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The resolution of sound: Understanding retro game audio beyond the '8-bit' horizon

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In 2012 the Public Broadcasting Service aired a 'special' dedicated to the popularity of retro-videogame-themed music, design, and art.[1] Combining interview snippets with footage of historic examples of video game technology as well as their modern imitations, this seven-minute program titled *The Evolution of 8-Bit Art* is implicitly built around the premise that the meaning of '8-bit' itself is self-evident. Also, '8-bit' is presented as something that is coherent across the divide between sound and the visual domain. Highly pixelated characters built from jarring and sparse colour palettes populate the screen in this video, accompanied by the obviously outdated bleeps of the early video game era.

Technically, a bit is a unit of information. In one bit, one minimal piece of information can be stored, specifying whether something is 'true' or 'false'. Often, this is encoded as '1' and '0', respectively. '8-bit', then, is a collection of eight such units. Only 256 different states or numbers can be represented with the help of eight bits. But does it mean that the 'resolution' of such audio is lower than, for example, in the case of 16-bit video game consoles? How does '8-bit' relate here to other technical characteristics that also state the number of bits, such as '24-bit' digital recordings or '64-bit' operating systems? And what does the number 8 tell here about specific aesthetic or technical choices in music, art, or design? To understand how this popular '8-bit' discourse relates to the notion of resolution in sound one has to consider several specific technical developments of the recent decades.

In this essay, I argue that in most cases the popular notion of 8-bit audio is, despite its technically-sounding name, not grounded in a knowledge or

understanding of specific technologies. Instead, it obscures the rich technical and discursive history of digital electronics. By embedding the discussion of retro-videogame-themed audio in the technical history of the medium, this article strives to contribute to a realignment of the term itself towards greater specificity. In the first part I outline how concrete examples of video game technology have defined the boundaries of what was acoustically possible with respect to the 'resolution' of pitch and rhythm parameters, the number of instruments, and other components of musical performance. Then, I show how the general label of 8-bit is being applied to more modern imitations of this aesthetics in ways that mask or distort the history of digital audio. Finally, I discuss why this blurry and technically inadequate term is attractive for many audiences.

The labelling of aesthetic products as 8-bit has become a fixture of today's popular cultures. From visuals created from large, colourful blocks to audio incorporating some sort of imagined 1980s video game aesthetics, the reduced 'resolution' of such artefacts arguably remains their defining feature. Yet, what could a word like resolution mean exactly in this context? Contrary to the general belief, 8-bit audio normally does not specify the amount of information used to encode a normalised section of audio (if it did so, it would have been comparable to the number of dots per inch on a screen or on printed paper). Satisfactory audio quality is in fact usually taken for granted, even if the exact requirements vary between domains of use and individual listeners. Instead, 8-bit refers here to a nebulous amalgam of technical and aesthetic imaginaries that all connect to a vision of grossly inadequate audio and video quality of the previous decades. Whereas such use of the term 8-bit is currently mostly typical of non-specialist discourse, with academic authors often taking a more balanced standpoint, its popularity risks influencing future musicological and media-theoretical literature on game aesthetics. An alternative term that would account for the complicated nature of the relationship between technology and aesthetics in the case of 8-bit-era music could be proposed here, but it seems more probable that such a term will emerge by itself once the understanding of the underlying theoretical problem becomes widespread.

In *The Evolution of 8-Bit Art*, a closer examination of the choice of the interviewees makes it evident that the authors did in fact see different strands within what this program seemingly presents as a quasi-monolithic 8-bit culture. On the one hand there are statements from members of the band *Anamanaguchi* who see retro-videogame aesthetics merely as unspecific 'building

blocks' and who distance themselves from the technical exactness of those who create so-called demos (software for old devices that pushes the boundaries of the technically possible by generating extreme visual effects).[2] On the other, the musician behind the *Minusbaby* project is quoted discussing the merits of 'true 8-bit' and speaking about particular technologies and models of hardware as the very basis for his work. Inevitably, the question arises: what is 'true 8-bit'?

True 8-bit

The shortcomings of today's 8-bit audio discourse can be summarised as follows: 1) Despite the presence of a concrete technical descriptor, 8-bit, in the name of this aesthetic label, specific technological points of reference are mostly absent from the discussion. 2) What is commonly called 8-bit audio today is often only superficially related to examples of previous-era audio technology and aesthetics. 3) The seemingly simple label 8-bit describes a whole host of aesthetic areas that are technically specific and historically diverse. What is absent here is exactly the 8-bit component. Thus, to bring it back in, one needs to take a look inside the black box of a typical video game console or a home computer of the early 1980s.

The CPU, or the main processor of the console or the computer, is the place where the most important calculations take place, enabling the program to run, and controlling all the other chips on the board of the device. It has some specific technical features and limitations, with the number of bits that can be processed, at the same time being one of the most important or visible. Thus, generations of processors are grouped into 8-bit chips, 16-bit chips, etc., with 64-bit as the current standard in consumer devices. While technical boundaries can be rather blurry here,[3] the consoles and home computers with 8-bit CPUs were and are being perceived as aesthetically and culturally different from later generations.

However, discussions of early video game audio also need to take into account the dedicated audio chip of the respective console or home computer.[4] Being an additional component, those chips brought with themselves possibilities and limitations that were different from those of the CPU. In other words, saying that the console or the computer is 8-bit only describes one parameter of its CPU, but tells virtually nothing about its audio.

The most important difference between today's video game audio hardware and the audio chips of the 1980s is that today's games mostly rely on the playback of pre-recorded sounds, while earlier technologies used synthesis much more often. This move away from synthesis occurred because of the proliferation of large and inexpensive data storage solutions such as the CD-rom during the 1990s, and was spurred by the perceived inferiority of the synthesised sounds when compared to professionally recorded audio.

Thus, the main technical features of a typical audio chip from the era of the 8-bit CPUs are:

1) The resolution of its tuning. The information about the pitch of a note to be synthesised is represented using differing amounts of bits in different chips. For example, the audio chip of the popular Atari VCS video game console from 1977 uses only 5 bits to encode the frequency of a note. Thus, only 32 different notes can be played by it without changing the settings of the synthesised voice. Moreover, because of further technical limitations, these notes do not correspond directly to known musical scales.[5] By contrast, the audio chip inside the Nintendo Entertainment System console from 1985, which is also considered 8-bit, uses 11 bits to encode pitch, making the much more fine-grained resolution of 2048 different frequencies possible. [6]

2) The synthesis techniques used. One of the most recognisable features of 8-bit-era game sound is the direct use of simple waveforms such as triangle, pulse, or sine. [7]

3) The number of voices. Because each sound or note needs to be synthesised in real time by a dedicated synthesiser circuit, the number of simultaneous voices is typically very limited in the sound chips of that era, ranging mostly between 3 and 5. [8]

A number of characteristics of early video game sound are also related to the way the music was programmed during that era.

4) The use of temporal grids. To simplify the process of manually programming the music of the game, so-called music engines were widely used. These were programming building blocks that further abstracted or reduced the possibilities of the chip to make the program itself more readable for the programmer and to reduce the amount of memory needed to encode the music. Often, the pitch and the length of notes were restricted by the music engine to a small list of possibilities.

5) Impossibility of intuitive musical input. Unlike a player of a musical instrument, the typical game programmer of the early 1980s had to encode the music with the help of a list of numbers, thus lacking the possibility of intuitive control of fine details of musical performance. [9]

> 6) Repetition. To save memory, which at that time was an expensive asset in digital computing, and to make use of the affordances of the music engines, repetition was widely used in video game music and sound. [10]

This list makes it evident that archetypal 8-bit-era video game music would have coarse tuning, primitive synthesis, few voices, inflexible note lengths, mechanical performance, and a lot of repetition. Yet, a very limited subset of these characteristics is often enough to label a performance as 8-bit. For example, modern imitations typically rely on a music encoding standard called MIDI, which provides great flexibility and detail with regard to tuning, timing, voice number, and the subtleties of performance. Thus, a tune that employs an imitation of a simple-waveform synthesiser, but otherwise has a standard tuning, 10-20 voices, and was recorded live using a MIDI keyboard would today still normally qualify as 8-bit, at least among the non-specialist listeners.

How do other parameters of sound technology relate to this CPU-centric definition of 8-bit? What does normally constitute low and high resolution in today's audio? Given that today's various sound technologies are digital by default, it is unsurprising that a whole host of different bit parameters is used in this case. MP3 files are usually accompanied by a number like 128 kBit/s to show the amount of compression to which the recording has been subjected. This parameter tells the number of bits needed to encode one second of sound. The higher this number is, the less information has been discarded during the process.[11] In a recording studio, engineers will normally use professional audio resolutions like 96 kHz, 24-bit for production, and consumer-oriented resolutions like 44.1 kHz, 16-bit for output. These sets of parameters indicate the temporal resolution employed during the digitisation of the initially continuous sound vibration (96kHz meaning that the vibration was measured 96,000 times per second) and the number of bits used to encode the value that was measured each time. Using 24 bits, 2 to the power of 24 different measured values can be stored. The scope of this article does not permit a more detailed description of these parameters, but, comparing them to the description of 8-bit-era sound given above, it should be clear that despite the presence of the word bit in all of them these sound-reproducing technologies are fundamentally different from the sound synthesis environments of an early video game console or computer. Whereas in the case of the recording (studio) and encoding (mp3) resolutions the numbers indicate directly how much information has been used to represent one second of

audio, the situation with 8-bit retro audio is much more complex. There, various technical parameters – from the structure of the CPU to the music engine used by the programmer – need to be taken into account when describing the sounds on the technical, as well as on the aesthetic level. And yet, the general label 8-bit music has emerged as a seemingly self-evident description of any kind of sounds that are considered similar to or inspired by the early videogames of the 1980s. Moreover, the confusion over the exact meaning of the bit parameter has arguably led to the false impression that the generations of computer hardware (8-bit, 16-bit, etc.) relate to each other in the same way as recording or encoding resolutions. In other words, there might be a false belief that 8-bit music sounds like it does because it was somehow 'encoded' in a lower resolution. The parallel here stems from the popular retro-themed visual filters that are in fact able to automatically turn a modern photograph into a highly pixelated image with a strictly reduced colour palette. Yet, from the discussion of the technical complexity and specificity of 8-bit-era audio it should be clear that no such automatic conversion of music from, for example, a CD recording of an orchestra performance into an 8-bit videogame tune is possible, at least without transcribing, arranging, and programming the music, which would be a much larger effort than in the case of a predefined visual filter. A more direct parallel to creating an authentic 8-bit version would be in this case the recreation of the original photograph using methods from *pixelart*, the practice of manually building low-resolution, small-palette visuals from individual pixels.

From pixels to chiptunes

Today's imitations, homages, and evocations of 8-bit-era sounds and visuals represent a wide range of approaches, from the technically faithful to the only superficially inspired. On the one side of this spectrum stand the historically and technologically informed works that respect the specific possibilities, limitations, and traditions of their medium. In music, the *chiptunes* strand of retro-videogame styles represents this approach. Chiptune artists generally show a larger interest for and understanding of the history of video game audio and its various technologies. Mostly working with original hardware of the era, they create their music according to the technical affordances of their machines. The degree of identification with old technology varies, however, even among this group. Whereas the most ascetic of the

chiptuners will use only the tools available to the programmers of the device's period of popularity such as the assembly programming language or the music engines discussed above, others will modify the device to include MIDI support, thus foregoing some of the limitations of their platform, but utilising others such as the built-in synthesiser chip. Even more undogmatic chiptuners will use samples (short recordings) from historic videogame devices in a modern context, combining them freely with other sounds, triggering them using today's music hardware and modifying them with effects. At this point, however, they will arguably already have transgressed the boundary around chiptunes, entering the territory of 8-bit-styled retro-themed artefacts. Here, everything is possible as long as there are listeners or viewers willing to accept the result as belonging to the realm of 8-bit, retro, or pertaining to classic video games.

Different tools exist that lend themselves to use in either the more traditionalist or the more imitationalist scenarios. For example, Nintendo Entertainment System sounds can be composed with the help of the *Famitracker* program that runs on modern operating systems, but otherwise faithfully recreates various technical parameters of the console's audio hardware.[12] One clearly visible proof of *Famitracker*'s orientation towards the traditionalist, original-hardware group of users is that tunes composed with the program can be played back on historic hardware. This technical specificity, however, makes a steep learning curve seemingly inevitable, at least given that the general culture of chiptune, and even more so, of demo programmers can be said to privilege virtuosity, obscurity, and secrecy over openness and maximum understandability. On the other hand, a program called *GXSCC* exists that enables everyone to turn a MIDI file into a retro-videogame-inspired rendition of itself with literally one click.[13] This remarkable feat is possible only because MIDI files contain a set of musical instructions (therefore, they are different from audio recording formats like MP3 or WAV), and as such already represent one substantial part of the technical system that has historically created the synthesis-based videogame sounds of the early era.

One relatively popular example of rather unspecific recreation of 8-bit aesthetics is *8-Bit Cinema*, a series of short animations based on the plot of popular movies.[14] Here, the visuals do not imitate a concrete video game platform, but they still feature several characteristics common to 8-bit, as well as 16-bit-era home computers and consoles such as reduced palettes and animations consisting of a strictly limited number of frames. A short behind-

the-scenes documentary published in 2015 reveals that these videos are a result of a moderate team effort, combining the work of several pixelart animators employing modern software and hardware with 8-bit themed music created with the help of today's sampling technologies.[15] Still, the creators' attention to stylistic detail, as well as the comical effect of recreating well-known movies in a kind of a cartoonish retro-themed technical caricature can help explain the relative (yet limited by YouTube's standards) popularity of their videos.

By contrast, two examples of very successful high-budget productions that rely on evocations of 8-bit aesthetics, *Wreck-It Ralph* (2012) and *Pixels* (2015), can shed light on how this theme is used with broader audiences. Both films significantly bend the boundaries of what can be considered fitting or authentic, if judged against the background of the technical situation of the 1980s. *Wreck-It Ralph* is quick to transform the character from its highly pixelated 2D origins into a smoothly-rendered 3D figure typical of more modern animation. Likewise, in *Pixels* the 2D arcade games of the early era resurge as 3D characters, but this time they are made of glittering blocky rectangles – a feature that can be read as an attempt to find a balance between the expectations of the more traditionalist retro video game aficionados and the broader blockbuster public. The trailer for *Wreck-It Ralph*features sounds resembling those created by the chips and programs of the 8-bit era arcade machines, but transitions to more recent sound aesthetics when the main character leaves behind its 2D past to enter the 3D stage. The *Pixels* trailer, however, is almost completely void of 8-bit sounds, incorporating them only very briefly (and against the much more prominent background of a different musical theme) during the introductory scene showing videogames from 1982.

An especially telling example of what I would like to call *recursive* retro is the comprehensive collection of Beatles albums rendered in retro-videogame-inspired style and published on the YouTube channel That Gamer.[16] This channel's banner features the pixelart-styled female character from the main screen of the *GXSCC* program and the tagline 'A true master of GXSCC'. Additionally, the channel description includes the line 'I upload MIDIs shoved through GXSCC, I guess. I've heard it can do 8-bit stuff.' Which, depending on the inclination of the listener, can be read as an ironic downplaying of the amount of work that goes into preparing the MIDI to sound more authentic on *GXSCC* or as a blunt confession of the program's limitations when compared to specialist chiptunes software like *Famitracker*.

From the sonic impression alone, it could even be speculated that at least some of the recordings are in fact carefully crafted chiptunes that were played on historic hardware, with the *GXSCC* reference being just a sarcastic side note. Yet, upon my request, the owner of the channel confirmed, 'all of my 8-bit work consists of putting […] Beatles and Led Zeppelin MIDIs into GXSCC and nothing else'.[17] Regardless of the amount of work that went into creating them, this channel's cover versions of Beatles albums constitute a case of multiple remediation, including 1) a recreation of typical videogame sounds of the 1980s with software from the early 2000s and published on a video sharing platform between 2013 and 2014, thus utilising video and internet technologies that were unavailable when the program itself came out, and 2) a transformation of an entertainment product created in the 1960s (a Beatles record) into an imitation of the sound component of a product from the 1980s (a video game). The multiple ironic as well as nostalgic references to the entertainment cultures and technologies of the past that are intertwined here can help explain the niche appeal of this project.

At the same time, by putting the imitations of 8-bit-era sounds into the technical environment of a modern video-sharing platform, a clashing of different technical parameters related to the number of bits is created, probably leading to some mild confusion over what exactly is being adjusted by the YouTube player's settings button. The platform itself offers listeners a choice of different automatically created video resolutions, ranging in the case of *That Gamer*'s rendition of the *Please Please Me* album from 192×144 to 1440×1080 pixels. Higher resolutions require higher bandwidths to transport the information needed to represent video and audio. By choosing the setting labelled '144' the user will normally use only 76 kilobits per second for the video part of the stream, whereas the setting '1080' will result in a 1182 kBit/s download. Invisible to the user, multiple audio encodings with different settings for sound quality are also being created automatically by the system.[18] The current interface of the YouTube player hides most of this information, but it still gives the user the possibility to choose the vertical amount of pixels of the video component (accordingly, high or low audio quality will be automatically chosen by the system), enabling the switching between and the comparison of different resolutions. This possibility of technological choice regarding video and audio resolution is metaphorically mirrored by the listener's choice of audio aesthetics – in this case, they have consciously decided to listen not to the 1960s recording created by the original

band using the studio equipment of that time, but to a recreation of video-game sounds of the 1980s made in 2013 using a tool from 2002.

The popularity of 8-bit

In his book *Mp3. The Meaning of a Format* (2012) Jonathan Sterne has discussed the often ignored difference between an artefact's definition and its correspondence to reality. Drawing on Michel Chion's formulation that 'No one complains of nonfidelity from too much definition', Sterne points out that the terms 'aesthetic pleasure', 'immersion', and 'high definition' do not have the clear or necessary relationship to one another that the manufacturers of audio equipment often try to postulate.[19] Sterne's observation that 'compression practices have created new kinds of aesthetic experiences that come to be pleasurable in themselves for some audiences'[20] is relevant for the discussion of why 8-bit as a label has become popular: in the same way that the people who grew up with the Mp3 as the predominant audio format may later *prefer* the distortions of compressed audio over uncompressed formats, the players of early video games can have a certain aesthetic predisposition towards low visual (pixelated characters) or musical-temporal resolutions (audio grids in early games' music engines). In *The Audible Past* (2003) Sterne has also shown that the early sound reproduction technologies such as the Edison phonograph are 'shot through with the tensions, tendencies, and currents of the culture from which they emerged, right on down to their most basic mechanical functions'. Their specific technical features were answers to deeply held wishes, such as the previously merely imagined possibility of preserving the voices of the dead.[21] Today's imitations and evocations of 8-bit-era sound aesthetics are technologies themselves, and as such they must at least partially originate from a similar cultural mechanism, even if they are oriented towards a different set of desires. Yet, the question arises: what are those desires?

One compelling, but speculative answer to this question is that making the technology seem small and manageable is among the most deeply held wishes of *our* time. Some of today's most advanced digital technologies can seem threatening, but the 8-bit past is supposedly soothingly simple. An editorial published in the influential science journal *Nature* in 2016 alerts readers to the dangers of next-generation artificial intelligence and robotics, ranging from 'permanent mass unemployment and increased inequality that hits

hardest along lines of class, race and gender' to 'autonomous offensive weapons systems' and a scenario where 'Machines and robots that outperform humans across the board could self-improve beyond our control – and their interests might not align with ours.'[22] At the same time, the electronics industry's constant drive for generating replacement purchases has led to a steady rise in the devices' characteristics.[23] Most notably this has happened in the field of video resolution, raising the norm first to 720 vertical pixels, and then to 1080 and beyond, with the recent advent of 4K screens and data storage technology.[24] Similar trends can be seen with regard to the rising size of computer hard drives or the already mentioned leaps in processor complexity that are indicated by the proliferation of 16, 32, and 64-bit CPUs. Against this background, the modest specifications of 8-bit era video and audio can make the technologies of the past seem simple and controllable. They also enable a temporary nostalgic return to the culture of believing in the future and of delighting in a technologically-driven optimism that was prevalent from the 1960s (space exploration) to the 1980s (computers and robotics).[25] Finally, in the environment of 24-bit audio and 64-bit processors, the 8-bit music is destined to convey certain feelings of technical, as well as historic superiority, even if these numbers are not directly comparable. Thus, an imaginary past is conjured up by familiar-looking blocky visuals and tinny sounds, one where technology and threat are perceived as opposites, not as bywords. What is being excluded from memory in this process are of course the widespread fears of nuclear war of the early 1980s or the fear of destroying the living environment that proliferated in the wake of the 1986 Chernobyl nuclear accident.[26]

Second, the label 8-bit underscores the technical obsolescence of the referenced aesthetics. There exists a peculiar cultural dynamics where certain items experience a steady decline of their perceived value, only to be rediscovered later. Michael Thompson, who has analysed this phenomenon in his 1979 book *Rubbish Theory*, argues that the state of value that those items achieve at some point is a prerequisite for their resurgence as sought-after historical relics, because only in this state are they free from the influence of powerful actors who normally determine the value of important objects. Crucially, he also stresses that the value ascribed to the object by the society is determining how well it will be preserved, not vice versa.[27] As mentioned above, the technologies of 8-bit-era home computing have been devalued many times due to the creation of several new generations of processors, storage media, as well as graphics hardware. Thus, they are a perfect example

of initial material to undergo the process of revaluation described by Thompson. Most evidently, the attempts at ascribing a higher value to previously culturally invisible assets manifest themselves in the label 'classic' that is being variously attached to games and devices from the 8-bit era.[28] Continuing economic interests of game hardware and software manufacturers are also a driving force behind the recasting of short-lived technological novelties of the 1980s that were largely displaced by the 1990s into the cultural icons of the early 21st century that the 'classic' games and devices have become today. Reissued versions of old games, with varying levels of technological and aesthetic authenticity, have flooded the game market since the advent of the retro trend.[29] Moreover, some manufacturers who were successful in the 1980s have included characters from their early games in their new products, with the Mario figure from the games produced by the company Nintendo being the most widely recognised.[30]

Thirdly, the generalised term 8-bit can be attractive precisely because it erases technical specificity and thus enables approximate stylistic copies that can then serve as a replacement for the unattainable past. The cultural phenomenon of nostalgia is central to the understanding of the current popularity of 8-bit sound. Sean Fenty has offered a multifaceted discussion of game nostalgia in his article 'Why Old School is "Cool": A Brief Analysis of Classic Video Game Nostalgia", arguing that interactivity and a system of automatic rewards were defining new features of early games culture. Crucially, however, Fenty draws our attention to the fact that 'nostalgia felt for video games is […] a desire to recapture that mind-altering experience of being in a game for the first time', and as such impossible to regain. Therefore, the experience of an old game, replayed today, can never be the same as in the past because our perception has changed.[31] New products that utilise an approximate stylised imitation of 8-bit aesthetics offer a solution for this problem. They remind the user of the 'liminal' (Fenty) moment of play from their childhood, but they do not make the impossible claim to equal that exact medium, or feeling.[32]

Finally, while specific motivations exist that influence the popularity of the 8-bit audio label, the term itself would be of little relevance if the overall retro-gaming trend were not constituting the strong cultural current that it does today. Without reopening the general discussion about the popularity of retro games,[33] I would like to draw attention to three additional speculative points that may have contributed to it and that are linked to the specific

technical and economic situation of early video games: their perceived authenticity, individuality, and imperfection. Whereas today some of the highest-earning and most popular computer games are being designed by large teams of professionals working on multimillion budgets, the early era of videogame production mostly saw games as the result of a sole programmer's work, often done without proper training or the technical tools that were deemed essential in more developed industries.[34] This situation may have led to a view of early video games as more individual projects than their recent counterparts, even if the early developers were often not credited by their company.[35] Accordingly, the limited technical and methodic resources of early games may have created an impression of their widespread technical predisposition to bugs and errors, a view that has arguably contributed to the recent popularity of so-called glitch aesthetics that simulates errors and computer crashes, often combining them with retro game elements.[36] The 'authenticity' of early video games and the modern imitations of their aesthetics is also tied to the working conditions of the early game industry. Being mostly the result of a single developer's work, they can be imagined to be a more direct representation of a real person's fantasies and inclinations. Also, the early games' low (by today's standards) technical parameters such as the resolution of their graphics can be perceived retrospectively as a sign of their 'honesty', as if they were consciously avoiding overblown effects that would have otherwise deceived the player.

Conclusion

During the short, but diverse history of video game audio a steady rise in the number of 'bits' (from 8 to 16 and beyond) has, with varying levels of clarity, indicated the often complex ways in which technology and aesthetics have shifted over this period. Later imitations, with the notable exception of *chiptune* and *demo* works, have largely ignored the often subtle technical and aesthetic differences by constructing 8-bit audio as a generic umbrella term. Attractive due to a number of cultural reasons related to such issues as the fear of technology or the dynamics of nostalgia, the label 8-bit has contributed to the popularity of big-budget productions such as *Pixels*, niche projects like *La-Mulana*, and popular retro-themed games in the vein of *Minecraft*.[37] This essay links areas of knowledge and practice such as the technical history of video game audio and the cultural history of retro to explain

the popularity, as well as the shortcomings of the 8-bit discourse. By differentiating between distinct meanings of the number of bits in varying contexts related to audio and its resolution, this essay contributes to a media history grounded in technology as well as in culture, and helps uncover hidden and lost discourses that have shaped the popular notion of 8 bit audio.

Author

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Notes

[1] Available at: http://www.pbs.org/video/off-book-evolution-8-bit-art/ (accessed on 27 February 2018).

[2] Michael Nitsche's short article 'Demo' discusses different meanings of the term demo with respect to video games, describing the visual demos as 'noninteractive, real-time animation sequences' that rely on 'procedural generation and optimized code' (Lowood & Guins 2016, pp. 104-105). Anders Carlsson's chapter 'Chip Music: Low-Tech Data Music Sharing' offers a concise introduction into the history of computer demos (Collins 2008a, pp. 153-162). With respect to the difference between technically accurate and free recreations of retro game aesthetics, it should be noted that the goal of this article is not to establish a ranking between the two possibilities that would prioritise one of them. Rather, this account of different possibilities in dealing with the technical and cultural history of video games aims to enrich and sharpen the relevant terminology.

[3] The successful 8-bit processor *MOS 6502*, for example, uses 8 bits for data, but 16 bits for addressing the memory.

[4] Models without a dedicated audio chip also existed, prompting the development of so-called 1-bit audio whose aesthetic features are similar to those of 8-bit-era sounds, but whose technical discussion is beyond the scope of this article.

[5] Specific techniques such as changing the settings of the synthesiser during playback allow for a slightly larger palette of pitches. Conversely, it is possible to limit the set of notes available to the composer to those that are close to the familiar Western intervals. Montfort & Bogost (2009, p. 131) give a description of a case where the developers of the game *Pressure Cooker* have resorted to this measure for the game's music.

[6] Cf. Dittbrenner 2007, p. 30. Altice (2015, pp. 249-288) offers a detailed discussion of the NES audio chip and the related *chiptune* practice.

[7] Roughly, a waveform used to create electronic sound corresponds to the shape that would have been created by the vibrating speaker if its undulations were recorded on a moving piece of tape.

[8] For a more comprehensive overview of the number of voices in different chips see Dittbrenner 2007.

[9] In his article 'The Influence of the UNIX Operating System on the Development of Two Video Games' Peter Langston describes the technical situation of a typical one-programmer early video game project, including the sole use of the assembly programming language for all tasks, and contrasting it with the methodically more sound working environment at his previous company, Lucasfilm Games (Langston 1985, p. 1).

[10] For example, both in the case of the Atari VCS and the NES consoles hardware cartridges with memory chips were used to store games, which, combined with the limitations of the CPUs used, drastically restricted the amount of memory available to the programmer. Taken together, the individual technical characteristics of a mass-produced console or home computer can be understood as forming a standardised computing platform. Cf. Schweizer 2014.

[11] For a discussion of the technology behind perceptual audio coding and the history of the Mp3 format see Sterne 2012.

[12] http://famitracker.com (accessed on 27 February 2018). As of this writing, the program has not been updated since 2015.

[13] http://www.geocities.co.jp/SiliconValley-SanJose/8700/P/GsorigE.htm (accessed on 27 February 2018). This program was last updated in 2002.

[14] CineFix: *8-Bit Cinema* (playlist). https://www.youtube.com/playlist?list=PL1AXWu-gGX6LNsfQ-KkeGPxL76CFONTom (accessed on 27 February 2018).

[15] CineFix: *Star Wars: The Art of Sprite Building – 8-Bit Cinema Behind-The-Scenes*. https://youtu.be/AhdfXByQlWA (accessed on 27 February 2018).

[16] That Gamer: *The 8-Bit Beatles* (playlist). https://www.youtube.com/playlist?list=PLEE04A4B1C4C9EBEC (accessed on 27 February 2018).

[17] Private online conversation with the owner of the channel *ThatGamer360* on Youtube.com, 20 February 2018.

[18] The quality of the audio component of a YouTube video stream is adjusted by the system, with settings including a low-bit-rate 24 kBit/s version as well as a standard-quality 128 kBit/s file. Information regarding the formats available for the video *The 8-Bit Beatles – Please Please Me* by the user *That Gamer* (https://youtu.be/IHtJo-BhVa8, accessed on 21 February 2018) was extracted with the help of the program *youtube-dl* (https://rg3.github.io/youtube-dl/, accessed on 21 February 2018). The specified standard bandwidth for a given format does not represent the real amount of data needed to encode a specific stream. For example, because modern video compression only saves the full information at given time intervals, but otherwise merely encodes changes occurring between the frames, a static picture will occupy less bandwidth than a moving sequence.

[19] Sterne 2012, pp. 4-5.

[20] Ibid., pp. 5-6.

[21] Sterne 2003, p. 8.

[22] *Anticipating Artificial Intelligence*, p. 413. For a more detailed discussion of ethics of artificial intelligence see Bostrom & Yudkowsky 2014. While an overview of the literature that analyses the political implications of existing digital technologies is beyond the scope of this article, Rieder & Simon (2016) are an important recent example of this strand of research.

[23] For a discussion of the cultural dynamics of planned obsolescence see Sterne 2007.

[24] As noted by M.J.P. Wolf, the imaging device itself only presents an 'upper bound for resolution' that can be further diminished by lacking processing power and inappropriate software. Cf. Wolf 2014, p. 50.

[25] While a discussion of the history of utopian technological thinking and techno-optimism is outside the scope of this article, the broad appeal of the cultural trend of *retrofuturism*, an aesthetics that references previous futurisms, is a testament to their influence.

[26] A survey of fears of nuclear war among Soviet and American children published in 1988 offers an example of the atmosphere of fear which was prevalent during periods of political tension in the early 1980s (Doctor 1988).

[27] Cf. Thompson 1979, pp. 7-12. Thompson's primary examples are stevengraphs – woven silk pictures which were popular at the end of the 19th century, have lost their value later, but became fashionable collecting objects during the 1960s.

[28] For a discussion of the term 'classic' with regard to video and computer games see Melanie Swalwells' chapter *Classic Gaming* in Lowood & Guins 2016, pp. 45-52. This move towards 'classicism' might well also have personal implications for its originators, who often belong to the generation that grew up during the 8-bit era: by raising the cultural status of the pastimes of their own childhood they seemingly at once free themselves from the guilt induced by their parents for 'wasting' their time at the console and make themselves into keepers of a past that has been regrettably forgotten.

[29] Matthew Thomas Payne (Whalen & Taylor 2008, pp. 51-68) offers an example of such repackaging of 8-bit-era games as a self-contained commercial device in the early 2000s, contrasting it with non-commercial projects that emphasise expandability and free access.

[30] Cf. Whalen & Taylor 2008, p. 1. For a list of releases that include the Mario character, ranging from the 1981 *Donkey Kong* arcade game to projects published in 2017, see: https://www.mariowiki.com/List_of_games_by_date (accessed on 27 February 2018).

[31] Whalen & Taylor 2008, p. 23.

[32] This unattainability of a true return to the past is possibly the driving force behind hobbyist retro-styled videogame projects that mix stylistic and technological markers from the 8-bit-era with more modern elements. Brett Camper describes the moment of design crisis that the developers of the game *La-Mulana* faced when 'they worked ever more to match the source of their inspiration', but 'a sense of satisfaction did not follow, even in their success', followed by the developers' decision to abandon their former goal of stylistic purity (Camper 2009, p. 6). Another example of imitationalist, but technically unrestricted use of elements from gameplay, visuals, and sound aesthetics of the early video game era is the popular independently developed game FEZ (Polytron Corporation, 2012).

[33] See Whalen & Taylor 2008, pp. 1-18 and Thomasson 2014, pp. 343-344.

[34] See the description offered by Peter Langston (1985).

[35] David Fox, who has worked with Peter Langston on game projects at Lucasfilm Games in the early 1980s, has discussed in his talk from 2004 how programmers sometimes had secretly inserted their names into the product to circumvent the policy of anonymity imposed by some publishers such as Atari: https://youtu.be/xqKf0Lu_EDU?t=27m12s (accessed on 27 February 2018).

[36] Nathan Altice offers an especially telling example of user expectations that early games would contain errors, where the phrase 'I am Error', uttered by a character in a NES game, and meant as a 'sly computer malfunction reference', was and still is being taken literally as a manifestation of a real bug in the game's code (Altice 2015, p. 1).

[37] https://minecraft.net (accessed on 27 February 2018).