Chapter 7
The Extended Composer

Creative Reflection and Extension with Generative Tools

Daniel Jones, Andrew R. Brown, and Mark d'Inverno

Abstract This chapter focuses on interactive tools for musical composition which, through computational means, have some degree of autonomy in the creative process. This can engender two distinct benefits: *extending* our practice through new capabilities or trajectories, and *reflecting* our existing behaviour, thereby disrupting habits or tropes that are acquired over time. We examine these human-computer partnerships from a number of perspectives, providing a series of taxonomies based on a systems behavioural properties, and discuss the benefits and risks that such creative interactions can provoke.

7.1 Introduction

One of the distinguishing features of human society is our usage of tools to augment our natural capabilities. By incorporating external devices into our activities, we can render ourselves more quick, powerful, and dexterous, both mentally and physically. We are effectively extending ourselves and our practices, temporarily taking on the capabilities of our tools in a transient hybrid form (McLuhan 1964, Clark and Chalmers 1998, Latour 1994).

Recent advances in computational technology have resulted in software tools whose flexibility and autonomy goes beyond anything previous possible, to the extent that the tools themselves might be viewed as creative agents. This class of tool suggests an entirely new type of relationship, more akin to a partnership than to the causally unidirectional usage of a traditional tool.

In this chapter, we direct particular attention to how the computer can be used as a partner to augment the practice of musical composition. By "composition", we are

D. Jones (✉) · M. d'Inverno
Goldsmiths, University of London, London, UK
e-mail: daniel@jones.org.uk

M. d'Inverno
e-mail: dinverno@gold.ac.uk

A.R. Brown
Queensland Conservatorium of Music, Griffith University, Brisbane, Australia
e-mail: andrew.r.brown@griffith.edu.au

J. McCormack, M. d'Inverno (eds.), *Computers and Creativity*,
DOI 10.1007/978-3-642-31727-9_7,

talking in the traditional sense: the creation of a *static, determinate musical work*, whose value is in virtue of its musical content rather than its means of production. Though we will touch on ideas of improvisation, we wish to set aside performance, interactive artworks, and group creativity, and focus on the common situation of an individual artist, developing a body of work through computational means. We will explore the partnership with generative computational systems from a number of distinct perspectives, and outline some of the opportunities and hazards of such partnerships.

In considering the practice of composing with semi-autonomous music software systems, we wish to highlight two particular outcomes. Firstly, an interaction with such systems can serve to actively *extend* and reshape our creative behaviours in response to its own creative acts, encouraging unusual creative directions, or enabling actions which are otherwise unlikely. Secondly, by mirroring our own creative behaviours—either as a whole, in part, or through transformations—such a tool can help us *reflect* on our own stylistic habits and tropes.

Though the capacity to alter innate human practices is not exclusive to digital tools, we argue that computational methods enable more comprehensive and precise support of an artist's behaviour. The analytical, generative and adaptive features often found in these tools can offer new creative routes based on dynamic awareness of context and past history, harnessing the powerful probabilistic capabilities of the microprocessor.

These tendencies can change our relationships with tools and may reshape our creative processes. This influence is possible if we accept that creativity is influenced by experiences and opportunities, including those driven by our internal drives as well as by the network of instruments, methods and stimuli that we adopt. Taking the thesis that the *means* by which we produce an art object impacts upon its nature, it follows that amplifying the autonomy possessed by these means serves to broaden the range of objects that we can produce. By observing the successes and failures of this hybrid human-technology system, we can learn new ways of working which may otherwise not have arisen.

In the mainstay of this chapter, we examine human-agent partnerships from several perspectives, identifying a number of characteristic properties which distinguish them from their predecessors in the non-digital world. Along the way, we formulate a series of taxonomies which can be used to as a starting point to categorise different forms of creative technological partnership.

Before doing so, we will take a step back and consider some theoretical building blocks relating to tool use. We will later draw on these ideas in our discussion of digital tools and interactive music systems.

7.1.1 Thinking Through Tools

> People need new tools to work with rather than tools that 'work' for them. (Illich 1973, p. 10)

In daily life, the use of tools is second nature to us. We seamlessly conduct our goal-orientated activities via physical objects without the slightest awareness that we are doing so. So accustomed are we to the use of knife and fork, computer keyboard, can-opener and door-key, that the only times we become aware of their presence is when they malfunction and interrupt our activity (Heidegger 1977).

Through the complex mechanical and chemical mediation of biro on paper, we are able to convey structures of our thought to unseen recipients. Consider the example of a drawn diagram. Relationships between spatial and temporal elements can be relayed clearly and concisely, with reasonable expectation that the message will be successfully received. Moreover, by working through the details of the diagram on paper—through sketching, drafting, and observing the formalised realisation of our ideas—we can use the process of diagramming as a means to develop our own thoughts (Goel 1995). Yet, the role of the pen is completely invisible throughout. If we were continually distracted by the task of gripping the biro and steadily applying its nib to the paper, the task of relaying our ideas would be insurmountable.

In a well-known encounter, the physicist and Nobel laureate Richard Feynman discusses the archive of his own pen-and-paper notes and sketches. When asked about these "records", Feynman retorts:

> ... it's not a *record*, not really. It's *working*. You have to work on paper and this is the paper. (Clark 2008, pp. xxv, original emphasis)

The implication here is clear. This physical transduction of ideas—through arm, hand, pen, paper, and back to the mind via our optical apparatus—is not simply a trace of what is going on in our mental hardware, but an integral part of the thinking process. The application of pen on paper cannot be considered a passive artifact but as a fundamental machinery responsible for "the shape of the flow of thoughts and ideas" (Clark 2008).

The above case is cited as an exemplar of what Andy Clark terms the "extended mind" hypothesis (Clark and Chalmers 1998). In brief, Clark argues that the adoption of pen and paper and other such "cognitive scaffolds" serves to shift the actual processes of thought outside of our brains and bodies, and that our sensorimotor interactions with can-openers and door-keys are embodied forms of thinking. We can consider ourselves as "open-ended systems—systems fully capable of including non-biological props and aids as quite literally parts of [ourselves]" (Clark 2003). Just as our mental conditioning serves to subtly affect our reactions to tasks, so too do the nuanced differences in the form and function of the physical tools through which we act.

Feynman was in good company when observing that writing could be a form of active thinking, rather than simply passive transcription. A century earlier, Nietzsche's adoption of the typewriter had impelled him to observe that "[our] writing tools are also working on our thoughts" (Kittler 1999). Something new emerges from this formulation that we will return to shortly: that the causal relationship between tool and user is fundamentally reciprocal. We live through our tools, and our tools shape our experiences. Actions with tools involve a *feedback loop*. It is our belief that feedback loops are key to the creative process (McGraw and Hofstadter 1993); the reader will observe them cropping up repeatedly throughout this chapter.

Needless to say, many eras of industrial development have provided us with a menagerie of tools far more exotic than the typewriter, biro or can-opener. We will focus on one specific example, albeit the most general-purpose example that we can currently imagine: the digital computer.

7.1.2 The Computer as Meta-tool

The traditional conception of a tool is an implement which provides us with mechanical means to carry out some task that exceeds our natural capabilities; consider unscrewing a nut, or levering open a crate. *Epistemic* tools, such as the abacus, can perform the same role in the domain of cognition (Norman 1991, Magnusson 2009). The information age has heralded a qualitatively new kind of cognitive extension, in the form of digital computing devices. Equipped with a programmable computer, and given an appropriate physical interface, we can produce a wide array of epistemic tools. The computer, therefore, is a meta-tool, a platform upon which we can build and use new forms of cognitive scaffolding.

The tools that we construct upon this platform do not themselves have to be static and single-purpose. Their functionality can adapt to new contexts—even those which have not been anticipated ahead of time. Software components can be modularised and aggregated, resulting in complex assemblages which incorporate the features of multiple sub-tools.

Moreover, we can confer upon our computational tools a degree of unpredictability—a most useful property when seeking to catalyse innovation and one less common in mechanical tools. With digital pseudo-random number generators, we can harness the power of chance processes, deploying them in targeted contexts to stimulate and provoke by providing new options and uncertainty.

With more sophisticated software, applications can respond with extended, nonlinear outputs, opening up vistas of possibility in comparison to the predictable one-to-one response of a traditional tool. Sufficiently complex computational systems can operate with autonomy, produce novelty, and make assessments about fitness to purpose, all characteristics associated with creativity (Boden 2004).

Throughout this chapter we will assume that our agents are "black boxes" (Latour 1994), closed to functional modification and analysis; for all intents and purposes these programmed devices, though capable of semi-autonomous action, can be considered as a tool.

7.1.3 Digital Partners in Creative Practice

Looking towards the sphere of modern musicianship, we have seen technology emerge at countless new loci, bringing about new functional relationships and modes of engagement (Brown 2000). Almost all of the disparate tasks involved in music-making can now be performed using a single digital device: from recording, arrangement and production, through to networked collaboration and distribution to listeners.

Lubart (2005) proposes a loose taxonomy of the roles that we can metaphorically consider a computer as playing within a creative context: as a *nanny*, taking care of routine tasks and freeing up our cognitive faculties for the real creative grist; as a *penpal*, aiding the process of communication and collaboration; as a *coach*, providing exercises and collections of related knowledge through a targeted database system; and as a *colleague*, working as a "synergistic hybrid human-computer system" to explore a conceptual space in tandem. Though some of the associative elements of the "coach" role are relevant to this discussion, we are here mostly concerned with the latter case, in which the computer is embedded within the same creative framework, co-operating to create a work through a succession of interactions, to form a *partnership* between creator and computational system (Brown 2001).

The capacity for autonomy in computational systems can allow them to operate with distinct agency in the creative process, a property described by Galanter as *generativity* (Galanter 2003). When using generative processes, the artist sets up a system with a given set of rules. These rules are then carried out by computer, human, or some other enacting process.[1] A purely generative work involves no subsequent intervention after it has been set in motion; a work with no generative elements has no capacity for autonomous action, and so requires continual intervention to operate.

The class of systems that we are interested in lies somewhere between those which are purely generative and those which must be manually performed. Such a system is *interactive*; it does not produce output which is completely predictable from an artist's input, nor does it simply follow only its internal logic. The output of such a system follows somehow from the previous marks of the artist (and, in some cases, the computational system itself), but its output is mediated through some predetermined structure or ruleset. A prominent example is François Pachet's *Continuator* (Pachet 2003), which captures the performance of a user and subsequently plays it back under some statistical transformations.

Systems capable of such creative interactions can be described as having *agency*. Philosophically, agency is typically aligned with intent, goal-based planning, and even consciousness. It is not this strong type of agency that we are attributing to generative art systems. We have in mind a broader, anthropological description of agency, closer to that provided by Gell (1998) in relation to art objects. Here, agency is attributed to anything seen to have distinct causal powers.

> Whenever an event is believed to happen because of an 'intention' lodged in the person or thing which initiates the causal sequence, that is an instance of 'agency'. (Gell 1998, p. 17)

[1] For examples, see the crystal growth of Roman Kirschner's installations, Hans Haacke's *Condensation Cube* (*1963–65*), or Céleste Boursier-Mougenot's *Untitled* (*2010*), in which zebra finches are given free reign over a gallery of amplified electric guitars.

Such a liberal definition allows agency to be attributed even to fixed, inert objects such as coins, clarinets, and cups (d'Inverno and Luck 2004)—in fact, many objects which are more inert than the class that we are interested in.

We will restrict our discussion of agency to those entities which demonstrate behaviour that can be classified as generative; that is, with the productive capacity to autonomously produce musical output. By partnering with an interactive, generative system, we enter into a form of distributed agency, incorporating multiple distinct productive drives. Yet having agency alone does not ensure aesthetic interest; for that, we need creativity. In the human-computer partnerships we are concerned with in this chapter, creativity inheres within the distributed system as a whole.

7.2 Computational Aides for Algorithmic Inspiration

There is an extensive ancestry around strategies to provoke and direct creative action. A commonplace example is the varied pursuit of *inspiration*. A dressmaker, bereft of creative direction, might browse the shelves of the haberdashery for ideas in the form of patterns, fabrics and accessories. A web designer may surf through collections of layouts or graphic images; indeed, at the time of writing, popular social bookmarking site Delicious[2] lists over 4,500,000 web pages tagged with the keyword "inspiration". Such creative foraging is so ubiquitous across the creative industries that countless published collections are available—within design, fashion, architecture and advertising—whose sole purpose is the provision of creative nourishment.

In making the switch to outside sources of inspiration such as these, we are augmenting our internal cognitive search and delegating our ideational activity to the external world. This can be considered as another case of the extended mind (Clark and Chalmers 1998)—or, rather, the extended imagination.

Many approaches, of course, demonstrate a more explicit intentionality than simply disengaged browsing. Csikszentmihalyi (1992), for example, recounts an ethnographical report of the Shushwap Native American practice of uprooting and relocating its village every 25–30 years. In doing so, they introduced novel, chaotic challenges to their living practice, ensuring a continual enrichment of cultural cycles.

More recently, the Surrealist writers sought to subvert the conscious mechanisms of decision-making by encouraging "automatic" drawing: the accumulation of pen strokes produced without rational control, whose result was claimed to express the subconscious or paranormal.

The chance operations of the Black Mountain College and the indeterminate works of the Fluxus group formally introduced aleatoric processes as a means of creative inspiration and delegation. The forefather of both schools is composer John

[2] http://www.delicious.com/.

Cage (1968), whose comprehensive engagement with chance, randomness and indeterminacy informed the work of countless members of the avant-garde (Pritchett 1993).

La Monte Young, a student of Cage's, was a key part of the early Fluxus movement. "An Anthology of Chance Operations" (Young 1963) is perhaps the paradigmatic text, collecting numerous instructional scores and "open form" pieces: those which leave significant constitutive elements open to choices made by the performer. In doing so, certain formal structures are imposed—some very loose, some very precise—which can act as catalysts or frameworks for artistic innovation.

The improvised painting of the Cobra group drew up a manifesto describing the process of "finding" a painting through its production, seeking an art which is "spontaneously directed by its own intuition" (Smith and Dean 1997, p. 108). Later, the American abstract expressionists adopted practices such as action painting, aleatoric and combinatorial techniques, thereby surrendering unmediated authorship of their works (Smith and Dean 1997, p. 109).

A broader approach is taken by Eno and Schmidt's *Oblique Strategies* cards (Eno and Schmidt 1975), which indirectly suggest escape routes from creative deadlock via koan-like prompts. Similarly, sets of lateral, discipline-agnostic "heuristics" are collected in the works of Pólya (1971) and de Bono (1992). A heuristic can be thought of as a problem-solving rule of thumb; its literal translation, as Pólya notes, means "serving to discover" (Pólya 1971, p. 113). Rather than offering a concrete, logically rigorous method, heuristics provide imprecise but plausible ways to tackle a problem. In this case, they suggest formal approaches, in the form of rhetorical questions such as "Have you seen it before?" (p. 110).

A markedly different tack was taken by the Oulipo movement, whose exercises in constraint offer new creative routes to writers—paradoxically, through *restricting* the parameters of their production (Matthews and Brotchie 2005). Similar constraints were present in the theatre of ancient Japan, whose ritualistic practices subscribed to a well-defined set of norms (Ortolani 1990). Submitting to external demands can be seen as another form of delegating artistic decisions, trading the openness of a blank slate for a more focused problem domain.

7.2.1 Computational Strategies and Algorithmic Aides

Historically, the potential for deploying computational technology in a creative context did not escape even the earliest computer scientists. Alan Turing's fascination with such ideas lead to the establishment of the field of artificial intelligence (Hodges 1985). Partly due to the limited success of artificial intelligence in developing fully autonomous computational systems, and partly because of the increased access to computing tools by artists and designers, experiments with creative partnerships between artists and computing systems began to flourish.

Early experiments in computer-aided composition are successively described by Hiller (1968), Chadabe (1984) and Ames (1987), with early experiments building on statistical methods and generate-and-test techniques using models of musical procedures. Koenig (Laske 1981) and Xenakis (2001) incorporated more thoroughgoing stochastic constituents in their composition, with scores and synthesis determined by multi-level algorithmic processes. So too did Cage in a handful of later multimedia works, including HPSCHD, a collaboration with Lejaren Hiller (Pritchett 1993, p. 159). Cornock and Edmonds (1973) describe the transformations that interactive tools were already effecting on the roles of both artist and audience, written in the terminology of "art systems" and multi-agency processes.

In the last quarter of the 20th century, increased computational power has enabled the wider use of real-time interactive systems (Rowe 1993, Winkler 1998) and generative simulation systems based on physical and biological processes (Berry and Dahlstedt 2003, Nierhaus 2009). Other major touchstones of algorithmic composition include Karlheinz Essl's *Lexikon Sonate* (1992), David Cope's *Experiments in Musical Intelligence* (1996), and George Lewis's *Voyager* (2007).[3]

Interactive tools for musical creativity have begun to make their way into popular culture in a number of forms. Brian Eno (1996) has historically championed the cause of generative music through his significant media profile, recently creating algorithmic soundtracks for games such as Electronic Arts' *Spore*.[4] The translations of his ideas to the popular iPhone and iPad formats, in interactive ambient sound apps such as *Bloom*,[5] have attracted popular attention to generative music systems and this and similar apps underscore a move toward music making with semi-autonomous music systems.

7.3 The Human-Computer Partnership: Characteristics and Categories

Interaction with a semi-autonomous music system inhabits an unfamiliar midpoint on the spectrum of creative relationships. It resides somewhere between tool usage and human collaboration, inheriting some characteristics of each and adding some of its own.

In this section, we will explore creative partnerships with generative computational systems from a number of distinct but related perspectives, with a view to a fuller appreciation of the potential opportunities and hazards that such partnerships can yield. These perspectives do not follow a strict progression, but are ordered based on an attempt to guide the reader intuitively, beginning with abstract principles and ending with issues of assessment and evaluation. To provide an overview, we briefly summarise each below, before expanding further in the following sections.

[3] For a more complete history of algorithmic composition, we refer the reader to Collins (2009).

[4] http://www.spore.com/ftl.

[5] http://www.generativemusic.com/.

- **Feedback** (7.3.1)
  In which we examine the multi-level feedback loops which characterise creativity, particularly the iterated cycle of *generation* and *evaluation*.
- **Exploration** (7.3.2)
  In which we discuss different ways that novelty and serendipity can be introduced by algorithmic means.
- **Intimacy** (7.3.3)
  In which we argue towards the need for trust and intimacy with a generative partner, and the surrounding issues of embodiment and predictability.
- **Interactivity** (7.3.4)
  In which we introduce five classes of productive dialogue that can be entered into with a computational partner: *directed, reactive, procedural, interactive* and *adaptive*.
- **Introspection** (7.3.5)
  In which we consider computational partners as a conduit for introspection, allowing us to reflect on our existing creative habits.
- **Time** (7.3.6)
  In which we review different timescales of the creative feedback loop, ranging from seconds to centuries.
- **Authorship** (7.3.7)
  In which we reflect upon issues of authorship and non-human agency, and the surrounding moral objections.
- **Value** (7.3.8)
  In which we discuss the differences and difficulties in assessing the aesthetic value of an art object produced with computational partners, and the proper evaluation of autonomous creativity tools.

Throughout this coverage, we will continue to draw on key examples from the field of algorithmic composition and interactive performance.

7.3.1 Feedback

> Already at the very beginning of the productive act, shortly after the initial motion to create, occurs the first counter motion, the initial movement of receptivity. This means: the creator controls whether what he has produced so far is good.
>
> – Paul Klee, *Pedagogical Sketchbook* (1972, p. 33)

Feedback is at the very heart of creativity, from Klee's "initial motion" to the point at which we stand back and decide that a work has reached its finished state. We oscillate back and forth between creative acts and reflection upon those acts, with each new mark, note, or theorem offering subtle potential to alter the direction of a work. This is a *feedback loop*, in which data about the past informs the events of the future. After each new brushstroke, what *was* just about to happen is *now* in the past, and will affect whatever we do next. It is this short cycle of repetition (depicted in Fig. 7.1), in which the output of one act becomes the input for the next, that constitutes feedback.

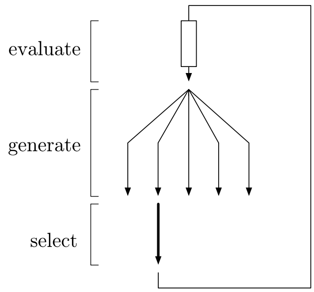

Fig. 7.1 The central feedback loop of the creative process. We iteratively *generate* creative acts, and *evaluate* how they fit into the work in its entirety

McGraw and Hofstadter (1993) describe this very cycle as the "central feedback loop of the creative process":

> Guesses must be made and their results are evaluated, then refined and evaluated again, and so on, until something satisfactory emerges in the end. (McGraw and Hofstadter 1993, p. 16)

Reducing this to its most abstract form we are left with two elements which repeat until we are satisfied with the outcome. These two elements are:

- **generation** (of the guesses that are made), and
- **evaluation** (of their results)

During the creative process composers switch from one to the other, alternating between the generation of new elements and the evaluation of the piece in its entirety.

The underlying goal of many of the computer-aided compositional strategies described above (Sect. 7.2) is to tinker with the makeup of these generate/evaluate activities, artificially expanding or warping the typical creative trajectory (Fig. 7.2). As we amplify the pool of material available for generation, we increase our creative scope. If we constrain the pool, we free up our decision-making faculties in favour of a deeper exploration of some particular conceptual subspace. Likewise, imposing a particular creative event enforces a radically new situation which demands an appropriate response, potentially introducing unanticipated new possibilities.

Generation by the computational system needs to be externalised, typically as sound or score, for our response. However, much of the human "generation" is internalised, a product of the free play of our imaginative faculties. By considering a collection of stimuli in the context of a given project, we can assess their potential to be incorporated. Disengaged browsing and creative foraging throw new (material) elements into our perception, enriching the pool of generative source material.

Imaginative stimulation is often assisted by reflective questioning. The likes of Oblique Strategies (Eno and Schmidt 1975) and Pólya's heuristics (1971) perform these types of operations as a way to provide lateral cognitive stimulus. Examples drawn from the Strategies include *Change ambiguities to specifics*; *Don't avoid what is easy*; *Remove a restriction*; and *Is it finished*?

These directives advocate a change to the parameters that we have tacitly adopted for our generation/evaluation routines. Some serve to highlight hidden, potentially

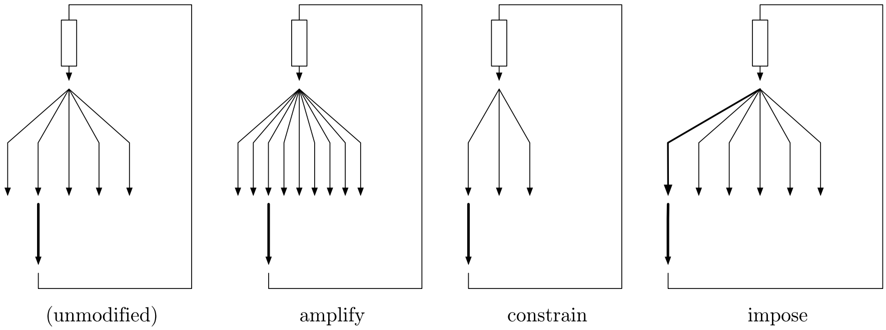

Fig. 7.2 Transforming the feedback loop using artificial methods. With generative (and even traditional) tools, we can *amplify* or *restrict* the pool of potential creative material, or *impose* a radically new direction

artificial constraints; others suggest explicitly imposing such constraints, to see what pops out.

In contrast with simple browsing, which expands the pool of creative *content*, these strategies amplify the diversity of *formal* ideas to utilise in a project. They feature analogy-based approaches, which can suggest metaphorical linkages with other domains, working on the presupposition that certain systemic structures can bear fruit when applied in a new field.

7.3.2 Exploration

Your mistake was a hidden intention

– Eno and Schmidt, *Oblique Strategies* (1975)

Let us return to the analogy of creativity as a search within a conceptual space, probing the dimly-lit peripheries of a problem for undiscovered terrain.

To take a purely logical stance, we can imagine such a search as the sequential application of deductive rules: *if* I have just played the dominant seventh, *then* I should next play the major tonic, *except* in the case that I wish to avoid immediate resolution, in which case I will play the major fourth. Many theoretical models of cognitive processes, prominently Markov chains (Wiggins et al. 2009), follow conditional rules, moving between states with probabilities that can be inferred from existing patterns of behaviour.

If we possessed such a cognitively-encoded ruleset for a given domain, and imaginative acts were simply the derivation of new consequences of these rules, it seems at first glance that the creative field would remain static and invariant. On a small scale, a fundamental source of diversity lies in relaxing or bluntly flouting these rules. Citing Thelonius Monk and his endeavours for his music "to find other places", Prévost (2004) suggests that the aspects of chance in an improvised musical performances are opportunities to make unforeseen *errors* which can subsequently

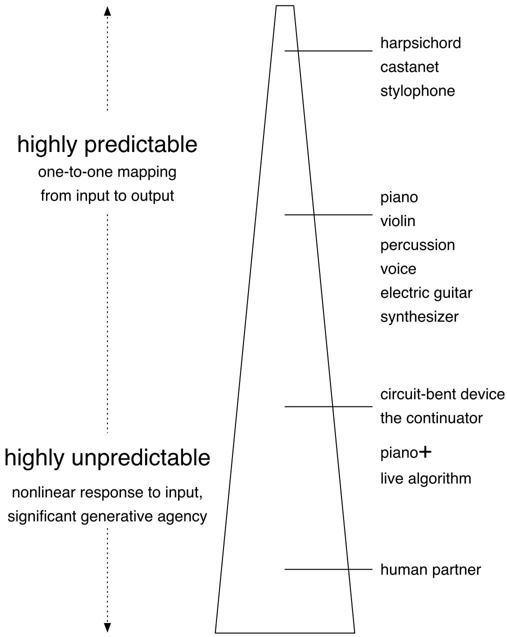

Fig. 7.3 A rough scale of predictability. Traditional acoustic instruments, giving tacit, embodied knowledge, have a one-to-one mapping from physical actions to acoustic events. On the *top* of the scale, instruments with only one degree of freedom (velocity or pitch) have limited variance. On the *bottom* of the scale, generative systems can produce an unlimited autonomous response to action, resulting in a more opaque experience. Human collaborators, though sometimes predictable, are capable of effecting a radical transformation of the interaction rules

be followed and investigated. He recounts a tale in which Monk, frustrated with an improvised performance, complained that he had "made all the wrong mistakes" (Prévost 2004)—indicating the existence and appeal of *correct mistakes*, which may aid us in this creative search.

To follow this path intentionally, then, we are effectively designing for *serendipity* (André et al. 2009, van Andel 1994): tacitly encouraging or inducing "correct mistakes" as a route to unforeseen discoveries and new creative terrain; introducing "disorder", as John Cage ordained (Cage 1968). One piece of generative music software that exploits these characteristics is Intermorphic's *Noatikl*.[6] This system relies heavily on constrained stochastic choice in selecting musical values and is advertised as a tool to "generate new ideas" and "break composer's block" (Cole and Cole 2008), providing an explicit use of aleatoric processes as a way of developing unexpected alternatives and jolting composers out of familiar habits and patterns.

A given creative act can generate a class of output along a scale of predictability as illustrated in Fig. 7.3. We may have complete, trained control over our actions, or we may surrender some control to chance. This surrender may be accidental (we slip and stumble) or intentional (we may use automatic writing, heavy air notes, or chance processes). Both these kinds of accident—intentional accidents and accidental accidents—can be retrospectively incorporated into the work.

[6] http://intermorphic.com/tools/noatikl/.

To clarify further, we shall take a look at some examples. Native Instruments' *Absynth*[7] is a virtual synthesiser, with scores of user-adjustable parameters to control a range of synthesis techniques. Alongside these determinate controls, Absynth has a feature called 'mutate'. When triggered, this nudges its parameters in random directions. Given the complex web of relationships between parameters, the output can thus be wildly unpredictable, whilst retaining a link to the previous settings. This may prompt the user to make further adjustments or suggest new sonic directions, purely through chance discoveries.

The tabletop *reacTable* (Jordà et al. 2007) device likewise has a *reacTogon* instrument which uses chance processes in hands-on interaction. Sequences of events are generated by nodes on a hexagonal grid, which collide and intersect to create unpredictable chain reactions, generating note sequences which could not be anticipated ahead of time. Effectively, we are exploring the space of *interactions* with a partner system, making use of its inherent scope for serendipity.

The fundamental benefit of these systems is that they can push us into new forms of creative adventure, by augmenting both the generative and evaluative aspects of the central creative loop. By introducing processes from outside the canon of traditional musical practice we are injecting innovation which may not have occurred through incremental, exploratory development. Such processes can generate new fragments of material that can be assimilated and modified by the artist.

In an interview, Björk Gudmundsdottir recounts an anecdote regarding composer Karlheinz Stockhausen and his everyday pursuit of the unfamiliar.

> Stockhausen told me about the house he built himself in the forest and lived in for ten years. It's made from hexagonal pieces of glass and no two rooms are the same, so they are all irregular. It's built out of angles that are reflective and it's full of spotlights. The forest becomes mirrored inside the house. He was explaining to me how, even after ten years, there would still be moments when he didn't know where he was, and he said it with wonder in his eyes. And I said, "That's brilliant: you can be innocent even in your own home", and he replied, "Not only innocent, but curious." (Gudmundsdottir 1996)

We experience a similar effect when we switch to a non-standard interface for composition. From experience, the first interactions with a system such as the *reacTogon* or McCormack's *Nodal* (McCormack et al. 2008) give rise to a creative play which pushes the user towards unfamiliar terrain. By overcoming the habits formed when repeatedly using a given interface or mode of creative operation, our curiosity and openness are restored.

In all of these cases, the "central loop of the creative process" (McGraw and Hofstadter 1993) is being widened to incorporate agencies which are not present in what may be considered "normative" creativity. The Romantic conception of an isolated painter, toiling for weeks over a canvas in visual engagement with his subject, makes way for a hybrid, collective creative intelligence, whose output is the result of an internal tussle between heterogeneous and nonaligned forces.

[7] http://www.native-instruments.com/en/products/producer/absynth-5/.

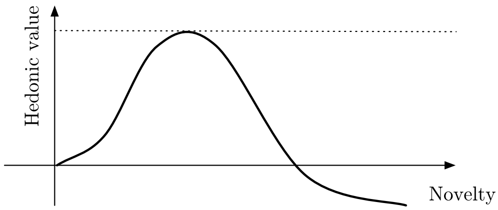

Fig. 7.4 The Wundt curve. As novelty increases, gratification rises to a peak, falling again as we move towards more extreme unfamiliarity

7.3.3 Intimacy

To enter into a meaningful and enduring relationship with a tool or creative partner, we must secure a degree of trust in it: trust that its responses will have some relevant correlation with our own, rather than it disregarding our inputs and behaving completely autonomously; trust that we can gain an increasing understanding of its behaviour over time, in order to learn and improve our interaction with it, either through embodied (tacit, physical) or hermeneutic (explicit, neural) knowledge; and, in the case of computational or human partners, trust that its activity will continue to generate interest through autonomous creative exploration. In other words, the output of such a system should be novel, but not too novel; as represented by the Wundt curve shown in Fig. 7.4.

Creative interaction with generative systems is often premised on a duality, wherein the computational system generates material and the human acts as a fitness function, selecting or rejecting materials and arranging them into a final product. This would be a tiresome process if the generated material varied widely from what was required. Consistency of operation also improves the confidence of an artist in the output of a generative system. Confidence and predictability in the system contribute to the development of a partnership and, ultimately, to the productivity and quality of the work.

Predictability aside, it is clear that all designed artifacts, including generative systems, are biased by decisions made by their developers and by the materials and processes they use. We must align our thinking with the patterns and prescribed methods that underlie the design thinking of the system (Brown 2001). Understanding these patterns is necessary to get the best out of the system.

For an effective partnership with a computational tool, we suggest that it is necessary to accept such biases as characteristics, rather than errors to be fighting against. Again, taking the analogy of a traditional musical instrument, good musicians learn to work within the range of pitch, dynamics and polyphony of their instrument as they develop their expressive capability with it.

A quite different difficulty lies in the material status of our tools. Magnusson (2009) argues that acoustic and digital instruments should be treated with categorical difference, with implications for our ontological view of their interfaces. The core of an acoustic instrument, he argues, lies in our embodied interaction with it, realised through tacit non-conceptual knowledge built up through physical experience. A digital instrument, conversely, should be understood hermeneutically, with its core lying in its inner symbolic architecture. Tangible user interfaces are "but arbitrary peripherals of the instruments' core" (Magnusson 2009, p. 1).

This implies that our interactive habits are developed quite differently with a digital tool. When playing an acoustic instrument, we can typically offload a large amount of cognitive work into muscle memory, which, with practice, can handle common tasks such as locating consonant notes and moving between timbres. An alternative to this development of embodied habituation for computational systems is the use of automation and macros that can capture repeated processes and actions.

This type of process encapsulation is inherent to many generative computer composition systems including *Max/MSP*,[8] *Supercollider*,[9] *Impromptu*[10] and so on. The hierarchical arrangement of motifs or sections that this type of encapsulation allows is well suited to music compositional practices. These come together in an interesting way in the software program *Nodal*,[11] in which generative note sequences and cycles can be depicted as graphs of musical events (nodes). Nodal allows for the creation of any number of musical graphs and for the user to interact with them dynamically. The behaviour of individual nodes can be highly specific, providing confidence in the exact detail of music generated, while musical fragments and riffs can be set up as independent graphs that "capture" a musical idea. However, despite this level of control and encapsulation, the interactions between nodes and graphs can give rise to surprisingly complex and engaging outcomes.

7.3.4 Interactivity

One of the affordances of computational systems is the shift from the traditional interactive paradigm, in which one action results in one musical response, to "hyperinstruments", which can respond to actions with multiple, structured events. This can be seen as meta-level composition or performance, described by Dean as "hyperimprovisation" (Dean 2003), where a computational improvisatory partner does more than react to human responses.

McCullough (1996) advises that dynamic control over high level operations rather than low level details yields a sense of control over a complete process in tool usage generally. This kind of meta-control is typical of manipulating generative processes. Beilhartz and Ferguson (2007) argue that the experience of connection and control for generative music systems is critical; "The significance of generative processes in an interactive music system are their capability for producing both a responsive, strict relationship between gesture and its auditory mapping while developing an evolving artifact that is neither repetitive nor predictable, harnessing the creative potential of emergent structures" (Beilhartz and Ferguson 2007, p. 214).

As a consequence of the more structured possibilities for tool-use relationships, many different kinds of control flow exist within computational creative tools

[8] http://cycling74.com/products/maxmspjitter/.

[9] http://supercollider.sourceforge.net/.

[10] http://impromptu.moso.com.au/.

[11] http://www.csse.monash.edu.au/cema/nodal/.

Fig. 7.5 Example of a drawing produced with Ze Frank's reactive v_draw system (zefrank.com/v_draw_beta). The volume level of sounds produced by the user is translated into lines on screen: quiet noises turn the line anticlockwise, loud noises turn the line clockwise

(Fig. 7.6). Awareness of these and how they might be combined within or across a generative system is an important step toward a better understanding of the range of creative relationships that are possible.

A *directed* tool is the classical form of computational application: controlled through a typical HCI device (mouse, keyboard, touchscreen), these are used to mediate creative acts onto a screen or printing device. The user exercises control over the outcome of their actions, which is produced (effectively) immediately. Typical examples are desktop applications for graphics, musical composition or word processing, such as Adobe Photoshop and Sibelius. Such a tool should operate predictably and readily learnable.

A *reactive* tool senses a user's creative acts, through a microphone, camera or other sensor, and responds proportionately—often in another sensory domain. A commonplace example is the real-time visualisation of music, as exemplified by the likes of Apple's iTunes media player. No expectation is produced for further development within the aesthetic narrative, though the user may be able to learn and master the mode of interaction.

Other examples of reactive tools include Ze Frank's *v_draw*[12] web application, which maps sound volume levels into drawn lines (see Fig. 7.5). Amit Pitaru's *Sonic Wire Sculptor*[13] performs the same operation in the other direction, transforming drawn 3-D structures into looping sound.

A *procedural* system involves a fixed process, typically designed by the user, which unfolds gradually when triggered. Examples include the phasing techniques used by Steve Reich, Iannis Xenakis' physical simulations of particle clouds, and the plant growth models of Lindenmayer systems (McCormack 1996). Though some indeterminate elements may be present, and a seed configuration may be input by the user (as in the case of L-systems), no subsequent intervention is required or expected.

[12]http://www.zefrank.com/v_draw_beta/.

[13]http://pitaru.com/sws/.

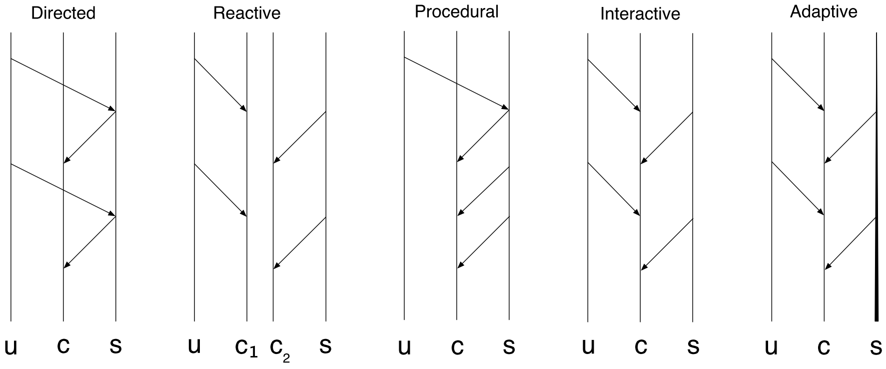

Fig. 7.6 Types of interactive dialogue. *u* is the user or artist; *c* is the “canvas” or constructive space; *s* is the computational system, which when adaptive changes its behaviour over time

An *interactive* system, conversely, tracks its users actions and responds to them within the same “canvas”, creating the potential for further development upon the system’s actions. This canvas may be an acoustic space, the virtual page of a word processor, or even a physical sheet of paper. It then becomes possible to respond to the system’s output, potentially reshaping *its* direction as well as our own. The outcome contains elements of both the system and user and attribution to each becomes blurred. An example is the MetaScore system (Hedemann et al. 2008) for semi-automatic generation of film music via control of a generative music system’s parametric envelopes.

An *adaptive* system extends beyond the interactive by developing its behaviour over a time period. These systems change the dynamics of their responses according to the history of observations or behaviours. This introduces a behavioural plasticity which allows its activity to remain relevant and novel to its user. Tools falling into this class often make use of dynamical systems such as neural nets (Miranda and Matthias 2005, Bown and Lexer 2006, Jones et al. 2009), evolutionary algorithms (Brown 2002) and ecosystems (McCormack 2003, Jones 2008; see also Chap. 2 in this volume).

7.3.5 Introspection

Early theorists of computer music—partly, no doubt, as a consequence of the technological limitations of the era—placed emphasis on the purification of the compositional process as a way of better understanding our own behaviours, either personal or cultural (Supper 2001, Hiller 1968, Ames 1987). To model the processes that tacitly underlie a existing musical system, we must first formalise them in an effectively computable form; i.e. transform them into a set of algorithms, with which we can generate new pieces that fall into the same class. By creating a computer program which executes these algorithms, we are therefore exploring the range of works within this class, which can enhance our understanding of their properties.

Besides the formal benefits offered by describing a style in an algorithmic form, this also serves to reveal selective bias within the application of these procedures. It is distinctly possible that artists fail to follow one pathway in some creative terrain due to their tendency to automatically follow a more normative path, as trodden by previous artists or by themselves on previous occasions. Like many tools, algorithmic descriptions of music are likely to emphasise existing tendencies, some of which the composer may previously been unaware of; conversely, there are many examples in the field of empirical musicology (e.g. Huron, 2006) in which algorithmic processes reveal novel patterns.

We might also create conjectural models based on emergent cognitive properties of music perception, such as those of Narmour (1990), Temperley (2007) and Woolhouse (2009). Rather than construct a descriptive system through stylistic analysis, this approach incorporates sensory capabilities such as patterns of auditory perception that exist *behind* traditional systems of musical composition—the systems beneath the systems. Such models allow us to reflect on the meta-reasoning behind whole classes of compositional style, such as the Western diatonic tradition.

We can likewise develop our insight into wider cognitive processes through computational simulation. Tresset and Leymarie's *Aikon-II*[14] creates facial sketches by observing the subject's salient features and drawing with a mechanical plotter on paper, visually perceiving the sketch as it draws. The project aims towards gaining an understanding of our own observational mechanisms by computationally implementing them, and in doing so illuminating any irregularities in the theory that may not exposed by contemplation.

The above approaches can be viewed as applied forms of cultural study, serving to illuminate historical and social tendencies on a broad scale. Following Boden's (2004) distinction between H-creativity (historical creativity, novel to an entire historical frame) and P-creativity (personal creativity, novel only to its creator), we describe this pursuit of understanding through cultural modelling as *H-introspection*.

Its counterpart is *P-introspection*, which applies to tools used to reflect and understand the user's personal creative acts. An example of P-introspection is Pachet's *Continuator* (Pachet 2003), which uses a Markov model to reflect a player's performance style through its statistical properties. The approach taken by the Continuator is what Spiegel (1981) describes as "extrapolation": the "extension beyond that which already exists in such a way as to preserve continuity with it, to project from it...". The high-level characteristics of a style are maintained, whilst creating new works "projecting" from the original.

By mirroring certain properties in such a way, the player may become attuned to features that they were not aware they exhibited, leading towards a more insightful mode of creative development.

[14]http://www.aikon-gold.com/.

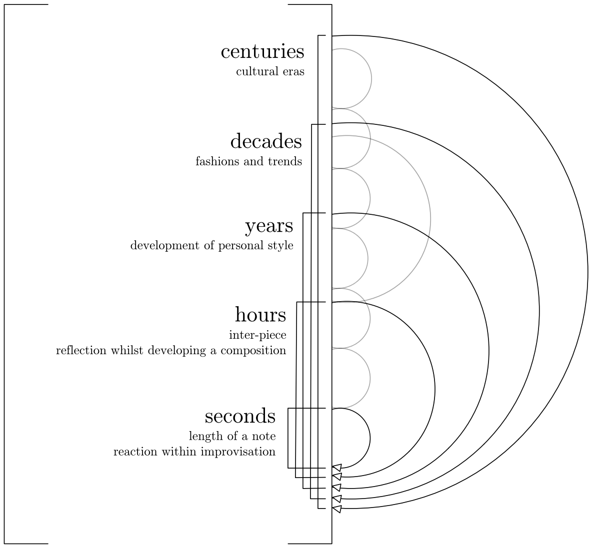

Fig. 7.7 Hierarchy of feedback timescales. Our actions at any point are a cumulative consequence of previous activity and reflection, with such reflection operating over a number of temporal levels

7.3.6 Time

A defining factor of the feedback loop between human and computational partners is the time taken for feedback to occur—that is, the period that it takes to produce and reflect upon each new act. Generation and reflection operate in a nested hierarchy, over multiple timescales (Fig. 7.7), each reflecting qualitatively different parts of the creative process.

We will briefly consider the representatives of digital technology within each of these timescale brackets: seconds and milliseconds, hours and minutes, years and months, centuries and decades. The boundaries of these temporal categories are not well defined and simply depicts a continuum from short to long time scales.

Seconds: On the micro-level, of seconds or less, an improvising musician produces sound events (notes, beats, timbres), observing their progression and relationships with the macroscopic structure of the piece in general. An error may be rapidly incorporated ("retrospectively contextualized" (Sawyer 2006)) into a performance and reclaimed as intentional, if the player possesses sufficient virtuosity.[15]

Numerous interactive pieces of software exist with which we can improvise and hone our skills. The likes of George Lewis' *Voyager* (Lewis 2000), Michael Young's *aur(or)a* (2008), and the field of live algorithms in general (see Chap. 6 in this volume) play the role of virtual partners, responding rapidly with semi-autonomy.

[15]See Pachet's discussion of bebop sideslips (Chap. 5) for a more in-depth treatment on how intentional error-like acts can be used to effectively demonstrate virtuosity.

Hours: On the scale of minutes and hours, we may develop a piece, adding phrases to sections and sections to movements. These can be replayed to observe their fit within the wider narrative.

Scaling beyond the length of a single piece of music, we have systems such as the *Continuator* (Pachet 2003), which reflects back the statistical properties of a user's musical behaviour over the length of entire phrases. The reward is that, through listening back to a distorted edition of their original patterns, the player can better understand their own habits by hearing them recontextualised.

Generative algorithms can be used to apply a similar process of segment organisation, perhaps with generated components or selections from a database. Applied in interactive composition environments, with an aesthetic fitness function provided by their human counterpart, such a process can provide an effective heuristic-based method of exploring musical possibilities (Wiggins et al. 1999).

The development of a single work is often achieved through iterated generation/evaluation with a particular interactive music system. It is also possible that an artist is able to modify the code of a music system co-evolving the work and the system. In this case a slower feedback loop can occur: the system is allowed to run, perhaps repeatedly, and its output observed (evaluation); based on this observation, the code is modified to alter or enhance the system's behaviour (generation). This process can be seen quite transparently in live coding performances, where code is written, run and modified as part of the live performance.

Years: Our personal style may develop with reference to previous works and external stimuli; a visit to a gallery may prompt a radical departure which causes us to rethink our trajectory, or consider it along a new axis. A prominent example of a system that evolved on this scale of feedback is AARON, an autonomous drawing system developed by Cohen (1995) over several years.

Developments at this scale can also be observed through data mining of musical corpus. For example, by matching musical phrases against a large corpus of recordings based on similarity measures, *Query-by-Example* (Jewell et al. 2010) enables its users to reflect on how their performances have developed over long periods—or relating them to bodies of other musicians' work. We could imagine such tools entering much more widely into the reflective practice of artists, allowing them to more closely understand their own historical lineage and their position within a wider context, potentially discovering hidden relationships with previously-unknown peers.

Decades: Over decades, cultural fashions ebb and flow. It is this temporal nature of styles which causes many works to fail to be accepted often for many decades. Punk, new-wave and dance music are all examples of cultural fashions in UK music for example.

Centuries: At the timescale of entire eras, we can interrogate historical tendencies through tools designed for H-introspection (Sect. 7.3.5). The work of empirical musicologists have laid some groundwork for computational analysis of trends at this scale, while musical models such as those of Cope (1996) study cultural movements by encoding them algorithmically and playing out their consequences. Insights from these approaches can aid us to better understand the mechanisms underlying these trends, potentially illuminating a class of valid compositions that can fall within the bounds of (say) a fugue or chorale.

7.3.7 Authorship

Tyrell: "More human than human" is our motto.

– (*Blade Runner, 1982*)

Collaborations with computational systems raise the issue of contribution toward and ownership of outcomes: when we replace parts of the creative process with an automated system, are we somehow dehumanising the resulting art object? Secondly, if such a system has been produced by another software designer, are we being invisibly driven by the tacit strategies and methods that have been encoded into the tool by their authorship? Finally, is it even *possible* to produce "creative" tools, and does it matter?

The "Inhuman" Argument If we accept that the output of a human-machine symbiosis will exhibit characteristics of both, it is frequently argued that we are introducing something (unfavourably) inhuman to a realm that is quintessentially human. At least as early as 1987, Charles Ames describes a "virulent" (Ames 1987, p. 1) resistance to the uptake of computer-aided composition on this basis.

We suggest that there are actually three underlying roots to this objection:

- that we are (knowingly or otherwise) cheating, by letting the tools do the work;
- that we are (presumably unknowingly) being directed by our tools into particular modes of operation;
- that recourse to reason alone has no place in musical composition in any case, a realm which should be driven by intuition, feeling, narrative, suffering, or other non-algorithmic concerns.

The last of these objections has been somewhat defunct in the world of avant-garde composition since Serialism or before. Barbaud (Ames 1987) responds with an elegant rejoinder:

> Music is generally called 'human' when it considers temporary or inherent tendencies of the mind, of part or all of a composer's personality. Such music is based on feeling and since it turns its back, in a sense, on pure knowledge, it might rather be called 'inhuman', for it celebrates what we have in common with all the animals rather than with what is individual to man: his reason. Algorithmic music is thus 'inhuman' only in one sense of the word, it is 'human' in as much as it is the product of rational beings. (Ames 1987, p. 173)

Similarly, in Nietzsche's comment on the typewriter "working on our thoughts", we are tempted to detect a certain pejorative tone in his voice: surrendering parts of our agency to technological devices, so the argument might go, means diluting our creative purity through the hidden bias effects of our supposedly passive tools.

Whether we prioritise intellectual or emotive forces, the acceptance of Gell's (1998) thesis negates such oppositions by arguing that *all* components of the creative process exert some agency. We suggest that the degree of such agency is not really of concern because the interactive nature of a creative partnership and the networked nature of a creative ecosystem inevitably involve some conflict and resolution, whether conscious or otherwise, and the only real concern is the status of the resultant art object itself. Contributions to the creative process can come from many directions, and while computational partners provide new opportunities, the complicated network of direct and indirect influences has long been acknowledged.

> … in truth, in literature, in science and in art, there are, and can be, few, if any, things, which in an abstract sense, are strictly new and original throughout. Every book in literature, science and art borrows, and must necessarily borrow, and use much which was well known and used before.[16]

No art production takes place in a vacuum, and is inherently made up of a nexus of eclectic forces, from the selection on instruments to the surroundings in which we develop our work. On the contrary, hermetically sealing our work within an isolation chamber would serve to starve it of the oxygen that it requires to live.

Despite this acknowledgement, the fear of technological control over our activities is deeply embedded in our culture. Themes such as these are pervasive in literature and film, from the 19th-century uncanny of Hoffmann's *The Sandman* to the dystopias of *1984*, the Borg species of *Star Trek* and the androids of *Blade Runner*. The ubiquity of networked agencies such as Web recommender systems, however, is surely beginning to allay these concerns in the public eye.

The "Invisible Hand" Argument Like with other tools, the design and development of generative music software locks in aspects of the maker's aesthetic judgement. When developing a tool which reflects a given process, certain decisions are made regarding the implementation, style, and scale of application. Further, when we incorporate general-purpose algorithmic tools the pertinence of this kind of argument rears its head in a different form: are we incorporating another *person's* creative work into our own?

As previously stated, our view is that all creative work is linked closely to its predecessors and the field in which it is located (Bown 2009). Insofar as we are taking a system and moulding it to our own goals and ends, adapting the frameworks of a third party are no more invidious than reading a magazine or visiting an exhibition in search of inspiration. Whether technological or conceptual, the raw material of ideas exists to be rebuilt, remixed and extended.

The "Creative Vitalism" Argument As we have seen previously, the objection to the idea that a computer can perform creative acts is deeply embedded in some parts of society. Noticing the level of emotive reactions to Cope's *EMI* computational composition system, Dennett comments:

[16] *Emerson v. Davies*, 8 F.Cas. 615, 619 (No. 4,436) (CCD Mass. 1845).

> It is apparently *not* crass, philistine, obscene ... to declare that all the first-order products of the tree of life—the birds and bees and the spiders and the beavers—are designed and created by such algorithmic processes, but outrageous to consider the hypothesis that creations of human genius might themselves be products of such algorithmic processes. (Dennett 2001, p. 284)

Prior to the 19th century, it was obvious to zoologists that the natural world could only exhibit its fantastic, interlocking adaptations by the hand of a designer. That a proposition is obvious, however, does not imply that it is true. The belief that the works of nature exceed the capacity of algorithmic processes is a failure of reasoning by analogy: nature appears to demonstrate the complexity of humankind's designership, and we have no better explanation, so we posit the existence of a superhuman designer. This kind of fuzzy reasoning may be useful as a rule of thumb, in the absence of a greater body of evidence, but is highly susceptible to the failings of human intuition.

However, we do not believe that this is critical to the proposition that there can be valuable creative partnerships with computational agents. Insofar as the creative acts are a result of both computer and human behaviours, the fundamentally important point is that the two together should exhibit some enhanced creativity. Rather than asking the question, "Can technology be creative?", the question can be formulated as "Can we be *more* creative with technology?" Surely, the history of human creativity with technology would suggest we can be optimistic about further extensions to this.

7.3.8 Value

During the early stages of an emergent media or technology, artworks often focus on the materiality of the medium itself. Take, for example, video art, sound sampling, and computer art. Over the embryonic years of each of these movements, many of the seminal works are those which place their medium at the forefront: Nam June Paik's distorted video signals highlighted the invisible ether of broadcast TV transmission; Christian Marclay's turntablism sonified the physical substrate of the wax record; Manfred Mohr's algorithmic drawings demonstrated the systematic, infinitely reproducible nature of computation.

These nascent experiments are undoubtedly a consequence of the exploratory and critical roles that art can play, acting as a speculum into the technology's intrinsic qualities. Subsequently, when a technology has been fully assimilated into society, it becomes a channel to convey other messages or perform other functions.

We see the same thing happening with computer-aided composition. Early practitioners such as Hiller and Isaacson (1958) and Xenakis (2001) foregrounded the formalised, computational nature of their compositions, explicitly presenting the work as being the result of automated systems. In doing so, this awareness became a part of the compositions' wider conceptual makeup: not just a piece of music, but a product of formal structures and mechanisms.

With the increasing maturity of such methods, the application of algorithms in composition has started to become more comfortably integrated with the rest of the cultural landscape. It is now incumbent on the critic to judge such hybrid human-computer works against the normal value scheme of creative works: responding to aspects of cultural fit, social impact, usefulness and beauty.

By incorporating generative processes into a feedback loop over which we then exercise selective control, one can effectively bypass the bulk of the arguments against the inhuman or uncontrollable nature of computational creativity: it is still the artist that exercises the decisive decision-making. For all the conceptual difficulty in realigning our technological understanding with our aesthetic past, the degree and complexity of reflection, development and conceptual weight are arguably all the greater.

Though a simplistic view of the human-computer creative partnership has the computer generating material and the human judging it, the reality in most systems is more complex. The degree to which the computational system or the human filters the results depends on the design of the system and/or the intent of the artists. Take, for example, the fairly hands-off approach (procedural interaction) of Iannis Xenakis with his *Gendyn* system, which was used to create the composition *Gendy 3* by generating complete works using handcrafted program settings. The final work was but one iteration selected by the composer. On the other hand, Biles' *GenJam* (Biles 1994) performs quite autonomously, improvising jazz solos created by a genetic algorithm and a database of human-performed solos. The user's control consists of playing solos that the system analyses and combines with other contextual musical information, including harmony and metre, to generate its own solos. During live performance with GenJam, there is no time for filtering of the computer's solos by the human partner.

Even though both these systems differ with regard to human filtering of the results, they both assume a considerable degree of autonomy over the generation of material. Generative systems with this degree of autonomy are often designed with a particular stylistic outcomes in mind in order to ensure that outputs fall within desired aesthetic boundaries. Other systems, such as *Nodal* (McCormack et al. 2008) and *Emily Howell* (Cope 2008), are more interactive, requiring the human to make frequent and often detailed decisions that guide the generative process. This approach can typically allow for a broader range of stylistic results because of the continual human guidance that is a check against undesirable output.

Regardless of the interaction and division of responsibility during the creation process, once music is completed by a human and generative system partnership, its value is judged like any other music by its audience appeal—whoever the audience is, and however value may be defined by them.

7.4 In Summary

> Most people who believe that I'm interested in chance don't realize that I use chance as a discipline. They think I use it as a way of giving up making choices. But my choices consist in choosing what questions to ask.
>
> – *John Cage* (Kostelanetz 1989, p. 17)

Over the course of this chapter, we have given a theoretical overview of computer-supported composition strategies, in which algorithmic systems serve to substantially augment an artist's creative activity. We hope to have convinced the reader that generative computational systems possess a distinctly new kind of agency within the creative loop, serving to increase novelty and productivity, with the distinct potential to transform creative behaviours even after our interaction with such a system has ended.

It should now be clear that there is no simple dividing line between passive and active tools; whether we explicitly encode autonomous functionality within our software or not, it still has a latent impact on the work that we do. Any description, therefore, of "normal" creative activity is a fallacy. Does our normative creativity occur after being locked in a room for a week, or after exposure to a buzzing cultural ecosystem of films, books, shops and media?

Given the capability of some interactive music systems to autonomously generate new creative trajectories on the same plane as their human counterparts, it seems only apt to characterise this relationship as a partnership. In many cases, however, it is likely that the less autonomous end of the spectrum—Absynth's randomised settings, for example—would not typically be considered as having any agency at all. Likewise, the tendency of certain production environments to funnel their users into certain modes of engagement is frequently overlooked as an active force within musical creation.

As computer music systems lend themselves to particular types of musical activity, they can be considered to embody a passive type of agency. Generative and analytical aspects of computational processes thus extend this agency to more active and significant levels. One hope is that the explicit consideration of generative tools as creative partners may heighten the awareness that even such minimal concerns *do*, in fact, impact on our creative behaviours more than we typically believe. How would the tone of this chapter have differed if it had been written in fountain pen on parchment, rather than plastic keys and a luminous LCD display?

7.4.1 Future Explorations

This research field, as with many areas of computational creativity, is still in its infancy. Partially due, no doubt, to the objections levelled in Sect. 7.3.7, these ideas have been gradual in taking hold within the musical world outside of avant-garde and academic composition. Moreover, for a composer to go beyond off-the-shelf tools and begin developing algorithmic approaches alongside their musical development has a major barrier of entry: namely, the technical know-how to do so, or the presence of an engineer-collaborator at hand.

In terms of a wider public perception, the most significant development for the field over the past decade has been a number of significant and high-profile incursions into the mainstream, often mediated through the gaming industry. The likes of *Rez*, *Elektroplankton* and *Bloom* enable casual players to make diverse and accomplished music through simple interfaces, giving a taster of what it may be like to engage with more advanced musical activities. A survey by UK charity Youth Music found that 19% of young people playing music games such as *Guitar Hero* were subsequently encouraged to start playing a musical instrument.[17]

Driven by this enlarged audience, new instruments are emerging which have some characteristics of these novice-friendly devices but with the scope to be used in more advanced, freeform contexts. The *Tenori-On*, a physical musical device designed by media artist Toshio Iwai, is a tactile sequencer with generative capabilities. Alongside attracting praise from untrained players, acting as an entry-level introduction to sequencing notions, the Tenori-On was used by innovative pop musician Björk on a recent tour. It can also be used to control user-created samples and external MIDI devices, eliminating another hidden limitation of many sound toys. With the inclusion of generative music capabilities in such devices, potential players are now presented with instruments which may reshape the gap between the beginner and the virtuoso musician, and enable many more of us to embrace creative partnerships.

7.4.2 Final Reflections

We could imagine quite different ways to group together and order these ideas. This format, however, has been brought about by our collective experiences within the field, based on the ideas, theories and questions which frequently emerge from applied use of computer-aided composition methods. It may well be that, as the field continues into maturity, further experiments will lead us to produce radically new sorts of questions and systemic categories.

Perhaps the single unifying factor which ties together each of these perspectives is that they all encourage us, in different ways, to reflect upon the entirety of creativity itself. To build generative software that operates appropriately in a creative ecosystem, we must secure some understanding of how we interact with our existing partners and tools, and how they interact with us. Likewise, designing new intimate interfaces to creativity means we must more fully understand what it means to develop a close relationship with an instrument, and the conditions necessary for virtuosity and value to arise from this.

Some understanding of the veiled process of creative partnerships with technology is necessary to drive the "productive entanglements" (Clark 2008) that we are here trying to foster. With luck, these entanglements should serve to reciprocally inform our understanding of creativity, creating another culture-scale feedback loop.

References

Ames, C. (1987). Automated composition in retrospect: 1956–1986. *Leonardo*, *20*(2), 169–185.

[17]"Why console-games are bigger than rock 'n' roll": http://www.youthmusic.org.uk/research-archive.html.

André, P., Schraefel, M. C., Teevan, J., & Dumais, S. T. (2009). Discovery is never by chance: designing for (un)serendipity. In *C&C'09: proceedings of the seventh ACM conference on creativity and cognition* (pp. 305–314). New York: ACM.

Beilhartz, K., & Ferguson, S. (2007). Gestural hyper instrument collaboration with generative computation for real time creativity. In *Creativity and cognition* (pp. 213–222). Washington: ACM.

Berry, R., & Dahlstedt, P. (2003). Artificial life: why should musicians bother? *Contemporary Music Review*, *22*(3), 57–67.

Biles, J. (1994). GenJam: A genetic algorithm for generating jazz solos. In *Proceedings of the international computer music conference* (pp. 131–137).

Boden, M. A. (2004). *The creative mind: myths and mechanisms*. New York: Routledge.

Bown, O. (2009). Against individual creativity. In *Dagstuhl seminar proceedings 09291. Computational creativity: an interdisciplinary approach*, Dagstuhl, Germany.

Bown, O., & Lexer, S. (2006). Continuous-time recurrent neural networks for generative and interactive musical performance. In *Lecture notes in computer science*. *Proceedings of EvoWorkshops 2006* (pp. 652–663). Berlin: Springer.

Brown, A. R. (2000). Modes of compositional engagement. *Mikropolyphonie*, *6*. http://pandora.nla.gov.au/tep/10054.

Brown, A. R. (2001). How the computer assists composers: a survey of contemporary practice. In G. Munro (Ed.), *Waveform 2001: the Australasian computer music conference* (pp. 9–16). The Australasian computer music association.

Brown, A. R. (2002). Opportunities for evolutionary music composition. In *Proceedings of the Australasian computer music conference* (pp. 27–34).

Cage, J. (1968). *Silence: lectures and writings*. London: Calder and Boyars.

Chadabe, J. (1984). Interactive composing: an overview. *Computer Music Journal*, *8*(1), 22–27.

Clark, A. (2003). *Natural-born cyborgs*. Oxford: Oxford University Press.

Clark, A. (2008). *Supersizing the mind*. New York: Oxford University Press.

Clark, A., & Chalmers, D. (1998). The extended mind. *Analysis*, *58*(1), 7–19.

Cohen, H. (1995). The further exploits of AARON, painter. *Stanford Humanities Review*, *4*(2), 141–158.

Cole, T., & Cole, P. (2008) Noatikl. http://www.intermorphic.com/tools/noatikl/index.html.

Collins, N. (2009). *Introduction to computer music*. Chichester: Wiley.

Cope, D. (1996). *Experiments in musical intelligence*. Madison: A-R Editions.

Cope, D. (2008). *Hidden structure: music analysis using computers*. Madison: A-R Editions.

Cornock, S., & Edmonds, E. (1973). The creative process where the artist is amplified or superseded by the computer. *Leonardo*, *6*(1), 11–16.

Csikszentmihalyi, M. (1992). *Flow: the psychology of happiness*. London: Rider Books.

De Bono, E. (1992). *Serious creativity: using the power of lateral thinking to create new ideas*. London: Harper Collins.

Dean, R. (2003). *Hyperimprovisation: computer-interactive sound improvisation*. Middleton: A-R Editions.

Dennett, D. (2001). Collision detection, muselot, and scribbles: some reflections on creativity. In D. Cope (Ed.), *Virtual music: computer synthesis of musical style* (pp. 282–291). Cambridge: MIT Press.

d'Inverno, M., & Luck, M. (2004). *Understanding agent systems*. *Springer series on agent technology*. Berlin: Springer.

Eno, B. (1996). Generative music. http://www.inmotionmagazine.com/eno1.html.

Eno, B., & Schmidt, P. (1975). *Oblique strategies: over 100 worthwhile dilemmas by Brian Eno and Peter Schmidt*. London: Apollo.

Essl, K. (1992). Lexikon sonate. http://www.essl.at/sounds.html#lexson-porgy.

Galanter, P. (2003). What is generative art? complexity theory as a context for art theory. In *GA2003—6th generative art conference*.

Gell, A. (1998). *Art and agency: an anthropological theory*. Oxford: Clarendon Press.

Goel, V. (1995). *Sketches of thought*. Cambridge: MIT Press.

Gudmundsdottir, B. (1996). Björk meets Karlheinz Stockhausen. *Dazed and Confused*, *23*.

Hedemann, C., Sorensen, A., & Brown, A. R. (2008). Metascore: user interface design for generative film scoring. In *Proceedings of the Australasian computer music conference* (pp. 25–30). Australasian computer music association.

Heidegger, M. (1977). *The question concerning technology and other essays*. New York: Harper & Row.

Hiller, L. (1968). *Music composed with computer[s]: an historical survey*. Experimental Music Studio.

Hiller, L. A., & Isaacson, L. M. (1958). Musical composition with a high-speed digital computer. *Journal of the Audio Engineering Society*, *6*(3), 154–160.

Hodges, A. (1985). *Alan Turing: the enigma of intelligence*. London: Unwin Paperbacks.

Huron, D. (2006). *Sweet anticipation: music and the psychology of expectation*. Cambridge: MIT Press.

Illich, I. (1973). *Tools for conviality*. London: Valder & Boyars.

Jewell, M. O., Rhodes, C., & d'Inverno, M. (2010). Querying improvised music: do you sound like yourself? In *ISMIR 2010*, Utrecht, NL (pp. 483–488).

Jones, D. (2008). AtomSwarm: a framework for swarm improvisation. In *Lecture notes in computer science*. *Proceedings of EvoWorkshops 2008* (pp. 423–432). Berlin: Springer.

Jones, D., Matthias, J., Hodgson, T., Outram, N., Grant, J., & Ryan, N. (2009). The fragmented orchestra. In *Proceedings of new interfaces for musical expression (NIME 2009) conference*, Pittsburgh, PA, USA.

Jordà, S., Geiger, G., Alonso, M., & Kaltenbrunner, M. (2007). The reactable: exploring the synergy between live music performance and tabletop tangible interfaces. In *Proceedings of the first international conference on tangible and embedded interaction (TEI)* (pp. 139–146). New York: ACM Press.

Kittler, F. A. (1999). *Gramophone, film, typewriter*. Stanford: Stanford University Press.

Klee, P. (1972). *Pedagogical sketchbook*. London: Faber and Faber.

Kostelanetz, R. (1989). *Conversing with cage*. London: Omnibus.

Laske, O. (1981). Composition theory in Koenig's project one and project two. *Computer Music Journal*, *5*(3), 54–65.

Latour, B. (1994). On technical mediation. *Common Knowledge*, *3*(2), 29–64.

Lewis, G. (2007). On creative machines. In N. Collins & J. d'Escriván (Eds.), *The Cambridge companion to electronic music*. Cambridge: Cambridge University Press.

Lewis, G. E. (2000). Too many notes: computers, complexity and culture in voyager. *Leonardo Music Journal*, *10*, 33–39.

Lubart, T. (2005). How can computers be partners in the creative process. *International Journal of Human-Computer Studies*, *63*(4–5), 365–369.

Magnusson, T. (2009). Of epistemic tools: musical instruments as cognitive extensions. *Organised Sound*, *14*(2), 168–176.

Matthews, H., & Brotchie, A. (2005). *The Oulipo compendium*. London: Atlas Press.

McCormack, J. (1996). Grammar based music composition. In R. Stocker, H. Jelinek, B. Durnota & T. Bossomaier (Eds.), *Complex systems 96: from local interactions to global phenomena* (pp. 321–336). Amsterdam: ISO Press.

McCormack, J. (2003). Evolving sonic ecosystems. *Kybernetes*, *32*(1/2), 184–202.

McCormack, J., McIlwain, P., Lane, A., & Dorin, A. (2008). Generative composition with nodal. In E. Miranda (Ed.), *Workshop on music and artificial life (part of ECAL 2007)*, Lisbon, Portugal.

McCullough, M. (1996). *Abstracting craft: the practiced digital hand*. Cambridge: MIT Press.

McGraw, G., & Hofstadter, D. (1993). Perception and creation of diverse alphabetic styles. *AISB Quarterly*, *85*, 42–49.

McLuhan, M. (1964). *Understanding media: the extensions of man*. London: Sphere Books.

Miranda, E. R., & Matthias, J. (2005). Granular sampling using a Pulse-Coupled network of spiking neurons. In *Lecture notes in computer science*. *Proceedings of EvoWorkshops 2005* (pp. 539–544). Berlin: Springer.

Narmour, E. (1990). *The analysis and cognition of basic melodic structures*. Chicago: University of Chicago Press.

Nierhaus, G. (2009). *Algorithmic composition: paradigms of automatic music generation*. Vienna: Springer.

Norman, D. (1991). Cognitive artifacts. In J. M. Carroll (Ed.), *Designing interaction: psychology at the human-computer interface* (pp. 17–38). Cambridge: Cambridge University Press.

Ortolani, B. (1990). *The Japanese theatre: from shamanistic ritual to contemporary pluralism*. Leiden: E. J. Brill.

Pachet, F. (2003). The continuator: musical interaction with style. *Journal of New Music Research*, *32*(3), 333–341.

Pólya, G. (1971). *How to solve it: a new aspect of mathematical method* (2nd ed.). Princeton: Princeton University Press.

Prévost, E. (2004). *Minute particulars: meanings in music—making in the wake of hierarchial realignments and other essays*. London: Copula.

Pritchett, J. (1993). *The music of John Cage*. Cambridge: Cambridge University Press.

Rowe, R. (1993). *Interactive music systems: machine listening and composing*. Cambridge: MIT Press.

Sawyer, R. K. (2006). Group creativity: musical performance and collaboration. *Psychology of Music*, *34*(2), 148–165.

Smith, H., & Dean, R. (1997). *Improvisation, hypermedia and the arts since 1945*. Amsterdam: Harwood.

Spiegel, L. (1981). Manipulations of musical patterns. In *Proceedings of the symposium on small computers and the arts* (pp. 19–22).

Supper, M. (2001). A few remarks on algorithmic composition. *Computer Music Journal*, *25*(1), 48–53.

Temperley, D. (2007). *Music and probability*. Cambridge: MIT Press.

van Andel, P. (1994). Anatomy of the unsought finding. Serendipity: origin, history, domains, traditions, appearances, patterns and programmability. *British Journal for the Philosophy of Science*, *45*(2), 631–648.

Wiggins, G., Papadopoulos, G., Phon-Amnuaisuk, S., & Tuson, A. (1999). Evolutionary methods for musical composition. In D. M. Dubois (Ed.), *Partial proceedings of the first international conference CASYS'97 on computing anticipatory systems*, Liége, Belgium, August 11–15, 1997. International Journal of Computing Anticipatory Systems.

Wiggins, G., Pearce, M., & Mullensiefen, D. (2009). Computational modelling of music cognition and musical creativity. In R. Dean (Ed.), *Oxford handbook of computer music* (pp. 383–420). Oxford: Oxford University Press.

Winkler, T. (1998). *Composing interactive music*. Cambridge: MIT Press.

Woolhouse, M. (2009). Modelling tonal attraction between adjacent musical elements. *Journal of New Music Research*, *38*(4).

Xenakis, I. (2001). *Formalized music: thought and mathematics in composition*. Hillsdale: Pendragon Press.

Young, L. M. (Ed.) (1963). *An anthology of chance operations*. New York: La Monte Young and Jackson Mac Low.

Young, M. (2008). NN music: improvising with a 'living' computer. In R. Kronland-Martinet (Ed.), *Computer music modelling and retrieval: sense of sounds* (pp. 337–350). Vienna: Springer.