble with trombonist and carnyx player John Kenny, trumpeter Tjorborn Hultmark and sound projectionist Chris Wheeler many times since 2001, and since 2012 in the British Paraorchestra. He said, "This is the first time I feel like a musician, not a disabled musician."[11]

Later, I created two new instruments for Clarence: the Doosafon and the Hi Note, both in collaboration with co-developer Pere Callopa (see paragraph "Recipes for Devices").

VIAGEM: Instruments for everyone

In 2009 Gehlhaar was commissioned to compose a performance event. This music, dance and multimedia project, named "VIAGEM," was to be performed entirely by people with a vast array of physical and mental conditions in the Sala Suggia in Portugal at the Casa da Musica, Porto, produced by Artshare. "The purpose of this 2-year project—'Instruments for Everyone'—was the development of tools that facilitate the musical expression of a well-defined group of physically and mentally challenged people."[12]

The obstacles of the project were great: the different kinds ability and limitation among the performers was extremely varied. It was logistically

9. John Kenny on the creation story behind HeadSpace: www.gehlhaar.org/life#h.3tvxphdlfxa8 (accessed September 1st, 2022).

10. Cormier, 2016.

11. Bannan, 2020, p. 18.

12. Gehlhaar, Rodrigues, Girão and Penha, 2014, pp. 167-196.

impossible to organise very many full rehearsals in the months before the show—only a handful were possible. The ten groups involved were geographically remote. The players did not all have the ability to follow the same conductor and score. And to make things even more complicated, the players were not able to play traditional instruments.

How could they meet this challenge? Gehlhaar wrote in 2014:

> In contrast to the 'normal' workshop situations where concentration and stamina had been an issue, in full rehearsals the players reacted to the intensive nature of the experience with uncharacteristic and increasing fortitude. Plausibly, for many, the looming performance in this significant venue was the influence.[13]

13. Gehlhaar and Matossian, 2014, p. 3.

> Upon the basis of interviews [with participants], the authors designed and built five prototype instruments… they were manufactured and handed over… at a day-long workshop to which other music educators and teachers for the disabled were invited to participate.[14]

14. Gehlhaar, 1998.

Gehlhaar and his co-creator Luis Miguel Girao were only one pair of inventors to design and build new instruments for the show. "We created egg box style puzzles which housed colourful electronic eggs that needed to be arranged in particular orders to release melodies. We chose eggs because it was Easter and this thematic link would give the particular players the motivation needed to engage and focus"[15] says Girao. Gehlhaar also designed and built electrified robotic versions of his two meter long "SuperString" instrument. Players with impairment in their limbs were taught to control fretting and plucking motors which shortened and struck the strings. Another team made electronic black rubbery tubes named T-sticks,[16] that triggered sounds like surreal wooden gongs or bells when hit or shook. Other devices used no-touch proximity sensors to play large sets of robot-hammered gamelans.[17]

15. Correspondence with Girao about VIAGEM 2022.

16. T-sticks further reading: https://josephmalloch.wordpress.com/category/dmi/t-stick/ https://www.nime.org/proceedings/2018/nime2018_paper0042.pdf (accessed September 1st, 2022).

17. VIAGEM further images and information: https://web.archive.org/web/20190401094240/http://vahakn.co.uk/illustrate/viagem-do-elefante (accessed September 1st, 2022).

Gehlhaar was tasked with the overall architecture of the show. Research with teachers, carers and directors led to a chain of command for the learning and execution of the show. Each school unit represented a different section of the orchestra and was assigned musical devices that suited their players' expertise. They were given segments of the score to rehearse with their own sub-conductors. In final rehearsals, Gehlhaar directed the sub-conductors, who in turn conducted their separate sections with their own agreed-upon cues. Eighty-five disabled performers took part in the performance, with an additional sixty-strong choir and dance troupe.

My role was to create a one-hour visual animation that was projected as a backdrop on the stage. When the performance was over, the audience of over a thousand people responded with a prolonged standing ovation.

Recipes for devices

SOUND=SPACE, HeadSpace and VIAGEM were exciting, new territory for Gehlhaar and his co-developers. Building from our experiences with them, we began to have more structured energised discussions about accessible music technologies (AMT). We officially formed our company, "Human Instruments." Our objective is to create professional-grade accessible music technologies and instruments with disabled people—not only keeping them in mind, but with their active participation on the design team.

New developments in sensors, and the miniaturisation of computers, enabled us to think and build beyond large complicated equipment or cumbersome touchscreens. We sought to create intuitive interfaces that could read delicate movements, to allow for precise playing. Since we are musicians ourselves, we know that it's not only the notes you want to control, but sometimes more importantly the tones, timing, timbre, sound quality and silence—all while in communication with other players. We wanted to create a new generation of musical instruments that have multi-sensory feedback.

To do this, we have to go through a process of asking questions: what kind of music does the player want to make? What body movement is at their disposal and how would they like to use it? Do they have arm strength, finger stroking, lip squeezing, breath pressure, eye gaze, head-movement, torso twisting? How can their movement be harnessed? With switches or sensors or cameras? How will the player *feel* on stage with a device that can capture this movement? And how can we link this all together to create sound or notes? What is the feedback? How will the player know or feel what they are playing?

Feedback gives back

Traditional musical instruments give a plethora of feedback during their sounding. The clarinet may send resonance into the jawbone or chest. The stickiness or slippery-ness of the violin bow hairs give the player an understanding of the tone of the vibrating string. The frets of a guitar are bumps that the player pushes against to obtain a clean or buzzy sound. All of this feedback is key for deliberate and precise control of notes. This is the essence of an instrument. How can we create a digital 'controller' that feels and plays more like an instrument? What feedback can be offered to the player to give them a truly immersive and finely-controlled experience?

With many new options to choose from, Human Instruments chose to focus on three devices that can be used by as many different kinds of disabled people as possible:

1) Typhoon: a hands-free 'universal' controller that can be held in a player's mouth and controlled with head movements and breath pressure. It can control standard synthesizer keyboards, hardware or software, as well as robotically-enabled mechanical instruments such as a MIDI player piano. Gehlhaar and I envisaged a mouthpiece that anyone who lacked the use of their upper limbs but had some degree of control over the movement of their head could play.
2) Doosafon (Figure 3): A 3D-printed electronic cross between a xylophone, a harmonica, and a wind instrument. Using a lightweight mouthpiece, musicians can strike a bed of pads laid out in a fan shape. By blowing harder or longer, they can vary the length and volume of the note.
3) Touch Chord (Figure 3): An evolution of the Doosafon. Co-developed with John Kelly, a disabled musician with limited range of movement in his arms. A wood and electronic instrument with note pads made from conductive paint, arranged in an arc shape. The touch-sensitive layout is a mix of piano keys, guitar strings and a new type of chord key. Labeled Major, Minor, Diminished, Seventh, and Augmented, these keys behave a bit like the shift key on a computer keyboard, allowing the musician to play complex chord patterns without the need for many fingers—or a high level of music theory training.

Kelly was crucial to the development of Touch Chord, helping us understand how differently shaped instruments match different body shapes. He designed one of the key features, the arc cutout that allows Touch Chord to be as close to the body as possible.

FIGURE 3 Left: Clarence Adoo plays Doosafon with Paraorchestra in Doha, Qatar, 2014. Right: John Kelly plays Touch Chord.

Kelly plays solo Punk Rock and Blues and with his band, The Blockheads. He also sings with theatre and dance shows internationally.

The birth of the Haptic Baton—from instruments to conductors

Decades of devising musical instruments for and with disabled people led Gehlhaar to wonder: what can we do for blind musicians who already play an instrument? We had met visually impaired musicians who had been turned away from orchestras. And we'd been to Paraorchestra rehearsals, where we'd seen the conductor and leader Charles Hazlewood leave the stage when blind musicians walked on. Believing it was discriminatory if only the sighted players could follow his cues, when blind players were part of the orchestra, they all played without him. Gehlhaar thought it must be possible to create an elegant device that allowed visually impaired players to know when to play. And surely it could be done affordably, so that, not only every orchestra, but every school could have one.

In his North London study, Gehlhaar wired a movement sensor, a small smartphone vibration motor, and a mini AM radio transmitter together. Adding a few lines of code, he had a proof of principle. He brought it to my East London studio for testing. What this prototype lacked in immediacy, reliability, looks, robustness, range and usability, was made up in proving a simple, but crucial, thing. In its first field test, the visually impaired violinist Takashi Kikuchi wore the vibration motor on a wire tucked under his wristwatch. We agreed that on the fourth beat given by the baton he would commence a C minor scale. One, two, three… I never heard such a sweet C minor in my life. And when the visually impaired percussionist Kyungho Jeon took his place at the timpani, we asked him to begin a roll on the third vibration he felt. And he did. In perfect time. At that moment we knew we had proved that with a bit more work, a visually impaired player would be able to play in harmony and in time with sighted players in the same room.

The research tour

Kyungho Jeon agreed to be our main testing musician, and we began anthropological research on the movement of conductors' arms. We went to Oxford to visit the conductor Ewan Campbell, who gave us insight into the mind and movements of a conductor.

Campbell swayed his arms to a beautiful piece emanating from his speakers. "Ah yes, here we go, it comes in gently here…" He described how he might indicate *legato* in a passage in 4/4, or *pizzicato* in a passage of 2/4, while Kyungho delicately held his wrist to follow the movement, inferring

how it related to the timbre and bounce of the music during a performance. Kyungho asked "How do you beat this… how do you beat that? What does a 3/4 time signature look like? How do people know when to start… and how long then to stop? Is it always the same? What is the exact movement for the 7/8 time signature?" We filmed these complex questions and answers for our research.

The next stop on our research tour was with visually impaired flutist Liz Hargest, of the Ely Sinfonia. We were surprised to learn from her that a buzzy device on her wrist would *not* be annoying, but helped her stay locked in time. Because Kyungho is a a percussionist and a foot tapper, rhythm comes from below for him, and he preferred the vibration device to be tucked into his sock. Thus, we knew our final device would have to be adaptable to the needs of different musicians.[18]

18. And we are still finding new opinions. At time of writing the author is in Seoul testing with new conductors and new players with fascinating points of view emerging each day…

An abstract dance

With financial support from Dominant Agency and The Paraorchestra, we built the first reliable, wireless, multi-user version of the device in time for a test rehearsal and private concert with the British Paraorchestra, Dominant Agency Ensemble and Army of Generals, led by Charles Hazlewood. The studio was filled with musicians who had dedicated themselves to movements two and three of Beethoven's 5th for the occasion. All of the players were connected to the battery-powered Haptic Baton System. Their instruments were in hand and they were ready to be conducted for the first time together. BBC Ouch![19] film and the BBC World Service[20] radio teams were there to document it. Co-developer and programmer Charles Matthews and I were present with our laptops, live-monitoring the systems' inputs and outputs.

We gave a brief introduction to the technology before the orchestra made an attempt on the first bars of the 2nd movement. A catastrophic performance ensued! False starts, wrong notes, muddy syncopation, everyone out of time. Some players waited for other players to play, some started ahead, others gave up. Charles Matthews (the programmer) and I scrambled to understand if our tech was making errors. We were both hooked in, wearing the bands, and could clearly feel the steady exaggerated pulse of the conductor. We knew everyone else would be feeling it, too—unless there was some kind of wild anomalous interference at play. We scurried on all fours to check radio-packs—but everything was in order. The second attempt was worse than the first and abandoned even sooner. In the midst of confused muttering, a hand shot up from the piano. Yeji Kim asked in Korean, "Why are all the English players playing late? I can feel the beat. They are behind it!" It soon became

19. See "'Magic baton' helps blind musicians feel conductor" by Ruth Evans and Tom Mustill, 2019, www.bbc.com/news/av/stories-46994209 (accessed September 1st, 2022).

20. Listen Zoe Cormier's podcast "The Haptic Baton," In the Studio, 2019, www.bbc.co.uk/programmes/w3csww8h (accessed September 1st, 2022).

clear that most of the visually impaired players had no reference for what conductor Hazlewood was doing. They didn't really know why the conductor was there, let alone the nuances of his gestures.

"Everyone put down your instruments!" Hazlewood said. He gave a light-speed history of conducting—from the 15th century to the present day. He explained what it was like in different countries. How perception of timing differed in the East and the West. What did his wild gestures mean? Here was a human dancing in the front, beating regular time, and the players had to create an organised unity… a flowing collaboration in motion. Now, the visually impaired players understood, and they were physically hooked in via a kind of umbilical cord to the conductor's movement—they understood that he was not a metronome, but a support for the underlying excitement of music. They were still to listen and play the music as they knew it, but now with this new feeling of support and direction.

Attempt three… It was music! For the first time, six visually impaired players and six sighted players performed in synchrony with the same baton and conductor, with no other sonic or human-made cues. Four days of rehearsal later, and the test concert gave way to standing ovations, tears and fascination from the audience.

Music education and the snake eating its tail

Professional music performance and production has been almost totally reserved for the non-disabled. Disabled would-be musicians face barriers at almost every level. This begins right at the start, in school.

Visually impaired trumpeter and consultant on the Haptic Baton Jaehyun Kang was told by his teachers when he was very young that he would never make it as a musician. He became a trumpet virtuoso nevertheless, but he has still been rejected from orchestra auditions because of his impairment. Despite knowing all the parts of entire symphonies by heart—while sighted players rely on printed scores—he has faced rejection.

John Kelly speaks of disabled musicians who have achieved professional performance standards who face acute discrimination in the form of inaccessible venues. Many musicians choose to *hide* their disabilities for fear of exclusion.

> I thought being lugged up sets of stairs [in a wheelchair] to get into a gig was a mainstream way of doing things. As an individual that experiences all these things you might not see that you're discriminated against. Then I realized that actually it wasn't my body, that's the problem. It's the way society is structured, and organised.[21]

21. DesignPartners, 2021, p. 24.

The root of the problem

A lack of music education for disabled children coupled with the nonexistence of accessible instruments results in very few players receiving the opportunity to develop from amateur to professional levels. Thus, even fewer new professional versions of accessible instruments are created, and yet fewer players demand that venues be properly accessible. This lack of demand means a continued lack of innovation in the field.

Thus, few disabled musicians are seen on television and social media. (Whereas paraplegic sports have gained hugely in recent decades.) As a result, there is a near total absence of disabled music role models for disabled children. Like the age-old image of the snake eating its tail we are back where we started, with no demand for accessible instruments and a total lack of music education for disabled children. We have a society designed to limit the creative and professional choices for disabled people, with a population truly disabled *by* society. If a disabled child does not receive support in musical training it is unlikely they will ever meet the standard to become a professional musician and will never ask for an accessible instrument. How many undiscovered musicians might be out there?

Due to a lack of research and development funding in this area, many people are denied the opportunity to develop their minds and talents to their full potential. Many musicians will say that it is not really a choice to play or write music, but a matter of survival. They can't *not* do it. John Kelly says, "The greater experience of many disabled people is exclusion, discrimination and oppression, and those aren't just about technology. They're about the society we live in. And society makes value judgments about what they're prepared to spend money on."[22]

22. Design Partners, 2021, p. 10.

Music and the brain

A person's ability to follow rhythm in tapping and listening tests under brain observation has been linked to augmented language comprehension. Neuroscientist Dr Nina Krauss has noted that

> Musicians have highly consistent auditory-neural responses… It may be that musical training—with its emphasis on rhythmic skills can exercise the auditory system, leading to less neural jitter and stronger sound-to-meaning associations that are so essential to learning to read…and a crucial cue to understanding.[23]

23. Tierney and Kraus, 2013, pp. 225-231.

This begins to solidify "why music must exist in the schools at the heart of the curriculum—not as entertainment or relaxation, but as a unique way of knowing and as the foundation of feelingful intelligence,"[24] as Professor Gloria Keister says.

24. Kiester, 1987, p. 34.

If brain connections of multiple types are created and heightened through early music training, and these connections are not specific to music but directly transferable to other communication forms, thought and memory organisation, then access to music from an early age must be made available to everyone. The joy of playing music and exploring instruments is incomparable, yet some disabled people do not have the ability to operate traditional instruments. For people locked in their own bodies, such as crash survivors, music can be a freeing outlet of expression and escape, as "musical activity provides a mechanism for creating events that place the activity in a 'realm' different from the everyday."[25] Studies referenced in this article show that expressive musical output is not a luxury or a 'decoration,' but necessary for the development of self and of augmented social communication.

25. Dissanayake, 1988.

Why music? Ripples in society

While some believe that giving people equal artistic opportunity is good, a nice thing, maybe even a charitable endeavor, I and many artists, scholars and scientists argue that it is a fundamental human right. Study after study proves that music holds multiple unique keys to development, rehabilitation, education and the very fabric of social connection. Everyone deserves music and the chance to make it. If you have fingers, toes, arms, legs, muscles and health, then the world of music is yours. But "the disabled encounter many obstacles in their quest for self-expression through music. Most musical instruments are difficult to use. They are the result of hundreds of years of an evolutionary process that has favored able-bodied skilled performers […]."[26]

26. Brooks, Brahnam and Jain, 2014.

"Music is often regarded as entirely a decorative art, whereas instead it is the expression of man's deepest self."[27] Current scientific studies supporting this claim made some 60 years ago are being reinforced with ever more comprehensive studies.[28] Musical training at an early age is hugely beneficial, both in the moment, through enjoyment and development, but also later in life. It is proven that musical training of any kind before the age of seven augments connections in the Corpus Callosum, the information highway between the left and right parts of the brain, as well as the parts of the brain relating to hearing and self-awareness. It is physically thickened through musical education and performance.[29] This link marries logic, reason, emotion and imagination.

27. Cooke, 1959.

28. Cormier, 2018.

29. Steele, Bailey, Zatorre and Penhune, 2013, pp. 1282-1290.

What's in store for Human Instruments?

From 1978 to early the 2000's Human Instruments worked on interactive installations and our first experimental accessible instruments. From 2011

to 2016 there were handmade experiments, one-off devices and players performing on stage in ensembles. 2017 to 2019 saw our first printed circuit boards with multiple devices made and used internationally, and a world premiere with a small orchestra. Most recently, from 2020 to 2022, we have had five professional orchestral concerts, new collaborations with hearing impaired dancers, the filing of our first patent and our first collaboration with a commercial product design firm to create the first robust factory-manufactured system.

Human Instruments is only one of the actors in creating a level playing field for musicians globally. We are one small outfit making as big a wave as we can, growing more adventurous each year. Any designer will tell you that the hardest design problems are the juiciest to solve and create the most positively explosive outcomes. We have designs for instruments that connect together like Lego, allowing players to assemble the instrument they want to play. The strings of a guitar could connect to the mouthpiece of a harmonica, with the sound of sub-bass, all positioned in the best way for the player. We're making toys that expand to become full-fledged comprehensive playful sound engines.

Tim Palm, an award-winning musician and instrument designer, says, "In the same way people speak different languages, people speak with different instruments. And the more instruments available, the more people can participate in the conversation."[30] Without these instruments, people are silenced. They are removed from the most important and exciting parts of society, precisely where they are meant to flourish and influence culture at large.

30. DesignPartners, 2021, p. 8.

The era of exclusive design is ending. Radical inclusion is where we are headed and we will all be the better for it. Once we are there, it will be impossible to look back.

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