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Creative collaborations with machines

Abstract (150-250)

This paper analyses creative practice including virtual music composition by a human and sets of computer programs; improvisation of music and dance in human-robot ensembles; and drawings produced by a human and a robotic arm. In all of these examples, the paper argues that creativity arises from a process of human-robot collaboration. Human influences on the machines involved exist at many levels, from initial creation and programming, via processes of reprogramming and setup of underlying data and parameters, to engagement throughout the process of creative production. The decision to value a machine as a creative other is supported most strongly when collaborating with the machine directly, while witnessing the creative team at work, as opposed simply to seeing the result, is more likely to bring an audience to a similar understanding. The creativity of the human-machine collaborations analyzed in this paper relies on close interaction, within which there is a continual recognition of the otherness of the machine and its nonhuman abilities. Such relations can be theorized by extending Emmanuel Levinas' conception of the face to face encounter within which self and other are brought into proximity, but the alterity of the other is nonetheless retained. The paper's analysis of creative interactions between humans and robots supports the idea that machines need not be regarded as challenging human artistic practice, but rather enable new ways for creativity to arise through human-machine collaborations within which human and nonhuman creative abilities are combined.

Keywords (4-6)

Human-machine collaboration; creativity; music; dance; drawing

1 Introduction

This paper introduces a new framework for thinking about creative processes that involve humans and machines as collaborations, within which machines are recognized as active nonhuman participants in co-creation. The paper builds its argument through an analysis of a range of examples that involve humans and machines in the creation of music, dance and drawings. Various ideas of what constitutes creativity and creative work exist across different modes of artistic practice, workplaces and the everyday. This paper employs a basic definition of creativity as the production of something original or new that is perceived as having some form of value, a bipartite definition that Mark Runco and Garrett Jaeger (2012) identify as first used by Morris Stein in 1953. As will become clear below, when considering human-machine creativity questions arise in relation to both what counts as newness and how value is judged. Broadly, the paper finds that context—that is the positioning of the creative act within a surrounding cultural environment, including whether it is possible for an audience to see the creative process in action—is a key part of how people perceive the creativity of the machines themselves, as well as assessing the creative product that arises from human interactions with them.

The examples discussed cover a range of different forms of machine, from computers to non-humanoid robots. David Cope's Experiments in Musical Intelligence and collaborations with Emily Howell form a starting point from which to investigate the potential for computer programs to compose music. Following from this the paper moves on to consider a robotic musician, by exploring the way that

Shimon, the robot marimba player, improvises jazz in performance with a human pianist. The analysis then turns away from its discussion of music, but stays with the idea of performance, to consider creativity in a human-robot dance ensemble, artist Bill Vorn's Grace State Machines. The final human-machine partnership to be discussed involves Drawing Operations Unit (Generation One), a robotic arm that draws in close association with the human artist Sougwen Chung.

The influence of humans on these machines occurs at a number of levels that are often explored by their creators. In particular, humans are responsible for their initial creation and programming, as well as any reprogramming and setup of underlying data and parameters that follows. In the examples discussed below, humans also engage with the machines throughout the process of creative production. An analysis of the extent of human involvement may make it easier simply to regard the human-machine system as creative than to recognize a level of machine creativity. However, humans positioned within the collaborations often indicate that they recognize the machine as a creative other in its own right. While this can be seen to involve a level of anthropomorphism, in all cases the otherness of the machine is nonetheless an important aspect of the collaboration that takes place.

In order to theorize the juxtaposition of familiarity, supported by an anthropomorphic response, and difference between the humans and machines in question, the paper develops an argument that frames human-machine interactions as an extension of Levinas' conception of "the face to face" (1969, pp. 79-81). Although Levinas himself suggested that only humans could take part in this type of encounter, the decision to expand his theory beyond the human context is supported by existing scholarly work in the case of both human-animal interactions (Clark 1997) and human-machine interactions (Gunkel 2012; Sandry 2015). Employing Levinas' conception of the face to face encounter offers a way to theorize the separation that continues to exist between particular humans and machines, even as they interact together closely to produce music, dance or drawings. Levinas' theory insists upon a continual recognition of the absolute alterity of the other, which positions difference as opposed to commonality, as a key part of communication between self and other.

This conception of communication provides a new way to consider the human-machine interactions discussed below, for which the incommensurable differences between humans and machines are important in the creative collaborations that result. Although the machines respond to their human partners, it would be difficult to argue that they reciprocate on equal terms. Importantly, Levinas' face to face does not require that an interaction be reciprocal; instead, as Amit Pinchevski explains, Levinas' "provocative speculation" is that the face to face "is asymmetrical", such that the self is "responsible for the Other before and beyond being reciprocated by an equivalent concern" (2005, p. 9). The examples discussed below illustrate various different levels at which people recognize a machine as an other, with the latter examples in particular suggesting that this recognition is a valuable part of these creative human-machine collaborations.

2 Virtual composition within collaborative human-computer systems

David Cope's Experiments in Musical Intelligence (referred to as EMI or Emmy in most texts and interviews) consisted of a set of programs and outputs created over a number of years. EMI was designed to create compositions based on its analysis of libraries of music consisting of the works of one or more composers, using processes such as recombination and allusion. In essence, Cope's EMI programs produced new compositions that mimicked the work of existing composers.

Critics of Cope's work with EMI have suggested that it "*undermines* human creativity" (Cope 2005, p. 352), but this response overlooks the presence of human influences throughout EMI's process of music creation. As Cope notes, a human wrote EMI's programs, which ran on computers "designed and built" by humans (2005, p. 352). The libraries upon which the programs drew were carefully compiled by Cope to shape the composition of particular styles of music (Cope 2005, p. 360). Throughout EMI's analysis of the libraries, Cope continually monitored how the programs and libraries were operating together, fixing errors and making programming and data alterations as required to ensure "that the pattern-matching program's controllers" were working effectively (Cope 2005, p. 360). It was only after this preparation was complete that Cope "pushed the button", causing EMI to produce large numbers of new compositions (Adams 2010). Then, of the multitude of compositions EMI created, Cope selected only a few for translation into music scores that could be recorded and/or performed either electronically or by human musicians (Cope 2005, p. 360).

EMI's operation alongside Cope's influence could be theorized as a form of creative cybernetic system, within which many iterative feedback loops come into play as human and machine composer work together. This understanding seems particularly fitting because of the emphasis on computer programming, careful structuring of data in libraries, and fixing (of programs and data) required before and during the analysis phase. However, Cope himself argues that, even taking into account the multi-layered human influences described above, EMI itself was a musically creative entity (Cope 2005). A similar understanding of the machine as a composing agent, although only in the production of relatively simple music, can also be seen in the language used by Douglas Eck and Jürgen Schmidhuber when they describe the neural network they developed as a "music composition model" that "successfully learned the global structure of a musical form" based first of a set of sample chords, and then on the chords together with a line of melody, such that it could "compose new pieces in that form" (2002).

Questions can be raised over whether the process of composition followed by Cope's EMI and the neural network of Eck and Schmidhuber—analyzing past human creations, finding patterns and overtly alluding to these in new pieces—is derivative as opposed to creative. However, Cope argues that human composers themselves "cannot create music without reference to other music" and therefore the help of other humans (Cope quoted in Adams 2010). Indeed, this is something that his work on EMI highlighted, since it located the allusions in human music, introduced not just as a composer referenced their own past work, but also by their integration of phrases from the works of other composers (Cope 2005, pp. 125-176). Thus, Cope notes that both EMI (a machine composer) and human composers are creative within the environment of past creativity upon which they draw. From the perspective of a romantic ideal of creativity, which produces original work with little to no allusion, Cope's argument could be understood to undermine ideas about human creative practice as opposed to working in support of EMI as creative, but conceptions of what constitutes newness are becoming increasingly flexible, in particular given recent assessments of the value of "remix" as a form of creativity (Lessig 2008; Gunkel 2015).

The way that programs such as EMI are thought of as composing agents by their human programmers (Cope 2005; Eck & Schmidhuber 2002) leads to this paper's suggestion that, rather than seeing human and machine combined as a cyborg composer, recognizing them as separate entities emphasizes the differences between them, alongside the importance of those differences within the composition process. In particular, computers can be programmed to search for patterns within large libraries of music and to create output based on what this analysis finds, whereas human participants are adept at making the choices required to compile the initial sample library, then moving on to decide which of the created pieces to preserve. This brings to mind Joseph Licklider's conception of "[hu]man-computer symbiosis", within which people "will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations", while "machines will do the routinizable work" (1960, p. 4).

While positioning the work of EMI as "routinizable" might seem to support Cope as the only creative actor in this team, the blind variation and selective retention (BVSR) theory of creativity positions the creation of many variations, through processes of recombination and mutation, as an essential part of a creative process that also involves selection (Campbell 1960; Simonton 2010). In the case of EMI and Cope, the machine produces many variations, while the human selects the initial inputs as well as what is published as the project's final outputs. From the perspective of this paper, both participants in this creative collaboration are needed in order to produce new music. It is worth noting that while Cope might entertain the idea that he collaborates with EMI, the descriptions of Eck and Schmidhuber are not so open to this interpretation. In addition, the question of whether performers, critics and audiences recognize the new music created as valuable is another matter, which is returned to below.

Cope's more recently developed virtual composer, Emily Howell, is designed to produce original music, as opposed to closely mimicking existing composers. She is also more clearly located as a machine entity that enters into a dialogue to create music with a human. In part, this is because the interface for Emily Howell allows human collaborators to use language as well as the exchange of musical phrases to communicate with her, supporting the sense that human and machine are actively engaged in communication that supports a creative musical collaboration.

In discussing Emily Howell's operation, Cope continues to highlight the vital place of the human in continuously interacting with the programs via a central "association network" using either music or language cues (2005, pp. 330 & 341). In order to work properly, the association network must "be trained on the language used" and "the musical style intended" for the composition (Cope 2005, p. 331). Eventually, the flexibility of the interface means that the user "can directly ask the program for new music, an allusion, or an example of contextual data", or alternatively the user can provide a musical phrase as a cue, provoking Emily Howell to respond with a related musical phrase of her own (Cope 2005, pp. 330-331 & 341). The human can also edit sections of music outside the program and then pass these back through the interface to Emily Howell. Cope stresses that it is possible for the program to "act *creatively*, responding to text and musical input in unpredictable ... ways" (2005, p. 331 original italics). The human partner is then able to assess what Emily Howell produces and can accept, edit or discard it as part of the final composition.

Composing with Emily Howell therefore takes place through a process of continual interaction between human and computer involving a form of turn-taking dialogue using either language or music as the human desires (Cope 2005, p. 341). Cope is careful to emphasize that "*teaching* language and music to an association network requires an enormous commitment of time and energy" on the part of a human (2005, p. 344). The collaboration between human and computer cannot produce immediate results; rather, the new music develops through a form of compositional improvisation over the course of many iterative exchanges.

Emily Howell, embodied in the ubiquitous technological form of a computer, is easily positioned as "virtual" as the descriptions of her creator Cope attest. Her existence as a virtual composer is clearest for Cope himself, engaged in close interaction with the program via its language and music interface. Cope has described interactions with Emily Howell as being "a bit like dealing with a small child", although goes on to say that the program "is a cat not a dog", since "you can't take it for walks", but rather just "pick it up" and "point it" in a particular direction (Cope quoted in Adams 2010). Alongside this mix of anthropomorphic and zoomorphic understandings, Cope's sense of Emily Howell as a creative virtual entity is supported by his suggestion that her approach to composition is maturing and might take five years to become fully realized (quoted in Adams 2010). For Cope at least, Emily Howell has a distinct personality and musical style that is developing as he spends time interacting with her, guiding her composition of new music.

While Cope's anthropomorphic response to EMI may not be so clearly articulated in interviews or his writing, Douglas Hofstadter has suggested that he felt he was "Staring Emmy straight in the eye" in the title to his essay on Emily Howell's predecessor (2002). In some ways, this level of response may raise difficulties for popularizing considerations of these machines as creative others. The suggestion that the programs model a particular understanding of musical creativity developed through an analysis of human composers means that the "virtual" composer is positioned as humanlike in itself, not just as mimicking human composers with its own type of creative processes. Emily Howell's human language interface further reinforces this conception of her as a humanlike entity within a computer. In interactions with these sets of programs the otherness of the machine, while clearly underscored by their virtual nature (or even their non-humanoid embodiment as a computer, if this is remarked upon), may be somewhat lost in the mind of the user, because the actions of the program are so strongly framed as humanlike.

Cope's recognition of Emily Howell's personality and his devotion to working with her signals the responsibility he feels towards this machine other, an idea that can be theorized by drawing on Levinas' conception of "the face to face" (1969, pp. 79-81). During this encounter the self and other are brought into a proximity that allows the other to reveal a 'face' to the self, while also retaining a continued sense of its alterity. The self takes responsibility "both *for* and *to* the Other: for the Other's fate, and to his or her address" (Pinchevski 2005, p. 75), a level of responsibility that Cope would seem to take seriously in his work with Emily Howell. As already mentioned, Levinas argued that only humans can take part in this type of encounter, but scholars have already extended his work to include animals and machines (Clark 1997; Gunkel 2012; Sandry 2015).

As a virtual entity, it might still seem difficult to argue that Emily Howell can be encountered in this way, given the importance of the "face" and "proximity" in Levinas' face to face (1969, pp. 79-81). However, while in Levinas' own work the term face was used to refer to human encounters occurring in a shared physical space, his conception of the face is broad enough that it can be extended to apply to computer programs that provoke the sort of response seen in Cope and Hofstadter. This because the Levinasian face is not a physical human face, a set of physical features that can be seen, but is instead a term that draws together all the ways in which the other is able to reveal themselves as a personality during an encounter (Davis 1996, p. 46). It can therefore be argued that, as indicated by Cope's descriptions of what it is like to work with her, Emily Howell reveals a Levinasian face during her iterative interactions with him as they compose music together.

Although the face to face encounter is based in the idea that self and other are brought into proximity, a level of distance is nevertheless always retained between them. For Levinas, this distance protects the alterity of the other, acting as a reminder that the self can never comprehend the other completely. In the context of this paper, the retention of difference not only opens up space for machine others to take part in this type of encounter, but also draws attention to the way that their difference can contribute to a creative collaboration with a human (in what could be fundamentally different ways from another human's contribution). Emily Howell provides Cope with musical phrases and suggestions based on detailed computational analyses of libraries of past music, analyses that he might well struggle to complete on his own.

In contrast with Cope's appraisal, it is clear that, for people outside the collaborative partnership, Emily Howell is more easily thought of as "nothing but a computer program" (Weber quoted in Cope 2011). As Cope notes, this statement positions programs as "relatively worthless things", in spite of the fact that they "pervade most of our lives in critically important ways" (Cope 2011). However, the assumption draws attention to the way that without being involved in interactions with the program—without seeing the machine's otherness revealed through taking part in the turn-taking dialogues formed of language and musical phrases—it may be very difficult to perceive Emily Howell as a creative personality or to accept Cope's arguments that this is the case.

The compositions produced by EMI, and now Emily Howell, have received mixed critical and public responses. Cope notes that people say "they don't hear soul in the music", but he counters by arguing that what people feel when listening to music “comes from the emotional insight” inside them (Cope quoted in Adams 2010). He suggests that people are prejudging virtual music as lacking in musicality, artistry and creativity, because they assume this simply cannot be present in “the output” of a computer (Cope 2005, p. 345). In part, this may be driven by Cope’s tendency to slip between descriptions that position EMI and Emily Howell as creative individuals in their own right, and descriptions that focus on the ways in which humans are an essential part of the creative processes that allow them to create new music. It might also be ascribed to the fact that people outside the collaboration are not brought into proximity with the machine in a way that supports their perception of it as a creative other. Although drawing more people into such collaborations, and directly involving them in the creative process with machines might be difficult, it could therefore be beneficial to extend their awareness of the interaction between human and machine by allowing them to see the collaboration in action, as is the case for the next example.

3 Physical presence, movement and lines of sight in music improvisation

Shimon is an “interactive robotic marimba player”, which “improvises in real time” with a human pianist (Hoffman & Weinberg 2011, p. 233). This robot’s design was based on the understanding that musicianship is about not only “note production, but also communicating gesturally with the audience and with other band members” (Hoffman & Ju 2014, p. 98). Positioning musicianship as involving a “choreography of movements”, alongside the production of music itself, gives Shimon many more options to express an individual personality to the audience as well as to human collaborators, in contrast with EMI and Emily Howell. This sense of personality adds to people’s perceptions of the robot as a creative non-human jazz musician.

Shimon is not designed to appear humanlike, but does use strongly humanlike neck, head and gaze direction cues in managing interactions with human players. These movements are also noticed by the audience and interpreted as demonstrating the robot's attention both to the music and to their human co-performer. This level of listening and attention is understood to be a key part of jazz improvisations, when at any moment "an almost invisible musical exchange" can "take the piece in a new direction" (Sawyer 2008, p. x). As Sawyer argues, this means that for jazz "the group has the ideas, not the individual musicians" (2008, p. x). Sawyer's perspective emphasizes that, for Shimon in performance with a human pianist, it may make more sense to recognize a form of group creativity resulting from a human-robot collaboration, as opposed to making an attempt to unpick the creativity each partner brings as an individual.

When groups achieve a sufficiently concentrated level of attention to each other and the music they attain what Sawyer calls "group flow, drawing on Mihaly Csikszentmihalyi's use of the term "flow" to describe the state of heightened consciousness some people reach when engaged fully in a specific task (2008, pp. 41-43). Central to developing this group flow, and the collaborative opportunities it supports, is developing a sense of trust in one's fellow performers to listen and share responsibility for coordinating development of the improvisation. Trust can, of course, take some time to develop, but Hoffman has shown in previous work with AUR, that humans even learn to trust a robotic desk lamp over the course of a set of iterative experiments in completing a joint task. Their trust grows as the lamp shows itself capable of completing each task and, furthermore, learning the sequence of steps involved, such that it can anticipate directions from the human enabling the team to complete the experiment quickly and with no errors (Hoffman 2008). The situation is similar for Shimon, with trust developing on the basis that the robot is clearly an accomplished marimba player, able to take part in a jazz improvisation by following "a call-and-response pattern" or providing either an "opportunistic overlay improvisation" or developing a "rhythmic phrase-matching improvisation" that complements the playing of the pianist (Hoffman & Weinberg 2011, p. 239-242).

All of the improvisational strategies adopted by Shimon have been designed to use an "anticipatory structure of gestures", so that the improvisation can proceed in real time. These sequences are choreographed programmatically, but the music that results for any improvisation is unique, because it is wholly dependent on the current interaction between robot and human pianist. Of the three strategies, only call-and-response is described as a "common interaction in a musical ensemble" (Hoffman & Weinerg 2011, p. 239). In this sequence, Shimon is able to use the time taken by the human to play the call phase in order to anticipate, prepare and then play the chord sequence that should follow as a real-time response. The other improvisational strategies, "opportunistic overlay" and "rhythmic phrase-matching", were specifically designed by Shimon's development team to allow the robot to play either an improvised phrase or a set of chords in time and tune with the human musician, but working from wherever the robot is positioned at the start of the sequence. The design of these improvisation techniques for Shimon demonstrates the creativity of the human team building and programming the robot; however, they also result in a robot that creatively responds to a human player in improvising a jazz performance using its own nonhuman techniques. This understanding of individual creativity therefore operates alongside the idea of group flow and group creativity discussed above.

An essential part of recognizing Shimon as an entity capable of robotic musicianship is the way the robot's body movement works not only in support of its playing but also to enable its collaboration with a human. Shimon's movements have practical implications. For example, its head "bobs" to signal "the robot's internal beat", an action that allows human musicians to "cue their playing" on time (Hoffman & Ju 2014, p. 102). In addition, "when the robot takes the lead in an improvisation session, it will turn towards the instrument, and then it will turn back to the human musician to signal that it expects the musician to play next" (Hoffman & Ju 2014, pp. 102-103). Its gaze direction is therefore used to signal when turn-taking events take place during the improvisation. More broadly, the continuous movements of the robot as it plays promote the sense in which it is somewhat alive to human musicians and to the audience (Hoffman & Ju 2014, p. 103).

Considering encounters with Shimon in terms of Levinas' face to face may be easier than extending this theory for Emily Howell, not least because Shimon's physical embodiment is so much more expressive than a computer. As Sandry (2015) argues, Levinas' (1969, p. 262) assertion that "the whole body – a hand or curve of the shoulder – can express as the face" supports the idea that encounters with non-humanoid robots, even those that do not have clearly identifiable and expressive faces, are possible if they are expressive in other ways. Although not designed to be overtly humanlike, and clearly retaining machinelike qualities, Shimon uses its well-defined head and neck to express itself in ways that support people's appreciation for its machine otherness. Indeed, "audiences and critics have repeatedly commented on the prominent effect of the robot's social head and its expressive power" (Hoffman & Ju 2014, p.104). People's understanding of this robot as a Levinasian other is also underscored by audience feedback that judges Shimon as able to inspire, and be inspired by, the human musician (Hoffman & Ju 2014). Considering co-inspiration in this way draws attention not only to the bodily communication between Shimon and the human pianist, but also the musical dialogue that takes place. In a similar way to Emily Howell, Shimon can also be understood to communicate a sense of personality to the human musician through the musical phrases it plays. In contrast with Emily Howell, Shimon's performance in front of an audience means that this expression through music reaches out to more people alongside the robot's expressive movements.

Perceptions of the creative collaboration that occurs between Shimon and the human musician are strongly supported by their physical co-presence next to each other in front of an audience. Hoffman and Weinberg's experiments compared situations where the robot is visible to both pianist and audience, and those where Shimon is hidden but audible (2011). Human musicians found it easy to play with the robot when it maintained the tempo they had set, even without any visual contact; however, they found it more difficult in iterations where the robot was programmed to alter the tempo. The impact on audience perceptions of the robot was even more significant, with far higher ratings given to the robot when it was visible on stage with the human pianist (Hoffman & Weinberg 2011). These experimental results therefore emphasize the importance of seeing the robot's embodied movements as well as hearing its playing. Not only does this support a sense of Shimon's accomplishment as a musician, but it also enables it to drive the improvisation in new directions that are taken up by its human partner.

Shimon is a robot whose machine otherness is unquestionable, and yet whose nonverbal communication is recognized as somewhat humanlike and meaningful in the context of jazz improvisation. Much of Shimon's playing is shaped by the choices of the human musician, with the exception of experiments where the robot alters the original tempo in order to test the importance of a visual line of sight between human and robot. Within the framework of the human's contribution though, Shimon's responses are not fixed. While it is programmed to use particular improvisational strategies, these allow the robot to take part in a fluid musical dialogue within which it makes it makes its own creative contributions to the final improvised piece.

The improvised nature of collaborations with Shimon reassure people of the newness of the music they hear. Shimon's musical response strategies, and the processes followed by EMI and Emily Howell, are not the same; however, all of these machines make original contributions to the creative partnerships with humans in which they are placed. Shimon's advantage is that its collaborative potential is seen in action by the audience during a live jazz performance, as opposed to being represented by fixed pieces of music that have been produced by an unseen human-machine collaboration. The fact that Shimon's performance genre is jazz, not classical, may also encourage people to be more open in their assessment of the value of the performance as a whole, and Shimon's contribution in particular.

Interactions between people and Shimon can also be understood as a form of dance, rhythmical and timed within the musical framework it occupies, as their body movements mark the flow of musical improvisation from robot to human and back again throughout the performance. The next example stays with the importance of body movement and performance to consider a dance ensemble that combines human and overtly non-humanoid robot movement, where either human or robot can choose to alter the flow of an improvised dance at any stage.

4 Attention and choice in dances with robots

Grace State Machines (GSM) is a human-machine robotic art performance to music. It was designed by the artist Bill Vorn, and integrates a human dancer with a number of robots that are controlled by a central computer. Vorn's website explains that the project aims to explore "the close relationship between the real physical human body and machine body" (2007). The dance expresses how the human and robot sense each other's motion in response to music, such that their movements "intertwine, blend, mingle and become blurred as they interact" (Vorn 2007). Vorn creates robots that are designed "with wires and motors that you see", because he feels that the more a robot "looks like a machine … the better" (quoted in Faste 2007). Since he has "worked on them from a technical point of view", Vorn argues that he has "absolutely no sentimental relationship with the machines" (quoted in Faste 2007). This contrasts with the "anthropomorphic projection" that moving robots always evoke in audience members (Vorn quoted in Faste 2007).

The robots that are part of the GSM performance ensemble are able to move in response to the changing position of the dancer's body based on information collected by a central computer hub from "a high-end motion capture system" as well as "a set of biofeedback sensors and interfaces" (Vorn 2007). Overtly non-humanoid, the robots are in the form of flexible vertical columns, the bases of which are in fixed positions. Each column consists of a number of linked sections "similar to flight simulator platforms" (Vorn 2007). The sections compress and extend independently, such that each robot's body can bend and flex in complex patterns around and across its vertical axis. Although Vorn's website suggests the aim was for human and robot bodies to "blend into a single organism, where flesh, bones, wires and tubes become a whole individual body" (2007), on watching the video of the performance it seems likely that some viewers at least will continue to see the human and robot bodies as separate entities, albeit closely integrated through the process of moving together to create an improvised dance. This reinforces the idea that there are many different ways to understand human-robot interactions, from regarding them as cyborg relations within which human and machine are merged, to seeing instead the continued separation of human and machine even as they work closely together.

Clearly the human may choose to dance in a way that mimics the movement of the robots, or might decide to take a new direction; however, the same is true of the robots. Much of the time they do act on the information they receive about the human dancer's position to move in ways that complement this, but occasionally the robots choose to move in a new way, provoking a creative change in the flow of the dance to which the human dancer responds (Vorn 2007). Both human and robots are therefore able to add novelty to the development of the piece as a whole.

Although there is limited information about how the dancer, or indeed the audience, perceives these robots during a performance, they extend the argument of this paper by reinforcing the potential of human interactions with a set of overtly non-humanoid machines. In contrast with Shimon, whose body produces recognizable human cues, these robots are expressive in non-humanlike ways that nonetheless enable a human dancer to collaborate with them in a creative and improvisational performance. The video footage shows that the human's attentiveness to the robots is a key part of the collaboration, while the movements of the robots support the perception that they attend to the human throughout the dance. It therefore seems reasonable to suggest that these robots are regarded as machine others by the human dancer at least during the interaction. These robots certainly do not have physical humanlike faces, but their movements, as is true of a "curve of the shoulder" (Levinas, 1969, p. 262), allow the human dancer and the audience to perceive them as expressing themselves in response to the music. The sense of their otherness is also reinforced by the way that they do not just follow the human's movements, but are able to introduce new configurations to the dance, although this may not be so noticeable to audience members as it is to the dancer. In spite of this difficulty, it is only by seeing these robots in action that perceptions of them as machine others, capable of taking part in improvised dance collaborations, can be fully realized.

The idea of seeing the human-robot collaboration process is also a feature of the final example in this paper, moving the analysis on to a situation where a performance and a co-created artwork are the result of human and robot working together. Here, the harmony of what can easily be seen as a dance in videos of the collaborators in action results in the production of a unique improvisational drawing.

5 Collaborative human-robot drawing as process and product

Drawing Operations Unit (Generation One), D.O.U.G._1, is a robotic arm that creates pictures with the artist Sougwen Chung. The robotic arm is table mounted, and a camera and computer vision processing provide information that allows it to follow Chung's movements as she draws (Chung 2015). Chung and D.O.U.G._1 draw simultaneously, working from opposite edges of the same sheet of paper, to produce intricate patterns. The robot draws what could either be situated as an imperfect copy of Chung's lines on the page, or be viewed as a creative variation or improvisation based on its sense of her movements.

Although much of Chung's work is created through a process of "free-form improvisation", she notes that it is nonetheless "easy to become obsessed with mastery" when drawing on her own (Chung quoted in Varner 2015). The development of D.O.U.G._1 has allowed Chung to experiment with a new form of collaborative drawing that requires her to set aside any idea of perfecting her own drawing skills, to engage "in a process of slowing down, paying attention, and communicating entirely through gesture" with a robot (Chung quoted in Varner 2015). In saying this, Chung emphasizes the way that, while drawing with D.O.U.G._1, she is taking part in an extended encounter with the robotic arm during which she must continually attend to the robot and make attempts to communicate with it through her movements to support a process of co-creation. Although the technical description of what this robot does implies its program is designed to track Chung's movements, such that she is in control, her words demonstrate that the process is more iterative than it might seem. Chung responds to the movements of the robot, which are themselves a response to her movements. In this collaboration, robot and human circle around each other and in the process produce a work of art.

During creation of the robot with developer Yotam Mann, the central concern was "calibration, selecting algorithms, and tweaking numeric thresholds", a set of technical actions that sound similar to the setup Cope undertook each time he worked with EMI. In contrast, during interactions with the robot Chung "was surprised by the nascent vulnerability and immediacy of the experience" involving the use of "a completely different language" (Chung quoted in Varner 2015). While Vorn insists that the robots he creates "are always tools" (quoted in Faste 2007), Chung regards D.O.U.G._1 as a machine other with which she collaborates, recognizing the ease with which even simple behaviors are anthropomorphized. As she says, "physical form is powerful" and when combined "with computer vision and an algorithm to generate movement" it becomes "easy to assign agency, personality, and intent" (Chung quoted in Varner 2015). In this way, while the process of programming and calibrating D.O.U.G._1 situates the robot as under the complete control of humans, much as it did for EMI and Emily Howell, when it is drawing, the robotic arm takes on its own expressive identity as a robotic other for Chung. It seems reasonable to suggest that Chung regards D.O.U.G._1 in a way that positions the robotic arm as a Levinasian other, deserving of considered attention and response at least during the times when they are drawing together.

Chung's response to D.O.U.G._1 as a collaborator clearly differs from Vorn's appraisal of his robots as tools. This may result from the way that Vorn's interactions with his creations are always concerned with their development. He is focused on enabling open interactions with his overtly non-humanoid machines, within which other people can develop their own understandings. In contrast, Chung's personal interactions with D.O.U.G._1 cause her to move from one relation with the machine, setting parameters and tweaking programs, to another when they collaborate to produce art. Chung recognizes the strength of her anthropomorphic response during the drawing process, but it is also important to remember that the robot is clearly other-than-human in form and does not mimic Chung's movements precisely. D.O.U.G._1 always retains a level of alterity and in this collaborative human-machine relation, technical issues and unexpected responses are not regarded as bugs, but rather as features, since these "inaccuracies become part of the improvisation" (Chung quoted in Varner 2015). In this way, D.O.U.G._1 adds its own creative elements to the collaboration, even as it senses and responds to the human's movements.

In future developments, one idea is "to create a memory bank" for D.O.U.G._1 as human and machine "experiment with different styles" (Chung quoted in Varner 2015). The hope is to encourage D.O.U.G._1 to include "more variation and decision making" by providing the robot with recourse to "memory recall" (Chung quoted in Varner 2015). One suggestion is to mimic other artists, in a move that brings Cope's work with EMI to mind. In this mode, the work of D.O.U.G._1 might be understood either as a direct challenge to human creativity or even as a form of forgery, in a similar response to that seen for EMI's compositions; however, there is potential that such a bank could be used to provide D.O.U.G._1 with a memory of creative possibilities to be employed in drawing new works in collaboration with Chung via interactions more like those between Cope and Emily Howell.

Critical responses to D.O.U.G._1 are likely to be different from those to Cope's programs because of the embodied nature of this machine, and the way its movements, and the collaborative work they support, is recorded and presented as short looping videos to audiences. In contrast with the work of Cope and EMI or Emily Howell, where the collaboration is a private process only revealed in Cope's books and articles, or in interviews, the way that Chung and D.O.U.G._1 produce creative work is being showcased in a way that emphasizes not only the mutual connection, but also the difference that exists between human and machine throughout the drawing process. While watching these videos might reinforce the idea that D.O.U.G._1 is a creative robot individual, as is the case for Shimon, it is also possible to see them as depicting moments of group creativity, within which a creative human-machine system was achieving a flow state. While inside the interaction, as Chung's statements suggest, D.O.U.G._1 is perceived as robotic other, whereas from outside the continuous movement of human and robot seem so closely integrated that creativity is more easily understood to emerge from the interaction system itself, recorded as a drawing of flowing lines.

6 Conclusion

There are many ways to characterize human-machine interactions. It could be argued that the creation of music, dance and drawings by the types of ongoing human-machine collaboration discussed above is the result of a process of group creativity that is largely dependent on human actions, although machines also take part. From another perspective, which emphasizes the close relation that develops during human-machine interaction from initial programming to examples of ongoing iterative collaboration, the human and machine are in a cyborg relation, and it is the cyborg that is creative. While this paper recognizes elements of both these perspectives, it has concentrated on uncovering a third way to view these creative systems: as collaborations between humans and machines for which it is vital to recognise and attend to the differences between the collaborators. These differences are seen as a vital aspect of the system's creativity.

Invoking Levinas' conception of the self-other encounter in terms of the face to face, a meeting during which it is otherness and not commonality that is most important, is therefore helpful, because it emphasizes the alterity of the machine even as it is drawn into proximity with a human collaborator. Levinas insists that the other cannot be completely comprehended, and therefore always retains a level of difference from the self. This suggests that the machines discussed in this paper can be understood as creative in their own right, and potentially also in their own ways (as opposed to mimicking human creativity). They are, of course, positioned within fields (music, dance, drawing) that are theorized mainly as human creative endeavors, although other animals arguably create artworks, music and dance in their own styles and for their own purposes. The decorative art of the bowerbird, for example, can be called upon as an example of the visual art of animals other than humans (Diamond 1986; Endler et al 2010; Endler 2012). In spite of this, any act of artistic creativity, whether human or non-human, is most often judged through a human lens (although the work of non-human animal artists, as is the case for the bowerbird, will also be assessed by other non-human animals).

This may be why people find it so difficult to judge the works of EMI and Emily Howell as creative, since the virtual nature of these machines not only occludes people's understanding of how Cope works with them, but also leads to them being situated as humanlike entities within a computer. Their otherness is not brought to the fore when people look through the music scores or listen to electronic or human performances of the works they create. In contrast, audiences and critics have more positive responses when they can see embodied and expressive machines for themselves: Shimon, the 'cool' jazz musician with an expressive head and neck that communicates internal rhythm and attention on both its marimba and the human pianist; the GSMs with their unusual form and graceful non-humanlike dances that respond to a human dancer and set off in new directions; and D.O.U.G._1 the robotic arm whose movements operate in fluid concert with a human arm, giving a dancelike quality to their production of abstract drawings together. These robots are all anthropomorphized to an extent, but held alongside these understandings is a clear sense of their non-humanlike being. Shimon, the GSMs and D.O.U.G._1 are overtly non-humanoid, and this may free them from being prejudged, such that they are considered able to engage in their own forms of creativity in interaction with human musicians, dancers and artists respectively.

Considering the machines discussed here as new kinds of Levinasian other also reinforces the possibilities of group creativity, by theorizing how human-machine collaborations have the potential to draw together beings with very different skills, abilities and modes of communication into proximity. In these relations, as Sawyer (2008) argues is the case for group creativity, it is valuable for members of the group to communicate constantly, but it is better if they do not know one another too well. The creative productivity of the group is in part driven by the unexpected ideas and responses of other team members. Becoming too familiar with other group members can therefore reduce the creativity of the group as a whole. The potential of non-humanoid robots to reinforce a sense of alterity, even over the course of long-term interactions with humans, may be important in driving and maintaining the longevity of future creative collaborations between humans and machines. In addition, being able to see that a robot has a level of individual personality and ability, as well as how the robot and human attend and respond to each other, may help audiences extend an understanding of creativity to the robot collaborator, at the same time recognizing its position within a collaborative creative team alongside a human partner.

This paper takes the first step in introducing a new framework for thinking about machine creativity in cases where humans and machines can be understood to collaborate together as creative agents. Specific examples were chosen to build the argument presented, and the analysis of further examples is needed to test the ideas put forward here more fully. In particular, identifying more cases where information about audience responses is available, as well as creator and collaborator responses, would be useful to develop a better sense of how the machine's otherness and creative potential is understood not only by those within, but also those outside, the interaction itself.

References

Adams, T. (2010). David Cope. The Observer. UK. http://www.theguardian.com/technology/2010/jul/11/david-cope-computer-composer. Accessed 1 December 2015.

Campbell, D. T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. Psychological Review, 67(6), 380–400.

Chung, S. (2015). Drawing Operations. Sougwen Chung. http://sougwen.com/Drawing-Operations-D-O-U-G. Accessed 1 December 2015.

Clark, D. (1997). On Being “the last Kantian in Nazi Germany”: Dwelling with animals after Levinas. In J. Ham & M. Senior (Eds.), Animal acts: configuring the humans in western history (pp. 165–198). New York: Routledge.

Cope, D. (2005). Computer models of musical creativity. Cambridge, Mass: MIT Press.

Cope, D. (2011). Response to Noah Weber’s comments on Emily Howell. New Music Box. http://www.newmusicbox.org/articles/response-to-noah-webers-comments-on-emily-howell/. Accessed 1 December 2015.

Davis, C. (1996). Levinas: an introduction. Cambridge, England: Polity Press.

Diamond, J. (1986). Animal art: Variation in bower decorating style among male bowerbirds Amblyornis inornatus. Proceedings of the National Academy of Sciences USA, 83(9), 3042–3046.

Eck, D. and Schmidhuber, J. (2002). A first look at music composition using lstm recurrent neural networks. Istituto Dalle Molle Di Studi Sull Intelligenza Artificiale, 103. http://people.idsia.ch/~juergen/blues/IDSIA-07-02.pdf. Accessed 19 July 2016.

Endler, J. A. (2012). Bowerbirds, art and aesthetics: Are bowerbirds artists and do they have an aesthetic sense? Communicative & Integrative Biology, 5(3), 281–283. doi:10.4161/cib.19481

Endler, J. A., Endler, L. C., & Doerr, N. R. (2010). Great bowerbirds create theaters with forced perspective when seen by their audience. Current Biology, 20(18), 1679–1684. doi:10.1016/j.cub.2010.08.033

Faste, H. and Walter, A. (2007). A conversation with Bill Vorn. http://www.haakonfaste.com/conversation_with_bill_vorn. Accessed 1 June 2014.

Gunkel, D. J. (2012). The machine question: critical perspectives on AI, robots, and ethics. Cambridge, Mass: MIT Press.

Gunkel, D. J. (2015). Of remixology: ethics and aesthetics after remix. Cambridge, Massachusetts: MIT Press.

Hoffman, G. (2008). Achieving fluency through perceptual-symbol practice in human-robot collaboration. In Proceedings of the 3rd ACM/IEEE International Conference on Human Robot Interaction (pp. 1–8). Presented at the HRI, Amsterdam, The Netherlands: ACM.

Hoffman, G., & Ju, W. (2014). Designing robots with movement in mind. Journal of Human-Robot Interaction, 3(1), 89–122. doi:10.5898/JHRI.3.1.Hoffman

Hoffman, G., & Weinberg, G. (2011). Interactive improvisation with a robotic marimba player. In J. Solis & K. Ng (Eds.), Musical robots and interactive multimodal systems (pp. 233–251). Berlin: Springer-Verlag.

Hofstadter, D. (2002). Staring Emmy straight in the eye—and doing my best not to flinch. In T. Dartnall (Ed.), Creativity, cognition, and knowledge: an interaction (pp. 67–104). Westport, Conn: Praeger.

Lessig, L. (2008). Remix: making art and commerce thrive in the hybrid economy. New York: Penguin Press.

Levinas, E. (1969). Totality and infinity. Pittsburgh: Duquesne University Press.

Licklider, J. C. R. (1960). Man-computer symbiosis. IRE Transactions on Human Factors in Electronics, HFE-1, 4–11.

Pinchevski, A. (2005). By way of interruption: Levinas and the ethics of communication. Pittsburgh, Pennsylvania: Dusquene University Press.

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. Creativity Research Journal, 24(1), 92–96. http://doi.org/10.1080/10400419.2012.650092

Sandry, E. (2015). Robots and communication. New York: Palgrave Macmillan.

Sawyer, R. K. (2008). Group genius: the creative power of collaboration. New York: BasicBooks.

Simonton, D. K. (2010). Creative thought as blind-variation and selective-retention: Combinatorial models of exceptional creativity. Physics of Life Reviews, 7(2), 156–179. http://doi.org/10.1016/j.plrev.2010.02.002

Stein, M. I. (1953). Creativity and culture. Journal of Psychology, 36, 31–322.

Varner, M. (2015). Artist interview with Sougwen Chung. http://newhive.com/newhive/sougwen-chung-interview. Accessed 1 December 2015.

Vorn, B. (2007). Grace State Machines. Bill Vorn - Robotic Art. http://billvorn.concordia.ca/robography/GraceState.html. Accessed 1 December 2015.