Rolf Gehlhaar: A Pioneer in Creative Music Technology

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Abstract. This article evaluates the contribution to contemporary music and digital sound design of the German-American composer and inventor Rolf Gehlhaar (1943–2019). It sets in context his creative output, commencing with a biographical overview of his education in the USA, early career as a member of Stockhausen's circle in Cologne, and subsequent work as a composer informed by an increasing humanitarian commitment to the development of technological resources designed to widen participation in musical creation and performance. In drawing on published resources as well as the personal memories of the author, the article develops an initial bibliographical resource intended to represent existing research in the fields to which Gehlhaar made a key contribution, and to stimulate investigation into his life, times and continuing influence. While the article sets out to record these achievements, it also seeks to capture the character and personality of the man behind them.

Keywords: electro-acoustic; computer; improvisation; interface; accessibility

1 Introduction

Gehlhaar was born in Breslau towards the end of World War Two. His father was a rocket scientist, and his mother a teacher of fine art. The family emigrated to the USA in 1953 on the recruitment of his father by the American government to work on the rocketry programme in New Mexico. Rolf studied science, philosophy and music at Yale University from 1961, and commenced graduate studies at the University of California, Berkeley, in 1965. In 1967, he was invited to participate in classes with Karlheinz Stockhausen, who was Visiting Professor at the University of California, Davis (Kramer, 1998, p. 247). Stockhausen then proposed that Gehlhaar join him in Cologne, where he worked closely with the composer over the next four years as assistant, performer and sound technician.

Gehlhaar toured and recorded extensively as a member of the Stockhausen Ensemble. He played a part in the notation and directed rehearsals of a number of Stockhausen's works in the late 1960s, including *Kontakte*, *Mikrophonie*, *Prozession*, *Kurzwellen*, *Hymnen*, *Spiral* and *Stimmung*, including taking a leading technical and administrative role in the presentation of new music at the German Pavilion of the Osaka World Fair in 1970. However, creative differences led to the break-up of the group, and Gehlhaar, together with Johannes Fritsch and David Johnson, established the Feedback Studio in Cologne as a base for technical development and publication.

During the 1970s, Gehlhaar worked increasingly in the United Kingdom, including establishing the Electronic Music Studio at Dartington College. He married the writer Nouritza Matossian in 1976 and moved to London; but he remained active in Germany through association with the Darmstadt Summer Courses for New Music, which he directed in the same year. He was a founding member of the Electro-Acoustic Music Association of Great Britain in 1979.

Work at IRCAM in 1979, with a variety of collaborators, led to the development of the *SOUND=SPACE* instrument in 1984. Arguably the most significant of his achievements in the field, *SOUND=SPACE* is one of a series of new musical instruments developed by Gehlhaar between the early 1970s and his death, these including *SuperString*, *Multiverse*, *Headspace*, *Eyesound* and the *Haptic Baton*. In 2002 he was appointed Senior Lecturer in Design and Digital Media at Coventry University; at the time of his death, he was Professor in Experimental Music at Coventry University, School of Art and Design.

2 Education, Early Career and Achievements

Music would seem to have played a significant but not definitive part in Gehlhaar's early education, which embraced wide interests in science and philosophy. He played the piano and the trombone (personal communication, 1989) and recalled enjoying the teaching of Joseph Kerman at Yale. His earliest acknowledged works are *Cello Solo* (1966), *Klavierstück 1* (1967) and *Helix* (1967), the latter for a quintet made up of soprano saxophone, trombone, bass, percussion and piano. All subsequent works are available from Feedback Studio, Cologne, and detailed descriptions are accessible on his website, https://www.gehlhaar.org/music.

The political-cultural milieu into which Gehlhaar was introduced on moving to Germany with Stockhausen is captured in the account of new music in Cologne given by Custodis (2004). Gehlhaar's contribution to Stockhausen's development and output coincided with a change of direction in his mentor's composing practice, leaving behind the meticulously derived notation of works such

as *Gruppen* and increasingly exploring the generative potential of collaboration with performer-improvisers and with the relationship they were able to present between acoustic instruments and live electronics (von Blumröder, 2018; Dunn, 1992).

Gehlhaar later wrote:

> It was a heady, doubly significant time for me: I had decided to swap a graduate degree in music for an apprenticeship with the master and I was returning to Germany, from where my family emigrated in 1952 (Gehlhaar, 1998b, p. 53).

He recalled Stockhausen sharing his plans for the work that would become *Prozession* (1967):

> ... four instruments would play a sequence of events, gradually transforming them parametrically according to a sequence of signs indicating an *increase*, a *decrease*, or *no change* in one or a combination of the parameters *duration*, *loudness*, *register*, and *number of discernible elements* within the event (Gehlhaar, 1998b, p. 54).

In addition to contributing to the notation and production of music during this period, Gehlhaar acted as an administrator and technician, and developed a significant role as a performer specialising in eliciting sounds from a large tam-tam (big enough to hide behind) through the use of a variety of materials with which to activate the instrument. In joining Stockhausen's ensemble as the newcomer, he recalled: "We were a highly varied bunch, but strongly united by our intimate knowledge and deep appreciation of Stockhausen's music" (Gehlhaar, 1998b, p. 54).

Prozession, described by Roger Smalley (1970) as "probably the most significant score of the last decade", formalised the plus/minus notation that was to feature in several works of this period and remained conceptually influential on the development of Gehlhaar's organisation of the new instruments he invented: "The score ... consists almost entirely of various combinations of +, −, and = signs, stacked in orderly rows ..." (Gehlhaar, 1998b, p. 55). Smalley (1970) illustrated the efficacy of the technique by employing it to transcribe a passage of Beethoven. Source material ("events") to which these transformative processes were to be applied were drawn by the performers from their personal selection within Stockhausen's existing output. In detailing these choices, and proceeding to paint a pen-picture of the personality and contribution of each member of the ensemble, Gehlhaar developed a form of reflective practice that was to serve him methodologically in his documentation of the therapeutic and community music-making that was to figure strongly in his later career. At the same time, his analysis of the social and creative responsibilities involved in collaboration of this kind traced the characteristics that were to undermine the sustainability

of the ensemble, and provide an insight into the interaction of human and machine that would strongly influence Gehlhaar's compositional work and instrumental inventions.

Gehlhaar wrote an account of the genesis and rehearsal of the four-hour work *Ensemble* (1967), a collaborative piece that emerged from that year's course at Darmstadt (Gehlhaar, 1968), which included Stockhausen's form plan and excerpts from the contributions of the twelve composers involved (Smalley, 1969; see also Worner, 1973, p. 114). Stockhausen was later to reveal his irritation at this account, citing it as a reason to replace Gehlhaar with the journalist Fred Ritzel as writer for the documentation of *Musik für ein Haus* the following year (Iddon, 2004, p. 106).

1968 was a busy year, set against the background of political unrest throughout Europe. *Stimmung* was premiered in December, having been written largely in the USA the previous February and March (Worner, 1973, p. 64). *Aus den Sieben Tagen* was first performed in May. *Musik für ein Haus* followed in September, arising out of that year's Darmstadt Ferienkurse. Gehlhaar played a significant part in all three projects. He claimed (personal communication, 1997) to have suggested that Stockhausen include the reference to Barbershop as one of the events in *Stimmung*.

The score of *Stimmung* is set out through the provision of material (including poems and texts) for the six performers to employ in filling out a form-scheme. Instructions, including notated elements, are clear and exacting, controlling to a large extent the shape and character of the resulting performance. By contrast, *Aus den Sieben Tagen* and *Musik für ein Haus* (Worner, 1973, p. 170) employed texts to which the performers (or, as Gehlhaar later pointed out, co-composers (Iddon, 2004)) were required to respond. New definitions of the roles and working assumptions of those involved were derived and shaped by the experience.

Aus den Sieben Tagen had its origins in a week-long fast that Stockhausen underwent in response to his wife leaving him in May: a genesis that Gehlhaar later expressed as "Karlheinz's mid-life crisis" (personal communication, 1989). Hungry and sleep-deprived, Stockhausen composed fifteen texts for realisation "without thinking". No motifs or references to existing material were to inform the interaction of the musicians: they were to engage in "intuitive music" (Iddon, 2004, p. 91). Intuitive music "get[s] away from anything that has established itself as a musical style" (Stockhausen, in Iddon, 2004, p. 92), and represents "not indeterminacy, but intuitive determinacy" (Ritzel, 1969, p. 15).

Iddon (2004) draws attention to the differences between the kinds of text piece that emerged from the New York Fluxus group of the 1960s and those involved in Stockhausen's projects of 1968. There is a comedic surreality to La Monte Young's instruction to David Tudor in *Piano Piece No. 1* (1960) that he feed his piano on a bale of hay. By contrast, Stockhausen's texts have a quasi-liturgical quality that aims to determine the state of mind of the performer.

Iddon (2004, pp. 94, 106) traces the tensions that affected Gehlhaar and composers such as Vinko Globokar and Thomas Wells in performing their creative efforts as part of a work attributed to Stockhausen. The compositional intent captured in the medium of words did not necessarily elicit the response the composer envisaged. Where in *Musik für ein Haus* the instruction demands "Play a sound with the certainty that you have an infinite amount of time and space", Gehlhaar's proposal was "Play with the certainty that you'll receive your fee in any case" (Ritzel, 1969, p. 31). A significant aspect, though, of *Musik für ein Haus* was the importance of the relationship between performative interaction and the space(s) in which the piece occurred and was heard. This was to form a decisive aspect of the design of and musical response to the West German Pavilion for the Osaka World Fair of 1970, at which the Stockhausen Ensemble were in residence (Williams, 2015). In turn, the problems encountered in these projects, and the contribution he made to overcoming them, presented fertile ground for the nature of Gehlhaar's own musical inventions once digital technology provided the means for their realisation.

Williams (2015) provides an account of the difficulties involved at Osaka in realising the ideal of presenting music through three-dimensional dissemination in Bornemann's spherical auditorium. Such a project had been on Stockhausen's mind since his essay "Music im Raum" (Stockhausen, 1958, pp. 152–175), traceable in turn to the collaboration of Varèse and Xenakis on the Philips Pavilion at the 1958 Brussels World Fair, which Stockhausen had attended. While the ensemble faced frustration in attaining the level of performance intended – problems included the placement of wall speakers behind fabric which attenuated high frequencies and compromised the amplification system, the failure of the rotary switch known as the *Rotationsmühle* (dubbed by Gehlhaar the "coffeemill") to work as intended, as well as problems with the Sensor-sphere control devices – the performances at the Pavilion, for more than five hours daily, were attended on 183 days by an estimated audience of over a million people (Worner, 1973, p. 256).

Gehlhaar and Johannes Fritsch left the Stockhausen ensemble after the completion of their work in Tokyo (Popean, 2015). Gehlhaar had, together with Fritsch and David Johnson, already founded the Feedback Studio, Cologne, a new-music performance centre and publishing house, in 1969. It remained his publishing outlet; and issued Barlow's *Von der Musiquantenlehre* in 2008. But Gehlhaar himself began the next phase of his career largely in new centres for electronic music away from the influence of Stockhausen in Cologne.

3 Compositional Output Post-1970

Gehlhaar's post-Stockhausen output is characterised by works involving mastery of new technologies, together with other compositions that make more conventional use of notation and acoustic resources. The sound installations *Cybernet I & II* (1971/1972) comprised interactive analogue electronic environments which Gehlhaar acknowledged as the conceptual origin for the digital interface of *SOUND=SPACE*:

> An important aspect of the installations were the acoustic feedback loops, which were constructed to 'listen' to the space and to modulate the sound and re-inject it into the space. The sounds caused by these loops would not only slowly drift, modulating themselves, but would also be affected by the mere presence of people in the space due to the fact that the acoustic characteristics of an empty room are different from those of the same room with people in it, especially people moving about. Furthermore, a set of microphone 'telescopes' were used to bring in sounds from the exterior world, usually one channel of natural-animal sounds and one channel of human-machine sounds (Gehlhaar, n.d.a).

A further electro-acoustic invention was the *SuperString,* first built in 1971, which was an amplified monochord (Leopold, 2005, pp. 173–174) that was taken up by performers in rock music (Dzyan, 1974) as well as being utilised in Gehlhaar's work.

From 1974 onward, Gehlhaar commenced research and development in the area of computer-aided composition and digital sound synthesis that was to dominate the rest of his career. In 1975 he created the four-channel electronic work *Five German Dances* in the Electronic Studio of the WDR in Cologne. In 1976, Gehlhaar's marriage to Nouritza Matossian, who wrote the first monograph on the composer Xenakis (Matossian, 1986), brought a move to London, and he was appointed founder-director of the electronic music studio at Dartington College. He also directed the composition seminar at the Darmstadt Summer Courses for New Music in 1976 and 1978; and was in 1977 composer-in-residence at the Sydney Conservatorium of Music. 1979 brought a research fellowship at IRCAM, Paris, allowing Gehlhaar to develop "an acoustic analogue to a hologram" that would become *Step by step: Music for ears in motion* (1981) (Gehlhaar, 1996; Gehlhaar, 2019b). Several works from this period feature a solo instrument and tape delay. Examples include *Solipse* (1974; Gehlhaar, n.d.c) for solo 'cello, premiered by Siegfried Palm; *Rondell* for trombone (1975; Gehlhaar, n.d.c.), first performed by Jon English (Webb, 2007); and *Polymorph* (1978; Gehlhaar, n.d.c) for the bass clarinet of Harry Spaarnay (Fox, 1982). In contrast, his work for mixed choir *Isotrope* (1977) achieves its textures through combining a range of vocal sounds and body percussion without additional acoustic or electronic resources. Potter (1978) was impressed that Gehlhaar "could express complex ideas in a very 'performable' way".

4 Gehlhaar as Collaborator: A Convergence of Ideas

I had been aware of Gehlhaar from the early 1970s, when I was given a copy of Worner's (1973) book on Stockhausen and had heard works such as *Microphonie*. I was recording folk music on a scholarship in Cyprus in 1974 just prior to the Turkish invasion, and was shown a programme for the performance there of Gehlhaar's work the previous year, proudly described by Costas Ioannides (personal communication, 1974) as the first piece of electronic music to be performed on the island. This residency was recalled by Nouritza in a lecture and article for a subsequent festival forty years later (Matossian, 2013).

I first met Gehlhaar some fifteen years later when we were both engaged to contribute to an education and community project as part of a festival in the little village of Worfield in Shropshire. My project team *Compose Yourself!* with Malcolm Singer and Graham Elliott managed a group of musicians and dancers in mounting an event in the gardens of a stately home, leading to a computer-controlled firework display. Resources included Gehlhaar with his *SOUND=SPACE* and 'cellist Hugh McDowell with his fractal music system. Choreographer Jennifer Jackson was to supervise school-age dancers, working alongside young musicians. We distributed the performances around the garden, exploiting specific sites as most appropriate to the character of what had been prepared in a variety of school music rooms and studios locally. Audiences were led in groups through the sequence by "pied pipers". *SOUND=SPACE* was set up invisibly between two tall hedges through which the audience passed, activating an ambient program Gehlhaar devised, on their way to a knot garden in which dancers and musicians interacted with the spaces between shrubs and flowers.

It was my first encounter with *SOUND=SPACE*, and one aspect of what we achieved illustrated Gehlhaar's ingenuity and preparedness to run with ideas other than his own. After a few days of intensive preparatory work, we had an afternoon off, and decided to reward the generosity of our hosts in the village by organising a treasure hunt. Most of the clues were fairly mundane, and took people to local landmarks where they had to interact with one of us in order to be supplied with the next challenge. But Gehlhaar set up *SOUND=SPACE* so that the subsequent clue was triggered only through a participant locating a square centimetre within the space, and passing though it at the right speed and in the right direction. The frenzied dancing of people who had seen it triggered by someone else, but who could not immediately replicate the location and quality of movement required do so, was a memorable highlight of the week.

The success of Worfield led to a similar invitation being issued to present the outcome of school workshops on the bank of the Thames as part of the Henley Festival. Again, *SOUND=SPACE* played a significant part, this time deployed

along some 100 metres of riverbank and digitally arranged to interact with large numbers of dancers moving into different regions at different rates and either in synchrony or independently. Gehlhaar also looked after the sound system for the project as a whole, which included amplified vocal and instrumental soloists. *SOUND=SPACE* was set up separately on the evenings of the Festival when the students were not performing, as part of a performance given by the professional dancers and musicians, who also made use of the Industrial Gamelan built by Graham Elliott.

These experiences cemented a friendship and a commitment to working together on further occasions. We became especially interested in aspects of the potential of *SOUND=SPACE* that might interact with samples of live vocalisation that I was, in the mid-1990s, researching for a project with the Reading University Children's Choir (Bannan, 1998). Our university technician, Brian Hayter, had built a flight case containing a mixer and the Lexicon JamMan sample/echo device for easy transportability to school and community workshops, and we dubbed it the "Acoustic Mirror". We travelled in Gehlhaar's classic Mercedes to present on the potential of *SOUND=SPACE* and the Acoustic Mirror at the Technical University in Magdeburg, and met regularly to research the possibility of a work in which the composition would utilise *SOUND=SPACE* to interpret the gestures of a conductor.

I commissioned Gehlhaar to compose a work for the choir I directed at the time in London, the Esterhazy Singers. We trialled both the Acoustic Mirror and *SOUND=SPACE* with the choir during the preceding season, as well as continuing our own experiments on *SOUND=SPACE* "reading" the gestures of a conductor. When the score of *Sonnet* (1996) arrived, I was in no way disappointed that Gehlhaar had placed his creative confidence in the achievement of his ideas without recourse to electronics. He selected as the text Shakespeare's Sonnet Number 80, feeling that it would:

> ... allow me to create a sound-world with a highly volatile character, frequently changing, sometimes sounding electronic, sometimes instrumental, then like a cocktail party, then like a choir, then changing again to a jazz brass and percussion ensemble, and so forth (Gehlhaar, n.d.b).

All this was achieved through conventional notation for eight-part choir with occasional solos and passages of free iteration of material. The experiments with delay and electronic sampling were present in the textures, but created through acoustic means. The experience of rehearsing and directing *Sonnet* made a critical contribution to my own search for the application of "unplugged technology" (Bannan, 2005).

I arranged a concert in 1997 with my ensemble Act of Creation at which 'cellist Paul Cox performed Gehlhaar's *Solipse* (1974) with the digital echo of

the Acoustic Mirror rather than the tape-delay for which it was originally composed. Gehlhaar was guest composer at the University of Reading Summer Schools for young composers that I directed in 1997 and 1998, and he both deployed *SOUND=SPACE* (on which my son Richard composed a piece) and led sessions at which he solicited responses to tasks that made use of the plus/minus technique that had so characterised his own early work with Stockhausen.

These close creative encounters with Gehlhaar set in motion lines of development that were to influence the work of both of us for a considerable period. His comment on the frustration we encountered in trying to achieve a breakthrough with a piece for conductor and *SOUND=SPACE* was: "this won't be possible until we can develop a way of reading gestures that can be presented on a screen" (personal communication, 1997). This solution was eventually achieved with his *Multiverse* system. Experience of Gehlhaar's topographical distribution of musical material in *SOUND=SPACE*, and especially the software which deployed chords I, IV, V and vi in quadrants that permitted harmonic fields to be accessed through movement within specific spaces, had a clear influence on the spatial design of my gestural language for collective improvisation that grew out of work with the Reading University Children's Choir and became *Harmony Signing* (Bannan, 2019, 2020). My indebtedness to Gehlhaar's collaboration is fully acknowledged; but to understand this, we need to explore the significance of *SOUND=SPACE* itself.

5 The Centre of Things: *SOUND=SPACE*

As a musical instrument that one plays without touching it, *SOUND=SPACE* followed in the footsteps of the Theremin (Montague, 1991) and shares with it the characteristic of reading movement through electronic means in order to control sounds presented through loudspeakers. In discussing the potential of instruments of this kind, I coined the term *elektrokinaesthetic* (Swingler, 2004; Bannan, n.d.). *SOUND=SPACE* does not, however, present the performer with a 1:1 relationship between human agency and the instrument's response. Rather, it presents the capacity for collaboration with the variety of composing programs provided to respond to movement that the software has been designed to interpret: it is an "interactive musical environment" (Gehlhaar, 1991, p. 59). Gehlhaar recalled the seeds of the principle in the works in which he performed with the Stockhausen Ensemble, where "improvisation took place within a prescribed framework which indicated not so much the kinds of transformation as their degree and direction" (Gehlhaar, 1991, p. 59). Gehlhaar's experiments with

David Johnson in designing the *Cybernets* (1971–1972: Gehlhaar, n.d.a) had been:

> ... only partially satisfying. On the whole, they were slow to react, their direction was fairly unpredictable and the range of variation was limited. However, one aspect was undeniably successful: the response of the visitors was enthusiastic. I had, for myself, established the importance and validity of active participation by the audience as a part of the musical experience (Gehlhaar, 1991, p. 60).

Gehlhaar became aware in 1982 of the availability of ultrasonic ranging devices made by the Polaroid Corporation for their autofocussing cameras. Again working at IRCAM from 1984 with the computer programmer Philippe Prevot, he developed a prototype for temporary exhibition at the Centre Pompidou in 1985. It was permanently installed at the Museum of Science and Industry, La Villette, in 1986.

SOUND=SPACE has parallels with the echolocation through which bats and dolphins navigate their environment – a property that was especially evident in an early outing for the potential of *SOUND=SPACE* in music therapy, working with blind students in Edinburgh in the later 1980s. Gehlhaar also discovered that *SOUND=SPACE* was effective as a means of providing stimulation to children with autism (personal communication, 1989). At his wife Nouritza's suggestion (Gehlhaar, 1991, p. 62), the organisers of an installation of *SOUND=SPACE* at the Gulbenkian Foundation in Lisbon were asked to invite groups from several institutes for the handicapped which the Foundation supported:

> This was a great success, as the *SOUND=SPACE* offered many of them the first opportunity to make music freed from the awareness of their physical limitations. This installation also indicated to me that it would be possible and interesting to design control programs specifically for the handicapped, either for group or single use (Gehlhaar, 1991, p. 62).

Thus commenced a significant new departure that was to shape Gehlhaar's activities as musician, teacher and inventor for the remainder of his life.

Gehlhaar published two detailed accounts of the genesis and technical operation of *SOUND=SPACE*: an initial description (Gehlhaar, 1991, pp. 63–70); and a further reflection on the system's design and specifications that informs a report on its installation at the University of New England, Australia (Gehlhaar, 1998a). The more portable version required separation from the specialised hardware provided by Prevot. Gehlhaar decided

> ... to remake the whole system so that practically any microcomputer of sufficient capacity could be used to operate and monitor the control unit of the ranging system and, at the same time, control any commercially available synthesiser (Gehlhaar, 1991, p. 62).

Manning (1993) reviewed the contribution of Gehlhaar (1991) to understanding of this new phenomenon:

> Gehlhaar's ability to express potentially very complex mathematical and acoustical issues in a way that can be readily understood by the general reader usefully highlights the musical significance of his approach to the spatial movement of sounds in performance, a characteristic of the electronic medium all too often ignored or misunderstood by composers and practitioners alike (Manning, 1993, p. 316).

When I first worked with Gehlhaar in 1988, the computer at the heart of *SOUND=SPACE* was the model of Atari that I was familiar with as the platform for children's games – but it had the merit of providing the processing speed on which the system would depend for its capacity to provide real-time, dependable interactivity. It was always accompanied by a large plastic filing-box full of carefully labelled floppy discs. When Gehlhaar brought *SOUND=SPACE* into a new environment, or worked with new clients, he was able to customise the system's capacities to meet optimally the needs of the occasion, taking into account available space and acoustic; the number, capacity and musical experience of participants; preferences related to combination with other sounds; and aesthetic factors (tempi, levels of consonance or dissonance, specific cultural associations such as piano sounds, gamelan textures, and so on). In many ways, *SOUND=SPACE* was more a collaborative composing tool than an instrument, and it required a composer to operate it.

This is the principal factor that accounts for the failure of *SOUND=SPACE* to be developed commercially, despite plans for its mass production. Gehlhaar had set up SOUND=SPACE Ltd in 1987 (Gehlhaar, 1991, p. 62), and was close at one stage to signing a contract on a domestic version of *SOUND=SPACE* that could become widely available, perhaps even sold through toy shops (personal communication, 1996). But he felt forced to withdraw from this plan because the version of the system that could be marketed would inevitably limit its flexibility and effectiveness (personal communication, 1997). He did not want to repeat the experience of the La Villette installation, for which *SOUND=SPACE* had to be set permanently to just one arrangement of its extensive potential: as Gehlhaar wrote, "There is no definitive version of *SOUND=SPACE*" (1991, p. 70). Feehan understood the problem Gehlhaar had set himself: "Gehlhaar's work begets work: rather than presenting the participant with one experience, the piece is a framework for such experiences" (2010, p. 15). Gehlhaar himself was all too aware of the challenges involved in utilising his invention:

> I must hasten to add here that even to a person with no mental disabilities whatsoever, stepping into the space for the first time, it is not at all obvious how it works, what the organisation of the keyboards and their sounds is, nor the precise relationship of what goes on acoustically in the space to the little Ranging Units attached to the wall. Neither is this the point of *SOUND=SPACE*. If it were obvious, then within a short time it could become quite boring. *SOUND=SPACE* is not an instrument that is meant to be manipulated or mastered; it is an interactive environment that is meant to be experienced, and, if time and skills permit, to be explored and controlled (Gehlhaar, 1998a).

Meanwhile, replicating the entire hand-built system was expensive. Campbell (2003b) had been keen to procure it for use in Australia, but "at a cost of *c.* $35,000, the purchase of the Gehlhaar system was prohibitive". Surveying the production of electro-acoustic resources for new music during this period, Dalgleish concluded:

> ... while some alternative interfaces did appear, from relatively mundane wind controllers to more radical interfaces such as ... *SOUND=SPACE* by Rolf Gehlhaar, they did not achieve commercial success (Dalgleish, 2016b).

Nevertheless, what *SOUND=SPACE* did afford Gehlhaar was a unique resource for his own work as a composer. He first collaborated with dancers in 1986–1987 in France, resulting in the work *COPERNIC OPERA F6* choreographed by Kilina Cremona (Montpellier Danse, 1986; Didona, n.d.). *Diagonal flying*, realised in Australia, represented a new challenge: to scale *SOUND=SPACE* in order to achieve live interaction with the solo piano of Roger Woodward so that Woodward's hands as he played controlled two ranging devices located at each end of the piano keyboard (Gehlhaar & Woodward, 1989). This arrangement paralleled that which Gehlhaar was beginning to employ in his work with participants with a limited range of movement: "A personalised *SOUND=SPACE* can be set up for use at close range by a physically disabled person, not requiring any major displacement of the body at all, yet giving the same kind and amount of control over the music" (Gehlhaar, 1991, p. 70).

In *Strange Attractor* (1991), a work for the newly-released Yamaha Disklavier (a computer-controlled piano), Gehlhaar performed himself, employing a system that linked the keyboard with *SOUND=SPACE* (Lee, 2004).

6 SOUND=SPACE: Influence, Response and Critique

SOUND=SPACE continued for over two decades to provide a medium for projects in music education, therapy and performance. Evaluation by commentators in the field of new music recognised its attributes:

> The instruments of Rolf Gehlhaar ... are more personal and idiosyncratic, allowing the audience to control or directly interact with the music (Nelson, 1991).

> Max Neuhaus' LISTEN and Rolf Gehlhaar's *SOUND=SPACE* both aim to expand the participant's aural field by positing a new set of relationships between an environment and its sonic characteristics. However, neither piece provides the participant with any one clear next step or direction for future inquiry. Both are at a terminus of sorts, unavailable to a larger audience of composers and participants, each developing at the pace of a personal project rather than an aesthetic movement (Feehan, 2010, p. 12).

Imitation being the sincerest form of flattery, Gehlhaar's work also spawned alternative, perhaps cheaper, solutions by others as resources permitted:

> *Play+SPaCE* began its development in 1998 following a visit to Australia by Rolf Gehlhaar ... Gehlhaar brought with him his *SOUND=SPACE*, an ultrasonic sensing system that relayed measurements from sensors to a computer (Gehlhaar, 1991). The data was then used to control musical parameters, playing music back to people moving in front of the sensors. Numerous applications of the system were demonstrated and discussed by the composer, these including new music composition, workshops for children with disabilities (Gehlhaar, 1998a), performances in dance, and uses in gallery and museum installations. Following the Gehlhaar visit, there was considerable enthusiasm in the community, particularly the disabilities/special education community, to attain such a system (Campbell, 2003b).

SOUND=SPACE received considerable attention in Japan (Yamauchi & Iwatake, 2008) and the USA, especially at MIT (Feehan, 2010; Sparacino et al., 1999) as well as in Portugal (Almeida et al., 2009). Within a philosophical history of new sonic interfaces, Emmerson especially valued *SOUND=SPACE* as a means of empowering people with handicaps to engage creatively with music (Emmerson, 2019). But the most interesting developments to emerge from *SOUND=SPACE* were those for which Gehlhaar was himself responsible, as new technological solutions and aesthetic challenges influenced further projects.

7 Doctoral Studies, Teaching and Supervision at Coventry University

In 2001, Gehlhaar commenced associations with two institutions that shaped and supported the achievement of new projects in collaboration with a fresh generation of musicians and artists. He was appointed guest lecturer in the Department of Communication and Arts at the Universidade de Aveiro, Portugal; and visiting lecturer at the School of Art and Design, Coventry University. He received a D.Lit at Coventry in 2007, awarded for his documentation of the 1998 workshops for disabled children at the University of New England, *Sound as Object*. He was later appointed Professor in Experimental Music at Coventry.

Both there and in Portugal, he supervised the research projects of higher degree students and developed artistic collaborations that led to new performance opportunities.

Introducing in 2007 the innovative camera-based 3D environment *Multiverse*, Gehlhaar wrote:

> I performed with [*SOUND=SPACE*] for about 18 years, both in a solo and an ensemble context, continuously developing the software as newer, faster, more flexible hardware became available. This system did provide a very flexible and expressive environment but by 2005 I felt I had exhausted both its sound and gestural capabilities.... I wanted to develop something new: a more integrated technical solution, one that would work in a 3D space, whose functionality could be seen as well as heard, and one that did not involve only the triggering and manipulation of samples (Gehlhaar & Girão, 2007).

Multiverse, developed with Luis Miguel Girão in Aveiro, Portugal, was to be the system that both "read" gestures to control music and presented a visual referent visible to the audience on a screen that Gehlhaar and I had discussed in Reading a decade earlier. This was

> ... in contrast to many computer music 'performances' in which a number of motionless people sit on stage behind their laptops, completely engrossed in minute control movements that no one can see (Gehlhaar & Girão, 2007).

Two web cameras are positioned to "capture the torso, head and arms of the player" (Gehlhaar & Girão, 2007). Visual fold-back is provided for the performer as an image on a two-dimensional screen of the 3D virtual space they occupy. The musical component is activated via gestures that start, stop or reset 47 timers whose values are sent to two synthesis engines, one providing granular synthesis of sound samples selected from Gehlhaar's preceding works, and one providing FM synthesis. The parameter values generated by the timers can be stored as presets for subsequent performance.

Multiverse (Girão, 2008a) is just one of a series of new instruments designed by Gehlhaar and his collaborators as extensions or alternatives to *SOUND=SPACE*. *CyberSong* (Rodrigues, Girão, & Gehlhaar, 2005) was presented at the New Interfaces for Musical Expression conference in 2005 and involved a singer controlling electronic transformations through the CyberTails he wore:

> Then *CyberSong* by Paulo Maria Rodrigues, Luis Miguel Girão, and Rolf Gehlhaar took us in a decidedly more dramatic direction. A static noise began with house lights still up – technical difficulty or beginning of the piece? – then Mr. Rodrigues walked down the house right aisle, donning a tux jacket as he mounted the stage. A grand 'O Freunde!' yielded to falsetto sostenuto which then recycled through electronics in an eclectic cascade of conscious chaos. A later section turned into a hilarious remix of the recited text: 'A fish is a machine that preserves genes in water. A monkey is a machine that preserves genes up trees'. This segued into manipulation of 'radio' waves via [a] clownish mouthpiece. Overall, the piece was disjointedly non sequitur, but brilliantly performed, concluding with maniacal laughter building through feedback to a final 'Shut Up!' (Allen, Schedel, & Young, 2006, p. 90).

Where the therapeutic application of *SOUND=SPACE* had emerged as a welcome side-benefit of its original design and purpose, *HeadSpace* (2000) (Matossian & Gehlhaar, 2015) represented a specific response to the challenge of providing an interface that would provide or restore the capacity for handicapped musicians to perform: "Most musical instruments are difficult to use. They are the result of hundreds of years of an evolutionary process that has favoured able-bodied musicians" (Matossian & Gehlhaar, 2015, p. 200).

HeadSpace was developed for the trumpeter Clarence Adoo, who was rendered paraplegic as a result of a car accident in 1995. The control appliance Adoo proved capable of learning to play was based on "a commercially available head-mounted mouse device registering head position and breath pressure" (Matossian & Gehlhaar, 2015, p. 202). Further instruments followed, sold through the company Human Instruments. In each case, the aim was that:

> A more instinctive interface could be imagined that would link movement and expression directly to note control, timing, sound colour (timbre), sound quality and communication with other players. Musical instruments have multi-physical feedbacks. Pressure from a mouthpiece, resistance from a key or flex of a string, even before a note is played. Then, a plethora of others during the sounding of an instrument.... A player's uniqueness should be discernible through the playing of *any* instrument (Matossian & Gehlhaar, 2015, p. 203).

Typhoon was developed in 2015, also for Adoo, as a mouthpiece capable of reading positions for which new sensors and levels of reliability and resolution refined the player's capacity for control.

The *Doosafon* (2014) presented a further variant of the mouth and head operation that expanded Addo's range of performance. The breath and sip (in-breath) control involved in these wind instruments was also applied in the case of *Puffin* to initiating notes presented on a touch-sensitive keyboard in a manner that permits players with limited upper-body strength or arm control to perform polyphonically.

CaDaReMi (2008) revisited the capacity of a dedicated sound installation to provide a musical experience for special needs groups, similar to the design of

SOUND=SPACE and *Multiverse*. In *CaDaReMi*, the visual element is provided by an overhead digital infra-red camera which tracks and monitors movement within the space below (Gehlhaar, Girão, & Rodrigues, 2011).

A sequence of new works emerged over the period 2000–2012 that resulted from collaborations exploiting Gehlhaar's developing instrumentarium. Installations were presented at the Guinness Storehouse in Dublin (*Urban Spaces* and *Millennium Bridge*, 2000), the Hayward Gallery, London (*Observation* and *Sonic Boom Stairs*, 2000), Glastonbury (*Tunnel*, 2000) and The European Patent Office, Munich (*The Amazing Music Machine*, 2000).

The fifty-minute work *Viagem* (Gehlhaar et al., 2010) was performed at the Casa da Música in Porto, and incorporated several elements including one of Gehlhaar's earliest inventions, the *SuperString*; music groups from disabled and psychiatric hospitals; *SOUND=SPACE*, MATRIXX (a "nest" for generating rhythms); *InstrumentA* (a sequencer with menu choices controllable by clients with limited movement); a 60-voice choir; and an "orchestral" composition assembled from work achieved by a team of educators over the preceding year according to instruction set out by Gehlhaar.

Eyesound (2010) was developed by Gehlhaar and his son Vahakn, employing the Kinect controller developed by Microsoft for the *Xbox*, with software they designed that maps the three-dimensional visual field onto different "voices" of a sampler. Performers trigger and control samples with their hands by placing and moving them in the visual field of the Kinect. Performances with *Eyesound* include the TedEx presentation given by Rolf and Vahakn at Brighton (Gehlhaar & Matossian, 2012) and for Music in a Field (for Glastonbury in 2012), and one by Nouritza and Vahakn in Cyprus (Gehlhaar 2013a; Gehlhaar, 2013b).

8 Research into Gehlhaar's Inventions and their Influence

Gehlhaar's output has inspired a wide range of research, review and response. *Cooperation Game* (Girão, 2008b) is a computer-mediated social environment that Luis Miguel Girão created while studying with Gehlhaar for his MA at Coventry. *SOUND=SPACE* and its derivatives have featured in reviews of the field of movement-based musical interfaces by Frid (2019), Girão (2019), Giomi & Fratagnoli (2018), Howe (2016), Ungeheuer (2016), Wiederhold et al. (2016), da Rocha Almeida (2015), Phillips & Speed (2012), Hoadley (2010), Abadi (2008), Yeh (2008), Brooks et al. (2007), Drummond (2007), Figueiredo et al. (2005), Purcell (2005), and Hunt (1999). Dalgleish, a physically handicapped

performer and researcher who studied with Gehlhaar, has developed instrumental prosthetics for his own use and in support of musical engagement for others (Dalgleish, 2016a, 2016b; Dalgleish et al., 2013).

Campbell (2003a, 2003b) fully acknowledges the basis of his *M-SEA Sensor Interface* in setting out to emulate *SOUND=SPACE* for projects of his own in Australia at a fraction of the cost. The research team at Casa da Música, Porto, equally acknowledges the inspiration provided by Gehlhaar's work (Rodrigues et al., 2005), and the central role played by digital instruments arising from collaboration with him in the development there of resources making music accessible to all (Rodrigues et al., 2009).

9 Humanitarian and Philosophical Perspectives

Technology develops at a challenging rate: Gehlhaar's career was one that balanced protecting his inventions from obsolescence with relishing the new potential of the latest developments. His career straddled the shift from analogue to digital resources. His legacy and future influence reside largely in the two principal ideas that characterise his mature work: the development of musical instruments controlled without touch; and the provision of resources that permit handicapped people to perform. Both are exemplified by the continuing projects for which his son, Vahakn, was his chief collaborator. Reflecting on Gehlhaar's career, one perceives an unusual combination of the creativity of the artist and the concerns of the humanitarian. Music-making was almost never just about him, but was an opportunity to harness the creativity of others and to provide them with the means of self-expression.

Gehlhaar read widely in the sciences, and his approach to music was informed by psychoacoustics and human evolution. In 1998 I convened a colloquium at the University of Reading in order to introduce to each other participants with whom I had corresponded as part of my research into the origins and purpose of music. Daniel Schneck (Virginia Tech) presented on video and, in addition to Gehlhaar, those present were Jonathan Dunsby (University of Reading), Paul Robertson (leader of the Alberni Quartet and working on music therapy research at Kingston University) and Ian Cross (University of Cambridge). Gehlhaar's lucid presentation came as something of a surprise. He was keen to persuade us that music is not necessarily an aural experience, but rather has its foundations in forms of internalised physical and psychological experience that may be represented and exchanged through auditory perception. He knew the literature on the musical experience of the deaf, and we had discussed the recently published view of Steven Pinker (1997) that music is "auditory cheesecake" of no adaptive

significance. Gehlhaar's conclusions were summed up in his later paper written with Vahakn, quoting Deryck Cooke:

> "Music is often regarded as entirely a decorative art, whereas instead it is the expression of man's deepest self" [Cooke, 1959]. Current scientific studies [support] this claim that was made some sixty years ago (Matossian & Gehlhaar, 2015).

Conversations over twenty years were a key influence on my own evolutionary thinking, and seeing Gehlhaar's ideas realised in practice stimulated my application to music teaching of theories of musical adaptation. I was later amused to discover that performances of *CyberSong* (2003) included passages based on texts by Richard Dawkins.

Gehlhaar harnessed his understanding of acoustics and the complexities of sound synthesis to emotionally affective intentions. His *OM 7: Stereo tracks for meditation* (2001) was remastered for posting on *YouTube* just prior to his death (Gehlhaar, 2019a). He put his art and technical know-how to the service of others in such projects as the 2007 work for the steel 'cello and bow chime ensemble he achieved with Eastern European refugees (Palka, 2016). Dalgleish recalls the development of instruments which would enable his performing, such as "the *ServoString* instrument ... initially conceived as a collaboration with Gehlhaar during the winter of 2008–9" (Dalgleish et al., 2013).

Two projects certainly outlive Gehlhaar in coming to fruition in recent years. Gehlhaar's work with Clarence Adoo led him to become closely involved with the development of The British Paraorchestra, founded by Charles Hazlewood in 2011 (Gehlhaar & Hazlewood, 2011; Samuels, 2015). Adoo, playing *HeadSpace* in the orchestra from 2012, stated "this is the first time I feel like a musician, not a disabled musician" (Matossian & Gehlhaar, 2015, p. 202). The orchestra's concert series *The Nature of Why* was shortlisted for a 2019 Royal Philharmonic Society Award.

A newer project involving Hazlewood has been the development of the *Haptic Baton*, permitting blind musicians to follow the beat of a conductor through the transmission of information conveyed to a wristband worn by the performer. The *Haptic Baton* was created by Vahakn Matossian based on a prototype Gehlhaar developed in 2017 (Evans, 2019; Hymas, 2019; Matossian, N., 2019).

In 1997, Gehlhaar wrote a short story entitled *Virtual immortality* (Gehlhaar, 1997) in which the protagonist speaks to an avatar of himself. The image is exactly as I recall Gehlhaar from that summer:

> ... a smiling, full size familiar image of myself from sometime out of the near past – simply dressed in black jeans, olive shirt, with a colorfully checked wool shirt on top of that (Gehlhaar, 1997, p. 1).

A dialogue ensues that extrapolates from the workings of a system similar to *SOUND=SPACE* to describe a stage in which one can imagine:

> ... being able to shape yourself consciously, based upon your already gained experience and leave behind a monument, but instead of a monument *to* yourself, a monument *of* yourself (Gehlhaar, 1997, p. 3).

Gehlhaar remains in my thoughts because his example laid down pathways for my thinking. I recall and celebrate those many occasions on which, faced with an apparently insuperable technical challenge, that unique voice with its combination of the laid-back Californian and the Teutonically precise, would, after a brief pause, intone: "I have an idea...".

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