‘Integrated Tool Competency’: A Conceptual Framework for Understanding the Role of the Absent Tools of Musical Composition

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Abstract How do the tools of musical composition shape the cognitive processes of composition *in absentia*? In exploring the role of these absent tools, can progress be made towards an extended understanding of imagination and memory? This article posits the conceptual framework of ‘Integrated Tool Competency’ as a way of reconciling the powerful insights of externalist accounts of cognition with the fact that so much of the process of musical composition can take place without directly interacting with compositional tools. Effectively this concept extends the integration of tools into a composer’s cognition beyond the moment of their use, including both unconscious competencies such as audiation and conscious actions such as imagining using a certain tool. This article proposes the concept of Integrated Tool Competency and discusses its potential ramifications for understanding the tools of composition.

The cognitive processes of musical composition do not only take place in the head. This is the compelling perspective on creativity given by ‘externalist’ accounts of cognition. Usually grouped under the umbrella of ‘4E’ cognition (extended, embedded, embodied, enacted), these accounts share a common theme of seeing cognition as breaching the boundaries between mind, body, and world. The goal of this article is not simply to apply these existing theories to composition. Rather, it will propose ‘Integrated Tool Competency’ as a

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An earlier version of this article was presented at the 57th Annual Conference of the Royal Musical Association at Newcastle University on 16th September 2021. I extend my thanks to the editors of JRMA, and to the two anonymous reviewers, for their valuable comments and suggestions; and to Christopher Dingle, Howard Skempton, Edwin Roxburgh, and others at Royal Birmingham Conservatoire who have been so supportive of this research.

conceptual framework for understanding the effect of *absent* tools on cognitive processes in the context of 4E, particularly extended, theories of cognition.

The article begins with an example of what a 4E understanding of the traditional view of the composer-at-their-desk might look like. In answering an objection to this understanding (namely, what happens when the tools which are being considered a part of the cognitive processes are absent), the concept of Integrated Tool Competency is proposed. Through various examples, the article will then discuss how this concept might impact how we consider compositional tools, composition itself, composers, and compositional pedagogy. Additionally, it will demonstrate how this study of musical composition can provide a genuinely impactful contribution to externalist theories of cognition. It is hoped that future empirical study and applications of the concept, particularly in pedagogy, will arise in further research.

Background: the composer at their desk, thinking through things.

The composer at their desk has ready-to-hand pens, paper, scores, instruments, and so on.[1] In inscribing notes onto the paper with the pen, perhaps 'seeing through'[2] these tools so that they become transparent in the pursuit of the musical goal, the composer enters into a feedback loop between the 'music-produced-so-far' and the 'music-yet-to-come'.[3] Interacting with the piano provides one means by which the work of audiation can be offloaded

[1] Martin Heidegger, *Sein und Zeit / Being and Time,* trans. John Macquarrie and Edward Robinson (Oxford: Blackwell, 1962), 98; see also Graham Harman, 'Technology, Objects and Things in Heidegger'. *Cambridge Journal of Economics*, 34, no. 1 (2010), 17–25; Graham Harman, *Tool-Being: Heidegger and the Metaphysics of Objects*. (Open Court, 2011); and Jonathan de Souza, *Music at Hand: Instruments, Bodies, and Cognition,* (Oxford: Oxford University Press, 2017).

[2] Andy Clark, *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence* (Oxford: Oxford University Press, 2004), 38. The idea that tools can become 'transparent' – that is, so fully integrated into the cognitive process in question that they disappear from view during that process - is fully explained below.

[3] See Dirk Van Hulle, *Modern Manuscripts: The Extended Mind and Creative Undoing from Darwin to Beckett and Beyond* (London: Bloomsbury, 2013) for discussion of the role of the 'text-produced-so-far' in the creation of works of literature.

onto the environment,[4] where the sonorities of complex chords are made clear before being scribbled onto the paper. Rearranging completed pages allows for the structure of the piece can be tested and changed. Through the use of gestures, and by experiencing emotional reactions to the music-in-progress, the composer can think through the ebbs and flows of the piece in an embodied manner.[5] In need of inspiration, they can turn to the pile of scores on their desk, pore through the fossilised thought of their influences to see how they solved a similar problem.[6] The notation on the stave goes from left to right temporally, from low to high in terms of pitch. Andy Clark, one of the forerunners of the extended mind hypothesis, argues that we are spatial, bodily creatures, 'bad at logic and good at Frisbee'.[7] This spatialisation of musical thought therefore allows for the piece to be understood outside real time,[8] and thus the composition takes shape, in the most literal sense.

Before getting to the objection to this view of composition (what happens when these tools are absent?), it is important to understand historical perspectives on imagination in musicology, phenomenology, and the '4E' theories which underpin the above vignette. Hugo Riemann wrote at the start of the century that '[t]he process of notating an artistic creation as well as the

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[4] e.g., David Kirsh, 'The Intelligent Use of Space', *Artificial Intelligence*: *Computational Research on Interaction and Agency, Part 2,* 73, no. 1 (1995), 31–68 (p. 51); Andy Clark, *Being There: Putting Brain, Body, and World Together Again* (Cambridge, MA: MIT Press, 1998), 94.

[5] See George Lakoff and Mark Johnson, *Philosophy in The Flesh: The Embodied Mind and its Challenge to Western Thought* (New York: Basic Books, 1999); Michelle Maiese, *Embodiment, emotion, and cognition* (New York, NY: Springer, 2010); Marc Leman, *Embodied Music Cognition and Mediation Technology* (Cambridge, MA: MIT Press, 2008); Andrea Schiavio, Dylan van der Schyff, Julian Cespedes-Guevara, and Mark Reybrouck, 'Enacting Musical Emotions. Sense-Making, Dynamic Systems, and the Embodied Mind'. *Phenomenology and the Cognitive Sciences,* 16, no. 5 (2017), 785–809.

[6] See Lydia Goehr, *The Imaginary Museum of Musical Works : An Essay in the Philosophy of Music* (Clarendon Press, 1992); Michael L. Klein, *Intertextuality in Western Art Music* (Indiana: Indiana University Press, 2005); Benjamin Piekut, 'Actor-Networks in Music History: Clarifications and Critiques', *Twentieth-Century Music*, 11 (2014), 191–215. A '4E' understanding of the nature of the score as part of the cognitive process of composition could shine a new light on the role of the score in contexts of intertextuality, networks, and influence.

[7] Clark, *Natural-Born Cyborgs*, 5; 75.

[8] See George Lakoff and Rafael E. Núñez. *Where Mathematics Come From: How the Embodied Mind Brings Mathematics into Being* (Basic Books, 2000) for an exploration of the importance of embodied minds placing abstract concepts into 'space'.

sounding performance of the work are merely expedients to transplant musical experiences from the composer's imagination into the imagination of the musical listener.'[9] Similarly, Eduard Hanslick writes about *Phantasie*, that '[a] musical piece emerges from the Phantasie of the artist for the Phantasie of the listener.'[10] The tools of composition (including even performers), then, are seen as mediators at best, and there is a sense that the musicologists of the early 20th century wished that musical ideas, arriving fully formed in a composer's head, could be translated directly from composer to listener without any such tools.

Moving through the 20th century, the advent of computers, the development of AI research, and advances in neural imaging led to the 'computational' or 'cognitivist' view of cognition.[11] These are the varying 'internalist' theories that see the brain as functioning like a computer. A cognitivist view is a very similar one to the view which motivates the above quotations from Hanslick and Riemann, reinforcing the duality of mind and body, by seeing the mind as a computer which takes 'inputs', processes them, and then 'outputs' instructions.[12] Cognitivism is such an entrenched view – hence the radical nature of externalist theories of mind – that citing specific cognitivist studies of music is difficult. We can, however, look at how composers *report* composing. For example, Aaron Copland states (and this echoes the

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[9] Riemann, Hugo. "Ideen zu einer 'Lehre von den Ton Vorstellungen'." Jahrbuch der Musikbibliothek Peters 21/22: 1-26. 1914/15 Translated by Robert Wason and Elizabeth Marvin as "Ideas for a Study 'On the Imagination of Tone'." Journal of Music Theory 36, no. 1 (1992): 81-117 (p. 82).

[10] Eduard Hanslick, *Vom Musikalisch-Schönen,* Translated by Lee Rothfarb and Christoph Landerer, as 'Eduard Hanslick's On the Musically Beautiful: A New Translation' (Oxford: Oxford University Press, 1854/2018), 5-6. Lydia Goehr has noted that Hanslick's writings reinforce the nature/culture boundary by stating that music was 'founded upon, not found in, nature'. Goehr, *The Imaginary Museum of Musical Works,* 164.

[11] Interestingly, the limitations of AI seem to provide evidence for the idea that seeing the brain as a 'top down' thinking machine, separate from body and world, is an error. See Hubert Dreyfus, *What Computers Still Can't Do: A Critique of Artificial Reason* (Cambridge, MA: MIT Press, 1992).

[12] See Fred Adams and Ken Aizawa, 'Defending the Bounds of Cognition', *The Extended Mind*, ed. Richard Menary (Cambridge, MA: MIT Press, 2010), 67–81; Fred Adams and Ken Aizawa, 'The Value of Cognitivism in Thinking about Extended Cognition', *Phenomenology and the Cognitive Sciences,* 9, no. 4 (2010) 579–603, for defences of this view.

above view of Riemann and Hanslick) that 'the listener [...] must [...] relive in his own mind the completed revelation of the composer's thought.'[13] Again, just like at the turn of the century, tools are seen to be used merely to record and transmit 'real thought'. Martin Heidegger and Maurice Merleau-Ponty may have written about the importance of tools, bodies, and technology in thinking and being, very much against the Cartesian division between mind/body (and /world),[14] but the prevailing view at this point would still seem to be an internalist one. Of course, the 'progression' from one school of thought to another is not linear, and disparate schools develop at the same time, even in the same place. Nevertheless, the cognitivist view remains the dominant one through the mid-late 20th century.

In 1996, the scientist and educator Richard Feynman said, in an interview with Charles Weiner, that his work wasn't just done in his head: 'the paper isn't a record, not really. It's working. You have to do the work on the paper and this is the paper, okay?'[15] This reflects the turning point at the end of the 20th century when theories which see mind as varyingly embodied, embedded, extended, and enacted begin to be more widely explored. As early as 1990 Mark Johnson published *The Body in the Mind*,[16] and in 1995, David Kirsh published an article exploring the 'intelligent use of space',[17] and Edwin Hutchins published a monograph on the distributed cognitive processes of navigation at sea.[18] These were followed by Andy Clark and David Chalmers' seminal article on the 'Extended Mind', in 1998, which first states the 'parity principle': '[i]f, as we

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[13] Aaron Copland, *Music and Imagination* (Harvard: Harvard University Press, 1980), 2.
[14] Maurice Merleau-Ponty, *Phénoménologie de la Perception* (Paris: Éditions Gallimard, 1945); Heidegger, *Sein und Zeit / Being and Time*; Martin Heidegger, *The Question Concerning Technology and Other Essays,* trans. William Lovett (New York: Harper and Row, 1977). See also Lev Vygotsky, *Thought and Language* (Cambridge, MA: MIT Press, 1962).
[15] James Gleick, *Genius: The Life and Science of Richard Feynman* (California: California Institute of Technology Press, 1992), 409.
[16] Mark Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason* (Chicago, IL: University of Chicago Press, 1990).
[17] Kirsh, 'The Intelligent Use of Space', 1995.
[18] Edwin Hutchins, *Cognition in the Wild* (Cambridge, MA: MIT Press, 1995).

confront some task, a part of the world functions as a process which, *were it done in the head*, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world *is* (so we claim) part of the cognitive process.'[19] Through the beginning of the 21st century, these ideas have been further developed and specialised. See Clark's books expanding the Extended Mind Hypothesis,[20] Richard Menary's work on writing as thinking,[21] Lambros Malafouris and Colin Renfrew's work on Material Engagement Theory;[22] and studies of specific arts, such as Edwin Tribble's exploration of actors distributing memory through Shakespeare's Globe Theatre[23] and Dirk van Hulle's examination of the extended mind in the process of writers such as Samuel Beckett.[24]

Particularly important for this article is the role of *tools* in these theories, especially the idea of 'transparent technology'. Transparency, very much related to 'readiness-to-hand' (*Zuhandenheit*),[25] is a key idea in externalist theories cited above. Transparency is the idea that a technology can become so much a part of an agent's cognitive apparatus that it becomes invisible in use. That is to say, the cognitive process ceases to be 'interaction with tool while trying to solve the problem' and instead simply becomes 'trying to solve the problem,' because the tool is so integrated into the cognitive system. This goes for anything which has thus disappeared from view, from pen and paper to a

[19] Andy Clark and David Chalmers. 'The Extended Mind', *Analysis* 58, no. 1 (1998): 7–19 (p. 14).
[20] Clark, *Natural-Born Cyborgs,* 2003; Andy Clark, *Supersizing the Mind: Embodiment, Action, and Cognitive Extension*. Oxford: Oxford University Press, 2008).
[21] Richard Menary, 'Writing as Thinking', *Language Sciences*, *Cognitive Dynamics in Language,* 29, no. 5 (2007), 621–32. For a collection of important work developing and critiquing the extended mind hypothesis, see also Richard Menary, ed., *The Extended Mind* (Cambridge, MA: MIT Press, 2010).
[22] Colin Renfrew, 'Symbol Before Concept: Material Engagement and the Early Development of Society', *Archaeological Theory Today,* ed. Ian Hodder (Cambridge: Polity Press, 2001), 122-140; Lambros Malafouris and Colin Renfrew, *The Cognitive Life of Things: Recasting the Boundaries of the Mind*. (Cambridge: McDonald Institute for Archaeological Research, 2010); Lambros Malafouris, *How Things Shape the Mind* (Cambridge, MA: MIT Press, 2013).
[23] Evelyn Tribble, 'Distributing Cognition in the Globe', *Shakespeare Quarterly,* 56, no. 2 (2005), 135–55
[24] van Hulle, *Modern Manuscripts*.
[25] Heidegger, *Sein und Zeit / Being and Time,* 98.

tennis racket to prosthetics to cybernetic enhancement. Clark defines transparent tools as 'tools whose use and functioning have become so deeply dovetailed to the biological system that the [...] problem solving system just *is* the composite of the biological system and these nonbiological tools.'[26] He further notes that for tools to become transparent, training and practice may be needed. That is, it is a quality of the agent-tool relationship, not just the tool itself.

Examining the writings of Nicholas Cook demonstrate how this shift in thought about the substance and functioning of the mind was reflected in musicology, through comparing *Music, Imagination, and Culture*, which was published in 1990, with *Music as Creative Practice*, published in 2018.[27] The former uses the word 'body' 5 times, only once referring to a physical body (the other instances referring to bodies of work, knowledge, and so on), and this the physical body of a potter, not a composer.[28] The latter mentions the word 'body' 27 times, including 'instruments are extensions of the body',[29] 'the performing body',[30] 'the extent to which human cognition [...] is grounded in bodily experience',[31] and so on; and has an entire section on the extended musical mind, dealing with the ideas of offloading cognition in musical creativity exemplified in the opening vignette of this article.[32]

Studies of music in 4E contexts generally focus on *present* and/or *physical* aspects of external cognitive tools and structures. Performance and

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[26] Clark, *Natural-Born Cyborgs,* 2004, 37.
[27] Nicholas Cook, *Music, Imagination, and Culture* (Oxford: Oxford University Press, 1990); Nicholas Cook, *Music as Creative Practice* (Oxford: Oxford University Press, 2018); See also Holly Watkins and Melina Esse, 'Down with Disembodiment; or, Musicology and the Material Turn', *Women and Music: A Journal of Gender and Culture,* 19, no. 1 (2015), 160-168.
[28] Cook, *Music, Imagination, and Culture,* 2. This is an interesting foreshadowing of Malafouris' exploration of Material Engagement Theory through the example of a potter at the wheel. Lambros Malafouris, 'At the Potter's Wheel: An Argument for Material Agency', *Material Agency: Towards a Non-Anthropocentric Approach*, ed. Carl Knappett and Lambros Malafouris (Boston, MA: Springer, 2008), 19-36.
[29] Cook, *Music as Creative Practice,* 114.
[30] *Ibid.*, 117.
[31] *Ibid.,* 21.
[32] *Ibid*., 117-127.

improvisation have been widely studied,[33] and here the co-presence of fellow performers and the physicality of instrumental playing make the connection to general 4E arguments clear. There are also studies focused on the role of music itself, rather than the things involved in its creation, in certain cognitive processes (i.e., musical affordances – or 'what an environment offers, what it provides or furnishes' for musical action).[34] For example, there are studies exploring the affordances offered by music in day-to-day life,[35] and even music in infancy.[36] Similarly, Mark Reybrouck has recently taken an enactivist (thinking through doing)[37] approach to understanding musical sense-making as a process facilitated by interactions between mind, body, and musical stimuli.[38]

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[33] See David Borgo, 'Strange Loops of Attention, Awareness, Action, and Affect in Musical Improvisation', *Music and Consciousness 2: Worlds, Practices, Modalities*, ed. Ruth Herbert, David Clarke and Eric Clarke (Oxford: Oxford University Press, 2019), 113-24; Simon Høffding, 'Performative Passivity: Lessons on Phenomenology and the Extended Musical Mind with the Danish String Quartet', *Music and Consciousness 2: Worlds, Practices, Modalities*, ed. Ruth Herbert, David Clarke and Eric Clarke (Oxford: Oxford University Press, 2019), 127-42; Simon Høffding and Torben Snekkestad, 'Inner and Outer Ears: Enacting Agential Systems in Music Improvisation', *Philosophy of Improvisation : Interdisciplinary Perspectives on Theory and Practice, ed.* Susanne Ravn, Simon Høffding and James McGuirk (London: Routledge, 2021), 161-182; Marc Duby, 'Affordances in Real, Virtual, and Imaginary Musical Performance', *The Oxford Handbook of Sound and Imagination*, *vol. 2*, ed. Mark Grimshaw-Aagaard, Mads Walther-Hansen and Martin Knakkergaard (Oxford: Oxford University Press, 2019), 97-116; Justin Christensen, 'Improvisation: An Ideal Display of Embodied Imagination', *The Oxford Handbook of Sound and Imagination*, *vol. 2*, ed. Mark Grimshaw-Aagaard, Mads Walther-Hansen and Martin Knakkergaard (Oxford: Oxford University Press, 2019), 15-36.

[34] James Gibson, *The Ecological Approach to Visual Perception* (Boulder, CA: Taylor & Francis, 1979). Gibson states (p.127) that 'the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. [.... Affordance] refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment.' In 4E approaches to cognitive science, the term is often used to discuss specifically *cognitive* affordances found in the external world. See, for example, Damiano Menin & Andrea Schiavio, 'Rethinking Musical Affordances', *Avant,* 3 (2012), 202-215.

[35] Joel Krueger, 'Affordances and the Musically Extended Mind', *Frontiers in Psychology*, 4 (2014), 10.3389/fpsyg.2013.01003; Joel Krueger, 'Music as Affective Scaffolding', *Music and Consciousness 2: Worlds, Practices, Modalities*, ed. Ruth Herbert, David Clarke and Eric Clarke (Oxford, Oxford University Press, 2019c), 55-70.

[36] Andrea Schiavio, Dylan van der Schyff, Silke Kruse-Weber and Renee Timmers, 'When the Sound Becomes the Goal: 4E Cognition and Teleomusicality in Early Infancy', *Frontiers in Psychology,* 8 (2017), 10.3389/fpsyg.2017.01585.

[37] For an in-depth exploration of enacted cognition, which also demonstrates the blurred lines between the various 'E's, see Francisco Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991).

[38] Mark Reybrouck, *Musical Sense-Making. Enaction, Experience, and Computation* (New York: Routledge, 2021). Here Reybrouck also considers the important distinction between musical stimuli *in absentia* and *in praesentia*, though in smaller timescales than are being dealt with here, with regards to musical experience and how to understand music as a 'temporal art' (p.59) from an enacted cognition perspective.

Where the processes of musical composition have been explored through an 'externalist' lens, this has primarily been from the perspective of embodiment, which is only one of the 4 'E's (although, as Kevin Ryan and Andrea Schiavio note, the mind extending through the body is a crucial aspect of the 'second wave' of the Extended Mind Thesis),[39] and collaboration.[40] Scholars and educators have also explored the importance of embodied cognition (and to a lesser extent the other 'E's) to pedagogy,[41] including musical pedagogy.[42] Imagination, musical and otherwise, is widely studied but, with some exceptions, this work is separate from externalist theories of cognition. The Cambridge Companion to the Imagination, for example, has only one chapter out of 48 which is explicitly externalist;[43] and The Oxford Handbook of Sound and Imagination has only three explicitly externalist chapters out of 70,[44] across two volumes.

[39] Kevin Ryan and Andrea Schiavio, 'Extended Musicking, Extended Mind, Extended Agency: Notes on the Third Wave', *New Ideas in Psychology,* 55 (2019), 8-17.
[40] See Paul Craenen, *Composing under the Skin: The Music-Making Body at the Composer's Desk* (Leuven: Leuven University Press, 2014); Zvonimir Zagy, *Embodiment of Musical Creativity: The Cognitive and Performative Causality of Musical Composition* (London: Routledge, 2016); Karlin Love and Margaret S. Barrett. 'Learning to Collaborate in Code: Negotiating the Score in a Symphony Orchestra Composers' School'. *Collaborative Creative Thought and Practice in Music*, ed. Margaret S. Barrett (London: Ashgate Publishing, 2016), 49–64.
[41] See Iris Laner, 'Reflective interventions: Enactivism and Phenomenology on Ways of Bringing the Body into Intellectual Engagement', *Phenomenology and the Cognitive Sciences* 20, no. 4 (2021), 443-461; David Nguyen and Jay Larson, 'Don't Forget About the Body: Exploring the Curricular Possibilities of Embodied Pedagogy', *Innovative Higher Education* 40, no. 4 (2015), 331-344; Mia Perry and Carmen Medina, 'Embodiment and Performance in Pedagogy Research: Investigating the Possibility of the Body in Curriculum Experience', *Journal of Curriculum Theorizing* 27, no. 3 (2011).
[42] See Wayne Bowman, 'Cognition and the Body: Perspectives from Music Education', *Knowing Bodies, Moving Minds.* (Dordrecht: Springer, 2004), 29-50; Andrea Schiavio and Dylan van der Schyff, '4E Music Pedagogy and the Principles of Self-organization', *Behavioral Sciences* 8, no. 8 (2018), 72.
[43] Maria Koukouti and Lambros Malafouris, 'Material Imagination: An Anthropological Perspective', *The Cambridge Handbook of the Imagination*, ed. Anna Abraham (Cambridge: Cambridge University Press, 2020), 30–46.
[44] Ulrik Volgsten, 'Fantasy Control: Implications for Distributed Imagination and Affect Attunements in Music and Sound', *The Oxford Handbook of Sound and Imagination*, *vol. 1*, ed. Mark Grimshaw-Aagaard, Mads Walther-Hansen and Martin Knakkergaard (Oxford: Oxford University Press, 2019), 229-250; Duby, 'Affordances in Real, Virtual, and Imaginary Musical Performance'; Christensen, 'Improvisation'.

Answering an objection: Integrated Tool Competency

So, studies which focus on music and imagination, and studies which focus on music cognition in a 4E context, are largely separate, which reinforces the idea that a 4E understanding of creative cognition is only relevant when specific tools are in use. This brings us to an objection to the vignette which commenced the article: As compelling as its view of composition might be, it ignores what is happening in the *absence* of some or all of these tools. It ignores what is happening in the absence of pen, paper, piano, computer and so on, when compositional work is still clearly possible.

The simple answer to this objection might be that tools *can* be integrated into the cognitive processes of composition, but that they don't *have* to be. That is, even if one were to accept the externalist view of composition *when the composer is using tools*, the traditional view of composition, as an internal process of which the score is merely a record, would be correct the rest of the time. However, it seems more consistent to take a ground-up approach to understanding internal representation, where the 'ground' is an understanding of cognition and creativity as fundamentally embodied, extended, embedded, and enacted. This article argues this point primarily through the claim that the cognitive use of tools not only makes possible (or easier) certain cognitive processes, but also develops our capacity to complete similar tasks in the absence of those tools. In some instances, this claim simply re-affirms and synthesises arguments cited above. However, in the more radical cases, where tools and related gestures are completely absent from the process in question, it becomes an attempt to break new conceptual ground.

So, this article proposes the concept of 'Integrated Tool Competency' as a solution for the objection above. As a working definition, Integrated Tool Competency (henceforth ITC) refers to cognitive abilities developed through the

use of tools. These abilities a) remain in the absence of those tools and b) could not be (or have not been) achieved without those tools.

How might a tool become 'integrated' under this conceptual framework? Here, a five-stage process is hypothesised. An example of an application of these stages to the cognitive processes of musical composition will follow, but here they are described in their most general form.

1) Being able to make use of a tool as part of performing a cognitive task. This may even be to the point where it can be considered 'transparent' as described by Clark.[45] This stage is slightly complicated by the fact that some competencies may need to be developed and integrated in order for this tool to function as part of the cognitive apparatus, or for transparency to be achieved.[46]

2) Being able to make use of conscious, embodied referral (i.e., gestures) to a remembered tool when performing a cognitive task.

3) Being able to make use of conscious referral to a remembered tool when performing a relevant cognitive task, without an accompanying physical gesture.[47] Instead, the agent *imagines* using the tool and this aids in the completion of the cognitive task.

4) Being able to make use of *unconscious* referral to a tool used in the past, when confronting a relevant cognitive task. Interestingly, this could include unconscious bodily movement, despite being a deeper level of integration than embodied gestural reference to a past tool. In this instance, the agent is not aware that this is how they are completing the task. It is still

[45] Clark, *Natural Born Cyborgs.*
[46] Ibid., 37. See also Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*, (Oxford: Oxford University Press, 2005), 210. Latour points out that there are certain cultural competencies which are available as long as one 'subscribes' to the relevant equipment.
[47] This stage, and some instances of the previous stage, relate heavily to ideas of ideomotor simulation and musical imagery discussed below under the subheading 'Audiation and musical imagery'. The important thing is how this stage of integrating competency relates to other stages.

being ‘referred’ to, but, in the same way that *present* technology can become transparent in use, so now has the *absent* technology.

5) Being able to complete a relevant cognitive task without either conscious or unconscious referral to a past tool. The cognitive function the tool serves has become so integrated into the being of the agent, has perhaps developed so much surrounding competency in brain and body, that the task is simply *done*. This seemingly internal cognitive competency has, in fact, been developed through the use of a tool, perhaps could not have been developed without the use of that tool, and has been integrated through multiple extended, embodied stages.

These final two stages of integrating a tool-related competency are hard to separate from the point of view of the agent in question. Nevertheless, they are different conceptually. They also take the greatest departure from existing literature. In fact, one might even argue that it is unnecessary to explore these final two stages. After all, the prevailing view of cognition, which externalist accounts challenge, is that concepts and capacities are held in the mind, in the brain, inside the skin. Surely here we can just look to the wealth of ‘traditional’ work on the philosophy of mind and related disciplines, as explanations of how these seemingly interior stages function. However, if a fundamental truth of cognition is that we are embodied beings situated in a cognitively useful world, it is strange to have a completely different perspective on any cognitive process which does not clearly entangle itself with ‘external’ things in the moment it is taking place. The ITC concept is a proposal for how to start to bridge this gap, by providing a framework for exploring how the use of tools shapes the mind, even in the absence of those tools.

So, the ITC claim is that the use of tools in creative pursuits, such as musical composition, engenders competencies that would not exist without the past use of these tools. The referral to an absent compositional tool, in the

relevant cognitive process, acts in the same way as a referral to a present tool, whether consciously or unconsciously, or the tool may be instrumental in developing a cognitive competency which requires no such reference. As such, the tools of composition can not only be considered essential as constituent parts of the cognitive processes of composition in the moment of their use, but as essential in their integration as part of the cognitive competencies of the composer.

Examples: from manuscript paper, through audiation to digital notation.

The following examples include studies which provide evidence for the validity of the ITC concept, or to which it can be productively applied. Additionally, there are more speculative examples, which show how the conceptual framework of ITC could aid in understanding certain tools and cognitive processes involved in musical composition and, in turn, how exploring these might further illuminate the ITC concept.

Manuscript paper

Nicholas Cook, in describing the materiality of Beethoven's compositional process, observes that 'as you pore over the sketchbooks, you have an almost visceral sense of Beethoven's pen digging into the fibrous, handmade paper as he struggled to give expression to some recalcitrant, half-formed idea.'[48] This is a compelling view of the score: as something to interact physically with, as something which forms part of a feedback loop, as something which, for a time, constitutes part of the cognitive processes of composition. It is not, however, the whole story. Through the ITC framework, it would be possible to chart how this interaction with scores throughout a composer's career - and throughout the creation of a particular musical work - develops competencies which allow

[48] Nicholas Cook, *Music: A Very Short Introduction* (Oxford: Oxford University Press, 2000), 66-67.

for: a) faster or more effective composition when working with the score,[49] and b) composition in absence of a score.

Through ITC it is argued that an experienced composer has access (consciously or unconsciously) to experiences of various aspects of the cognitive system involving pencil and manuscript paper. These include the physical motions, the auditory feedback, the musical results (whether from audiation [see below] or experience of rehearsals, workshops, and performances), and so on. There may also be competencies which have been developed through the use of these tools to the point where not even unconscious referral is required. This allows for the completion of more complex compositional tasks *in the absence* of pencil and manuscript paper than would have been possible had they never been used. In other words, the skilled use of cognitive equipment is essential to the process of composition, and through using these tools, the composer will develop competencies which remain when those tools are absent.

Lucilla Cardinali and colleagues demonstrated in 2009 that not only does the use of a tool update the body schema (as they expected), but that the tool was also generalisable.[50] It was automatically used for 'pointing' tasks after training with 'grabbing' tasks. Most importantly for the ITC concept, they also found that this updating of the body schema remained in the absence of the tool, for at least 30 minutes. The participants felt that they had extended reach even after the tool which gave them that reach was gone. This empirical study

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[49] Beethoven is, perhaps, a pertinent example, due to his famously continuing to compose despite the loss of one of the key tools of composition: auditory feedback.

[50] Lucilla Cardinali, Francesca Frassinetti, Claudio Brozzoli, Christian Urquizar, Alice C Roy, and Alessandro Famè, 'Tool-use Induces Morphological Updating of the Body Schema', *Current Biology*, 19, no. 12 (2009). See also other related studies by the same group of researchers: Lucilla Cardinali, Claudio Brozzoli, Christian Urquizar, Alice Roy, and Alessandro Famè, 'When Action is Not Enough: Tool-use Reveals Tactile-Dependent Access to Body Schema', *Neuropsychologia,* 49 (2011), 3750-3757; Marie Martel, Lucilla Cardinalli, Giorga Bertonati, Christophe Jouffrais, Livio Finos, Alessandro Famè, and Alice C Roy, 'Somatosensory-guided Tool Use Modifies Arm Representation for Action', Scientific Reports, 9; Marie Martel, Lucilla Cardinalli, Alessandro Famè, and Alice C Roy, 'Tool-use: An Open Window into Body Representation and its Plasticity', Cognitive Neuropsychology, 33, no. 1-2 (2016), 81-101.

provides some initial evidence for the mechanisms by which the use of cognitive tools may extend our *cognitive* 'reach' beyond the moment of their use.[51] Further evidence comes not from studies of composers, or even of human cognition in general, but from two studies of apes.

In 1997, Roger Thompson, David Oden, and Sarah Boysen performed a study on chimpanzees (*Pan troglodytes*)[52] focused on developing their capacity to understand and identify second-order difference.[53] The chimps were taught to identify the difference between differences using coloured plastic tokens: one token which they would place next to pairs with the same difference (A/A and C/C), and another token which they would place next to the more different difference (B/B and D/E). The salient point for the purposes of this article is not that they learned to identify second-order differences through using these tokens, but that they retained this new cognitive competency in their absence. This was a competency absent in chimps who had never used tokens.

The researchers suggest that the chimps now have internal representations of these tokens, which allow them to then perform the task of recognising second-order difference, even in the absence of the actual, physical tokens.[54] Similarly, Richard Wilson examined studies on a bonobo (*Pan paniscus*) named Kanzi, contending that Kanzi had reconfigured his capacities for belief through use of a symbol board, which, again, he retained in absence of this

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[51] For further evidence of tool-use affecting perception and capacity, see Madhur Mangalam, James D Conners, Dorothy M Fragaszy, and Karl M Newell, 'Location of a Grasped Object's Effector Influences Perception of the Length of That Object Via Dynamic Touch', *Experimental Brain Research*, 236, no. 7 (2018), 2107-2121; Jeffrey B Wagman and Peter J K Smith, 'Perception of Affordances for Stepping Over an Expanse with Crutches', *Perception*, 47, no. 10-11 (2018), 1106-1109.

[52] Roger K. R. Thompson, David L. Oden and Sarah T. Boysen, 'Language-Naïve Chimpanzees (Pan troglodytes) Judge Relations Between Relations in a Conceptual Matching-to-Sample Task', *Journal of Experimental Psychology: Animal Behaviour Processes,* 23, no. 1 (1997), 31-51.

[53] Second-order difference refers to a difference between differences. The difference between A and A is the same as the difference between C and C, but different than the difference between D and E.

[54] This study was cited by Andy Clark in *Natural-Born Cyborgs* (pp. 70-72) which is in the bibliography of a huge number of articles and books about extended cognition published since, but few seem to have grappled with the significance of the 'internalised, external token' when considering more complex cognitive pursuits, such as creating a work of art.

tool.[55] This is further evidence for the argument that it is the ability to create *new* tools, to engineer our cognitive environment,[56] which allows for the undertaking of complex, long-term cognitive processes - for example, musical composition – and the development of related competencies.

Audiation and musical imagery

There is a particular compositional skill which could be productively explored through the ITC framework: audiation. Audiation, otherwise known as the 'inner ear', is the skill of hearing the correct sounds in one's head, either from reading notation, as a creative or improvisational act, in response to imagining playing an instrument in a certain way, or a combination of the above. Musical imagery has been widely studied, and audiation could be productively considered as *directed* musical imagery.[57] Kate Covington quotes Robert Schumann: 'He is a good musician, who understands the music without the score, and the score without the music. The ear should not need the eye, the eye should not need the (outward) ear',[58] and further notes that Schumann suggests to composers, 'do it all with your brain'.[59] The perceived immateriality of audiation, and its value as a 'mental' activity outside the limitations of body and world, were clearly as important in the 19th century as they were at the turn of the 20th. As audiation is seen as an important part of a musician's development, much has been written on the best ways to develop it.[60] Audiation

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[55] Robert A. Wilson, *Boundaries of the Mind: The Individual in the Fragile Sciences: Cognition* (New York: Cambridge University Press, 2004); Richard A. Wilson, 'Meaning Making and the Mind of the Externalist', *The Extended Mind*, ed. Richard Menary (Cambridge, MA: MIT Press, 2010), 167-188 (p. 180).

[56] Clark, *Supersizing the Mind,* 59; Latour, *Reassembling the Social*, (Oxford: Oxford University Press, 2005), 210. This is interesting in the context of ITC as *integrated* competencies remain regardless of the presence of equipment. The idea that competencies might need to be refreshed by reconnecting with the relevant tool(s) (and how much this can be done in the absence of the actual, physical, present tool) would also be interesting to explore.

[57] This is not a distinction made in the literature but is useful for the purposes of this article.

[58] Kate Covington, 'The Mind's Ear: I Hear Music and No One Is Performing', *College Music Symposium,* 45 (2005), 25–41 (p. 1).

[59] *Ibid.,* 2.

[60] See Edwin E. Gordon, 'Research Studies in Audiation: I'. *Bulletin of the Council for Research in Music Education*, no. 84 (1985), 34–50; Edwin E. Gordon, 'All about Audiation and Music Aptitudes', *Music Educators Journal,* 86, no. 2 (1999), 41–44.

is trained by exercises, by listening to music and reading scores, by learning instruments, and by interacting with the tools of composition when composing.[61] It is not as if some savant could pick up a manuscript having never seen one before and hear the music perfectly in their head – it is a learned skill, developed through the use of tools: scores, instruments, and even the composer's own voice.

The idea that imagining or acting out the action required to produce a sound is a mechanism by which an agent can 'hear' the sound internally is explored by Rolf Inge Godøy in his 2001 article, 'Imagined Action, Excitation, and Resonance'.[62] He argues that 'the visualisation of movement as trajectories in time-space could be an integral element of imagining a sound.'[63] Reybrouck specifies ideomotor simulation,[64] as the mechanism by which this occurs. He points out that 'the transition from overt action (sensorimotor) to internalized (ideomotor) forms of action [...] does not imply the abandoning of the sensorimotor control systems that link the sensors to the central nervous system and the effectors (the muscles). It only cuts off the actual manifestation of the output or effector side of the control system.'[65] Schiavio and colleagues have also taken a similar, 'embodied simulation,' approach to musical

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[61] See also Laura Bishop, Freya Bailes, and Roger T. Dean, 'Musical Expertise and the Ability to Imagine Loudness', *PLOS ONE* 8, no. 2 (27 February 2013) https://doi.org/10.1371/journal.pone.0056052, a study which found that expert musicians were more capable of imagining loudness and changes in loudness.

[62] Rolf Inge Godøy, 'Imagined Action, Excitation, and Resonance', *Musical Imagery,* ed. Rolf Inge Godøy and Harald Jørgensen (Amsterdam: Swets and Zeitlinger, 2001), 237-250.

[63] Ibid., 241.

[64] For non-musical examples exploring the ideomotor phenomenon, see Wolfgang Prinz, 'An Ideomotor Approach to Imitation', *Perspectives on Imitation: From Neuroscience to Social Science. Vol 1: Mechanisms of Imitation and Imitation in Animals,* ed. Susan Hurley and Nick Chater (Cambridge, MA: MIT Press, 2005), 141-156; Cristina Massen and Wolfgang Prinz, 'Movements, Actions, and Tool-use Actions: An Ideomotor Approach to Imitation', *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *364*, no. 1528, (2009), 2349–2358. For a musicological exploration of this relationship in both directions (motor behaviours to assist auditory imagery, auditory imagery to assist motor behaviours), see David Allen, 'Mental Representations in Clarinet Performance: Connections Between Auditory Imagery and Motor Behaviors' (Ph.D. dissertation, University of Sheffield, 2009)

[65] Mark Reybrouck, 'Musical Imagery between Sensory Processing and Ideomotor Simulation', *Musical Imagery,* ed. Rolf Inge Godøy and Harald Jørgensen (Amsterdam: Swets and Zeitlinger, 2001), 118-135 (pp. 129-130).

understanding.[66] In a wider 4E context these studies relate to enacted accounts of perception, such as those discussed by Alva Noë.[67]

Specific studies of the role of gesture in musical imagery include Mariko Mikumo's demonstration that enacting the gestures of piano playing aided with melody recall;[68] and Bruno Repp and Günther Knoblich's discovery that *deceptive* performed or observed keyboard actions, not related to the heard pitches, negatively impacted pitch recognition skills.[69] This latter study implies that participants normally used these gestures and interactions to help identify pitches. A study of expert classical performers found that they scored lower on aural pitch replication tests than non-experts due to 'over-reliance' on notation, which could imply that gestural reference is more useful to audiation than the kind of expertise a performer will have with musical notation.[70]

Understanding embodied reference to a tool used in the past as a process which affects the skill of audiation, as explored above, fits neatly into the first stages of the ITC concept. As a thought experiment, and an example of an application of ITC to a relevant compositional skill, it is interesting to therefore consider the development of the skill of audiation through the use of an already quite integrated tool – the voice. Applying the stages of developing a

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[66] Andrea Schiavio, Damiano Menin, and Jakub Ryszard Matyja, 'Music in the Flesh: Embodied Simulation in Musical Understanding', *Psychomusicology: Music, Mind and Brain,* 24 (2015), 340-343.

[67]Alva Noë, *Action in Perception* (Cambridge, MA: MIT Press, 2004). See also J. Kevin O'Regan and Alva Noë, 'What is it Like to See: A Sensorimotor Theory of Perceptual Experience', *Synthese,* 129, no. 1 (2002), 79-103. Noë's later work, on the extended mind in the process of writing and editing literary texts, also provides valuable insight into how the 'score-produced-so-far', and interaction with it, may influence the composer as they continue to work. See Noë, *Modern Manuscripts*.

[68] Mariko Mikumo, 'Motor Encoding Strategy for Pitches of Melodies', *Music Perception: An Interdisciplinary Journal,* 12 (1994), 175-97.

[69] Bruno H Repp and Günther Knoblich, 'Performed or Observed Keyboard Actions Affect Pianists' Judgements of Relative Pitch', *Quarterly Journal of Experimental Psychology*, 62 (2009), 2156-2170.

[70] Christopher Corcoran and Neta Spiro, 'Score-dependency: Over-reliance on Performing Music from Notation Reduces Aural Pitch Replication Skills', *Journal of Interdisciplinary Music Studies,* 10 (2020), 73-98. However, see Laura Bishop et. al, 'Musical Expertise and the Ability to Imagine Loudness', for a study which did find a correlation between musical expertise and certain aspects of audiation in the absence of tools. It is also worth noting that performers deal with notation in a unidirectional way (from written note to sounding pitch) as compared to composers, which may have caused this interesting result. Additionally, performers can always expect to have notation available when performing, reducing the need for competencies in its absence.

competency to the development of the skill of audiation through singing might look something like the following:

1) Vocalisation - actively singing to find or match a note or phrase, heard and/or written.[71]

2) Sub-vocalisation – 'imagining' singing to find or match a note or phrase, but still activating some of the relevant muscle groups. When one actively imagines talking, for example, the speech apparatus engages despite no noticeable movement of lips, tongue and jaw, and no sound production. In 1995 J. David Smith and colleagues explored the role of sub-vocalisation in audiation,[72] and Warren Brodsky et al. demonstrated in a 2008 study that sub-vocalisation plays a part in notational audiation.[73]

3) Imagined vocalisation without sub-vocalisation – 'imagining' singing to find or match a note or phrase, without relying on activating any muscle groups. This requires a higher level of integration, as it does not rely on active embodiment in the same way as sub-vocalisation. This allows the skill of audiation to break away from various restrictions imposed by active vocalisation or by sub-vocalisation, such as only being able to sing one line at a time, being restricted in register, or requiring all the musical imagery to be real-time.

4) Unconscious imagined vocalisation – feeling as though the correct notes are simply being imagined when needed, but still being achieved through unconscious referral to vocalisation, which may even include some unnoticed

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[71] For further exploration of the role of instruments other than the voice in aiding musical cognition, see Mark Reybrouck, 'Music Cognition and the Bodily Approach: Musical Instruments as Tools for Musical Semantics', *Contemporary Music Review* 25, no. 1–2 (2006), 59–68, and see also de Souza, *Instruments at Hand*.

[72] J. David Smith, Margaret Wilson, and Daniel Resiberg, 'The Role of Subvocalization in Auditory Imagery', *Neuropsychologia,* 33, no. 11 (1995), 1433-1454.

[73] Warren Brodsky, Yoav Kessler, Bat-Sheva Rubinstein, Jane Ginsborg and Avishai Henik. 'The Mental Representation of Music Notation: Notational Audiation'. *Journal of Experimental Psychology: Human Perception and Performance* 34, no. 2 (2008), 427–45.

activation of various relevant muscle groups. This may further allow the skill of audiation to break away from the restrictions mentioned when considering imagined vocalisation above. This is due to the referral to those vocalisations becoming 'seen-through' as transparent technology.

5) Complete transparency – simply hearing the correct notes at will or when engaging with visual stimuli. This is the final point of integration, and different from the previous stage as there is not even any unconscious referral to the mechanisms of singing. As mentioned in the initial description of the five-stage process, this is interesting in that this is how an internalist viewpoint would initially assume that such a phenomenon as audiation functions – but through examining it as built from the 'ground-up' from an embodied, extended interaction with the world, a more sophisticated understanding is reached – and could have far-reaching consequences.

This application of the ITC framework shows how it might be productively applied to various complicated issues of musical competency. The sub-vocalisation stage, and the studies evidencing it, also provide a useful bridge between the various overlapping stages, demonstrating how studying certain aspects of musical competency which are unique to music can contribute to a general understanding of creative cognition. This example also underlines the point that there are numerous studies, empirical and theoretical, which can be synthesised to explain the first stages of the development of an integrated competency, whereas the latter stages are an attempt to break new conceptual ground.

It might be argued that many composers report imagining and creating music in their heads before learning how to write scores or use other musical tools to a high level of proficiency,[74] and that this discredits the above

[74] 'I started composing in my head to relieve boredom while playing football [at school.]' Christopher Dingle and Julian Anderson, *Julian Anderson: Dialogues on Listening, Composing and Culture*, (London: Boydell Press, 2020), 276.

arguments. Audiation is important as a defence against this potential objection to the ITC concept, or indeed externalist claims about musical imagery more generally. Given that audiation is a skill which is partly developed by listening to music, it could be argued that, through listening to music, certain sounds (and aspects and combinations of those sounds, and even initial understandings of how those sounds are produced)[75] become integrated; and re-combining them becomes possible. So, if the skill of audiation can in part be developed simply by listening to music, this would explain composers reporting being able to imagine new music in their heads before having had formal training. However, there will be considerable differences in these initial musical images as compared to when the skill has been developed from learning an instrument, singing, using manuscript paper, or a combination of the above.

Through the ITC framework, it is important to consider how these active, directed moments of creative musical imagery will change through the integration of the experiences of using the tools of composition. So, composition at all levels can feel like – and be reported as – an internal process, of which the score is just a necessary record and an essential tool in allowing performers to perform the work, without discrediting the arguments made in this article and the surrounding literature as to the role of tools in musical creativity.

Performers and collaborators

While it has been argued above that the score is not just a tool for allowing performers to perform the work, but a constituent part of the process of musical composition, the fact that this is an *aspect* of the score is actually very important. The ways composers might act out (consciously or subconsciously) the physical gestures of performance are discussed above, but these also extend to a level of empathy with those who will make those gestures in the

[75] Godøy, 'Imagined Action, Excitation, and Resonance'

actual performance of the work. The composer's empathetic understanding of how a performer will understand their part, especially the physical gestures they will need to make in order to produce the desired sound, is an essential element of the process of writing that part.[76]

The important thing about the fact that the score is a set of physical instructions for performers, then, is that this is *implicit in the process of writing of the part.* Put bluntly, a composer can't write a violin part without thinking about a violinist. This connection, between composer and absent (future, remembered, or entirely imagined) performer, would be particularly interesting to examine through the ITC framework – how are the experiences of working with performers integrated into a composer's cognitive competencies? This also provides an angle for understanding other agents who may have acted in a similarly constitutive way, such as teachers, collaborators, audiences, and so on. Similarly, it will be valuable for understanding the role of extra-compositional but still musical experiences in developing compositional competencies, such as in the many cases of successful composer-conductors and composer-performers.

Fully exploring the role of performers and collaborators, and related ideas such as virtual performers,[77] is beyond the scope of this article. [78] However, it is certainly necessary to explore virtual *tools*. Virtual tools provide

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[76] See Elisabeth Le Guin, *Boccherini's Body: An Essay in Carnal Musicology* (University of California Press, 2006) for a study of this relationship in reverse. This book was a major part of the journey towards developing the ideas discussed in this article. In trying to understand how the connection Le Guin felt with a long-dead composer might be understood from the perspective of a composer with a performer, the question of the role of *absent* compositional tools – as well as performers - became an increasingly important problem to solve.

[77] See, for example, Eve Klein, 'Feigning Humanity: Virtual Instruments, Simulation and Performativity', *IASPM Journal*, 6, no. 2 (31 December 2016), 22–48. Exploring virtual instruments would also be particularly impactful when it comes to understanding the role of tools in the cognitive processes involved contemporary composition for film and media.

[78] See Michael Boyle, 'Empathetic Embodiment in the Compositional Process: A 4E Perspective on the Relationship between Composer and Performer', *Journal of Interdisciplinary Music Studies,* 10 (2020), 59-72 for an approach to this idea, one which might be better re-articulated in light of the ITC concept and other related work.

an essential perspective on the role of ITC in the compositional process, due to their blurring of the boundaries between 'present' and 'absent' tools, the powerful opportunities to offload the cognitive processes of composition they offer, and the possibility that their use may lead predominantly to competencies which still require access to these tools.

Digital editing of a score

Consider digital writing, editing, and engraving of a musical score. In contrast to Nicholas Cook's description of 'Beethoven's pen digging into the fibrous, handmade paper' as 'no disembodied act',[79] digital score-writing feels almost immaterial. On one hand, Kirsh describes interacting with the video game Tetris to rotate a block as a 'physical' act, opposed to imagining rotating the block, and points out how the former is more efficient in finding a place for the block to fit.[80] This sets a precedent to see interaction with digital software along the same lines as interactions with other tools. On the other hand, there does seem to be less of a *physical* connection to the musical work when inputting notes digitally than when writing them on to paper. This disconnect could lead to a change in the way competencies are developed, given that the integration of physical actions and their results is an important aspect of this process, as discussed above.

Another contrast with writing on pen and paper is that digital notation software allows direct audio feedback, with the option to play back notes on input, to play back a section once it has been written, or a combination of the two. These auditory affordances open up the possibility of working in a constant feedback loop of editing and playback, more akin to a potter at the wheel than a traditional view of the compositional process.[81] So, while there may be a disconnect between physical actions and notation when working

[79] Cook, *Music: A Very Short Introduction*, 67.
[80] Kirsh, 'The Intelligent Use of Space', 61-62.
[81] See Malafouris, 'At the Potter's Wheel'.

digitally, there is a *stronger* connection between notation and audio, at least while the tool is present, even without a well-developed 'inner ear'.

Another consideration is that, as mentioned above, a score is also a set of instructions for performers. While notation software will warn about notes which are outside the playable range of an instrument, it does not factor in any other practical considerations. Of course, neither does manuscript paper. The point here is that the software plays back what is written regardless of playability, whereas with paper and pen the 'playback' will not happen if the part isn't playable (in a performance, workshop, or rehearsal) or if the composer doesn't have the level of competency (which requires some practical understanding of the instrument) to 'hear' what has been written. As well as applying the ITC framework to understanding which competencies are developed through working with virtual tools, then, it is also worth considering whether certain competencies need to be developed before successfully working with said tools.

Digital Audio Workstations

Numerous scholars have studied the impact of digital tools on musical pedagogy.[82] These impacts can be better understood through considering the role of tools in shaping future cognitive processes, as well as the tools and experiences which may have to have been integrated before these digital tools can be used to their full potential. Thor Magnusson notes how new digital instruments are designed with music theory in mind in a much more explicit way than traditionally.[83] Similarly, in reference to popular music, Robert Strachan discusses how digital tools are designed to give a certain 'experience'

[82] For very recent examples, see Daniel Walzer, 'Blurred Lines: Practical and Theoretical Implications of a DAW-based Pedagogy', *Journal of Music, Technology & Education,* 13, no. 1 (2020), 79-94; Luciana Hamond, Evangelos Himonides, and Graham Welch, 'The Nature of Feedback in Higher Education Studio-based Piano Learning and Teaching with the Use of Digital Technology', *Journal of Music, Technology & Education,* 13, no. 1 (2020), 33-56.

[83] Thor Magnusson, 'Of Epistemic Tools: Musical Instruments as Cognitive Extensions', *Organised Sound,* 14, no. 2 (August 2009): 168–76.

in use – they are designed with transparency in mind.[84] From this perspective, the digital tools of composition are a perfect example of how humans 'make the world smart so we can be dumb in peace'.[85]

When considering the powerful affordances of virtual compositional tools, then, composers may develop competencies which still require access to those tools. To put it another way, they may develop competencies related to knowing where in the software to turn to solve a problem, rather than integrating experiences of being part of a cognitive system and retaining those competencies in the absence of that system. Digital tools may be a kind of cognitive equipment to which one must remain 'subscribed', as described by Bruno Latour.[86] The fact that the complex layers of affordance offered by Digital Audio Workstations (DAWs) are explicitly designed to feel like an 'embodied whole'[87] may lead even experienced composers to think, 'I know I can write this piece, I just need to get to my computer.'

A final example of digital tools is the 'piano roll' interface used to inscribe MIDI information in most DAWs. These interfaces place notes as lines of a length representing duration, and a height representing pitch. Also, rather than having 7 steps in an octave, as on a stave, with accidentals used to achieve the other notes in the 12-note system, the piano roll has 12 subdivisions. These two factors of a) democratising pitches and b) representing rhythm through simple lines denoting duration, are examples of 'properties intrinsic to DAWs [Digital

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[84] Robert Strachan, *Sonic Technologies: Popular Music, Digital Culture and the Creative Process* (London: Bloomsbury, 2017), 68; Although it's worth noting that this can mean that these tools become suddenly very opaque the moment a composer attempts to use them in a way for which they were not designed.
[85] John Sutton, 'Exograms and Interdisciplinarity: History, the Extended Mind, and the Civilizing Process', *The Extended Mind*, ed. Richard Menary (Cambridge, MA: MIT Press, 2010), 189-226 (p. 194).
[86] Latour, *Reassembling the Social,* 210. Relatedly, see Betsy Sparrow, Jenny Liu and Daniel M. Wenger, 'Google Effects on Memory: Cognitive Consequences of Having Information at our Fingertips', *Science,* 333 (2011), 10.1126/science.1207745 for an exploration of a phenomenon regarding search engines, whereby users know they have access to information and therefore don't remember it, they just remember the steps they have to take to access it..
[87] Strachan, *Sonic Technologies*, 67-69.

Audio Workstations] […] that have a fundamental bearing on what musicians and producers actually *do.*'[88]

Considering the feedback loop of editing and playback which was discussed above with regard to notation software, the piano roll interface makes working in this way far more intuitive and transparent. It allows for the formation of a cognitive system in which, for experienced users, the software and its interfaces are completely 'seen-through' in the pursuit of the musical goal. As this article has argued, tools do not just make possible (or easier) cognitive processes in the moment of their use. They also develop our capacity to undertake similar tasks in their absence, which implies that different tools will develop different competencies. So, from an ITC perspective, just as the pen scratching on paper, bringing form to a musical idea, shapes a composer's cognition *in absentia*, so does being part of an iterative system of editing and audio feedback. Just as notation re-shaped musical thought,[89] so too will instant access to audio in DAWs,[90] and the new visual metaphor of the piano roll.

It may be useful, however, to explore the *differences* between the competencies developed and integrated through the use of digital tools, as opposed to 'physical' tools. On one hand, the act of writing is less material than on paper, making conscious or unconscious referral to physical actions and their results more difficult (what muscle memory is there from inputting notes on a screen as compared to interacting directly with paper?). Similarly, the offloading of skills as complex as audiation and instrumental knowledge onto the virtual environment in such a complete way could perhaps reduce a

[88] Strachan, *Sonic Technologies,* 62.
[89] Henrik Sinding-Larsen, 'Musical Notation as the Externalisation of Imagined, Complex Sound', *The Oxford Handbook of Sound and Imagination*, *vol. 2*, ed. Mark Grimshaw-Aagaard, Mads Walther-Hansen and Martin Knakkergaard (Oxford: Oxford University Press, 2019), 191-218.
[90] Marc Duby, 'Affordances in Real, Virtual, and Imaginary Musical Performance', *The Oxford Handbook of Sound and Imagination*, *vol. 2*, ed. Mark Grimshaw-Aagaard, Mads Walther-Hansen and Martin Knakkergaard (Oxford: Oxford University Press, 2019), 97-116 (p. 104).

composer's competency in those skills in the absence of that environment.[91] The designed transparency of the software could also limit the potential competencies retained after its use, as well as any attempts to perform tasks outside its intended use.

On the other hand, the audio feedback of digital software offers a direct link between the visual and the auditory, which could aid in the development of notational audiation. ITC provides a possible explanation for how the experiences of being part of these powerful cognitive systems might shape the way composers plan new pieces, in the same way that it could be argued that working closely with expert performers shapes the way composers write complex music.

In light of all this, the role of the ITC concept in understanding digital technology, and vice versa, may be to explore how competencies developed through the use of various tools intermingle. In other words, to explore which competencies require other tools to be present to fully manifest. It will also be necessary to explore which competencies still require access to the relevant tool, therefore not being *fully* integrated; and which tools do indeed lead to the development of competencies through their use, re-shaping the cognitive processes of musical composition *in absentia*.

Discussion

Through developing the concept of ITC, this article has attempted to demonstrate a way to fully understand compositional creativity through primarily '4E' understandings of cognition. Through a study of the tools of composition, it contributes to both an understanding of the creative processes of composition, and to externalist accounts of cognition more generally. The tools of composition are no longer seen as 'merely expedients to transplant

[91] See Corcoran and Spiro, 'Score-dependency' for an example of this happening to certain classical performers with regards to notation.

musical experiences [...] to the musical listener',[92] but as essential parts of the creative process of musical composition, even in their absence.

As musical tools fade in and out of use, it is important to understand the competencies which are not being developed, and any new competencies which are. Digital technology, for example, often provides audio feedback on ongoing work in a very direct way – does this help or hinder the development of the skill of audiation? Similarly, digital tools are often designed to be intuitive, making them more easily 'transparent', but can by their nature be restrictive, if a composer attempts to do something which the software has not been programmed to achieve.

Future musical study could include an in-depth examination of specific tools, particularly in non-notated or differently notated musical cultures, and an exploration of how the development of musical tools throughout history has reshaped musical cognition. This latter exploration could aid in the creation and design of new compositional tools, including those in pedagogical settings. While this article has only touched on explicitly pedagogical concerns, ITC could, along with an understanding of the relationship between composers and performers, help shape compositional pedagogy through understanding how existing tools might develop and require different cognitive competencies.

While the ITC concept was developed through trying to understand the creative cognitive processes of musical composition, the concept is by no means restricted to composition and could be applied to understanding the cognitive processes of other creative acts. Some of these, often used as examples in work on 4E cognition, are much more *obviously* physical, iterative, and created through use of tools (for example painting, sculpture, or pottery), but this very fact could lead to the ignoring of the role of imagination and

[92] Riemann, 'Lehre von den Ton Vorstellungen', 82.

integrated competencies in the processes of these arts, making ITC a potential contribution to their study.

The most important contribution of the ITC concept towards a general understanding of cognition is in the way it explores the integration of aspects of the external world into the mind beyond the moment of their use. *Instrumenta in absentia*, instrumental even in their absence. Essentially, ITC attempts to provide a conception of the internal in cognitive processes which is built from an understanding of the role of the *external* in cognitive processes, rather than seeing internality as the standard model. It argues that tools re-shape the cognitive competencies of the thinker and remain an essential part of cognition even in their absence. This makes 4E answers to the question of the role of technology in thought equally applicable to clearly material cognition, such as Malafouris' potter at the wheel, an improviser with her instrument and co-present performers, or Clark and Chalmer's Otto with his notebook;[93] and seemingly 'immaterial' cognition, such as a musician imagining new music in the absence of instrument, computer, or score.

[93] Clark and Chalmers, 'The Extended Mind'. Otto (outside) and Inga (inside) are two characters used in a thought experiment to argue that we should consider cognitive use of 'memories' written in a notebook in the same way that we should consider cognitive use of 'memories' in an agent's head.