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Keenan, Fiona orcid.org/0000-0003-2046-9036 and Pauletto, Sandra orcid.org/0000-0002-9404-851X (2017) 'Listening back':exploring the sonic interactions at the heart of historical sound effects performance. The New Soundtrack. pp. 15-30. ISSN 2042-8863

https://doi.org/10.3366/sound.2017.0094

'LISTENING BACK': EXPLORING THE SONIC INTERACTIONS AT THE HEART OF HISTORICAL SOUND EFFECTS PERFORMANCE

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KEYWORDS
sound design , sound perception, sonic interaction design, Foley, sound performance, historical sound effects

ABSTRACT

The cinematic sound design practice of Foley developed from a rich history of performative sound design through materials, objects and mechanical devices created for theatrical performance, magic lantern shows and silent cinema screenings in the late nineteenth and early twentieth century. Now, as virtual and digital methods become available in film sound design production, it is time to evaluate the contribution of these historical sound design methods through the discipline of Sonic Interaction Design (SID). Exploring the use of everyday objects and sound effects devices in the creation of a soundtrack allows us to 'listen' back and forward simultaneously. Our knowledge of historical sound practice can be updated and new practices can be generated, at the same time deepening our understanding of sound for screen that is performative in nature. This article investigates the interactivity inherent in historical sound effects performance through a case study of a mechanical and digital wind machine reconstruction, and explores its potential to inform new interactive digital methods for sound design.

INTRODUCTION: BRINGING HUMAN ACTION TO DIGITAL SOUND

New digital methods are becoming available for film sound design, with advances in real-time sound synthesis processes making available new possibilities for digital sound creation (Telegraph, 2010) and even the independent performance of sound by computer systems (Dent 2016). New interactive sites for storytelling, such as virtual reality (VR) (Franklin-Wallis, 2015) are challenging film's fixed media format and raising the possibility of a need for new sound production methods.

Foley practice, however, remains rooted in the cultivation of an experiential, tacit knowledge (Polanyi 1967: 29) about the sonic possibilities of everyday objects and the movements needed to exploit these. At the heart of this art is human perceptual experience, which has been framed as enactive (Varela et al. (1992: 149) and Noë (2004: 1)). The concept of enaction arises from an ecological approach to perception, which frames human actors as active participants in what they perceive, rather than merely passive receivers of visual or sonic information (Gibson 1979). Gibson suggests that by acting in the world, we gain knowledge about our surroundings and the possibilities they offer for further action. Through a process of rehearsal, Foley artists acquire skill in perceiving the affordances of objects (Gibson 1977), and the possibilities they might offer for action and sound. Actions are performed while actively listening to the sound produced, and the sound simultaneously affects the trajectory or intensity of the action performed. This feedback loop of performance, listening and adjustment creates the embodied knowledge about everyday objects at the heart of Foley (Pauletto 2017).

If experienced Foley artists can confidently judge the quality of the feel (Ament 2009: 14) of their performance to film, can new digital methods offer the same perceptual experience both to the performer and the audience? What do we risk when abandoning the use of everyday objects to make everyday sounds? What do we gain by using interactive digital sound systems as part of performative sound design? We propose that by 'listening' to the craft of sound performance with acoustic materials through history, new solutions can be found and new practices generated to fully connect human action to digital sound production, and make these new digital methods as fluid and intuitive as possible (Dourish 2001: 99).

PERFORMATIVE SOUND: A BRIEF DESIGN HISTORY

Strategies for the creation and manipulation of sound existed long before the advent of digital media (Curtin 2014: xii), or indeed phonograph or tape recording. Sound design was once an exclusively performance-based practice, involving mechanical devices and carefully selected configurations of acoustic materials. The creative use of sound in theatre dates back to 1 BCE, and its particular 'acoustemology' of weather, battle and animal sounds (Brown 2010: 9) evolved through various different sites of live performance. This evolution gathered pace particularly in the late nineteenth and early twentieth century, when live sound effects performance became a regular feature of not only theatre and opera, but also magic lantern shows (Bottomore 1999: 485), silent film (Curtin (2011) and Altman (2007)), radio (Turnbull 1951) and early sound film (Ament 2009). This time period has been characterised as one of 'sonic modernity' (Curtin 2014: 12) or 'Ensoniment' (Sterne 2003: 2),[1] as sound became separated from music into its own particular area of thought and practice, resulting in an explosion of new ideas and new technologies both to create and reproduce it. It was certainly at this time that the practice of sound effects design and performance was widely publicised and published about (see Vincent (1904) and Hopkins (1913) for example), perhaps to defend it, as methods for recording and playing back sounds were becoming more ubiquitous. The inventive and not widely understood nature of the craft is highlighted in regular 'behind the scenes' pieces publicising and promoting forthcoming productions (e.g. the New York Times profile of Lincoln J. Carter's effects (Times 1913)). The skill generated through the practice of designing and building sound effects, and the method of their operation in performance, was usually passed between practitioners through practical training or apprenticeship (Curtin 2011). Later manuals by theatre sound effects designers seem to draw attention to the fact that their craft lacks an authoritative text, and that their effects are now being described after years of personal design and development work (such

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[1] Curtin's (2014) 'sonic modernity' occurs between 1890 and 1925, while Sterne's (2003) 'Ensoniment' covers the period between 1750 and 1925.

as those by Napier (1936), Green (1958) and Rose (1928) for example).

Theatres generally had their sound effects built by in-house carpenters, and they were often tailored to specific performances. Methods for the creation of particular sounds, such as thunder, wind and rain, were well established and their performance often involved the co-ordination of several performers (Napier 1936: 39). With the advent of silent cinema, the craft developed quite differently. This new performance space required only one or two performers (or traps drummers as they became known) to produce all of the sound effects with drums or percussion, usually to accompany a pianist (Altman 2007: 237). As a result, effects equipment began to be commercially manufactured and devices became more compact and portable.

The demands of performing sound for film resulted in the first attempts to create a single apparatus to produce many sounds, such as the Allefex machine at the turn of the twentieth century (Talbot 1914: 141). Devices like this coupled simple gestural control to the creation of many different sounds, adding a mechanical interface to processes that had previously been used directly. In the case of the Allefex, a rotated crank handle could produce gunshot, running water and wind sound effects, amongst others. Sound effects were also built into pianos and organs to create instruments such as the Wurlitzer, placing the full soundtrack into the hands of one performer (Altman 2007: 329).

The live performance of sound effects began to be synchronised to film around 1928, when Jack Foley and his team added footsteps and other sounds to the soundtrack of Show Boat (Pollard 1929) (Ament 2009: 7). The art of live sound performance in synchronisation to film, which was not termed 'Foley' until the 1960s (Wright 2014: 207) developed alongside techniques for close-micing which brought a new focus on the finer details of sound events. The practice used new materials for sound production, such as clothing for movement sounds, and incorporated the use of small everyday objects rather than just specially designed effects equipment. Although some of the mechanical devices and methods from the heyday of performative sound design were still in use in the middle of the twentieth century, they were no longer commercially available and had to be specially made by practitioners once again (Turnbull 1951: 215).

Bringing these diverse sources of information on live sound performance together and examining the different existing production methods for each sound effect, allows us to uncover effective action-sound couplings and allows us to compare different designers' approaches tackling to the same design problem. Sound effects were always the result of an approximation of a natural sound event. For example, rather than exploring the natural process at work behind the sound of the wind, designers approximated the sonic result using a method for creating high-pitched noise through friction, relying on the resulting sound and its perception as evidence of its effectiveness. Particular performer actions could be coupled to different resulting sounds. Rotation, for instance, is linked to the production of wind but also rain and crash sounds. The design problem, for these sound effects designers, appears to always consist of two fundamental questions that still resonate today: how good the resulting sound is in approximating the required sound and how performable the device is.

When considered as a complete body of work, the art of sound design through live performance represents a rich source of knowledge in the area of acoustic materials, the creation of new sounds with those materials, and the coupling of sounds to particular performer actions. As such, we propose that the design methodology behind historical sound effects is an essential source of knowledge for the discipline of Sonic Interaction Design (SID). SID research attempts to address two main questions: how to study the process of meaning creation with sound, and how to create and evaluate sonic interactions (Pauletto 2013). Central to this work is the creation and use of new digital sounding objects, which are physics-based synthesis models recreating everyday actions, materials and their resulting sounds (breaking a wood stick, or crushing a shell, for example) (Rocchesso et al. 2003). We are particularly interested in the design of physical objects that afford the user a particular hand action, and provide reliable sonic feedback, when interacting with a digital sounding object. We consider sound effects devices in the acoustic domain as interactive sounding objects, as they are operated with everyday actions and recreate everyday sounds.

Sonic feedback should 'connect a user's touch, movement, and audition' (Franinović and Serafin 2013: x). This involves the use of continuous sonic and tactile information; allowing a user to control a resulting sound through movement, while simultaneously getting sonic information back about the result of their own movements. Franinović (2013: 21) has defined the self-produced sound created in an interaction with a sounding object as enactive sound. She suggests that designers should tackle the problem of enactive sound design, and create sound always considering how it enhances multi-sensory experience, simultaneously influences each movement the user makes in an interaction, responds directly and continuously to a user's movement, and engages their willed action – that is, make them aware of the sonic interaction so that they can acquire new bodily knowledge. If we consider a Foley performance of rustling paper through the manipulation of a newspaper in front of a microphone, the sound produced is clearly enactive in the same way. Assuming we could capture the essence of this simple interaction in some way and fully recreate it in the digital realm, the sound might bind to other modalities to create new meanings – something Collins (2013: 39) calls a kinesonic synchresis, welding bodily action to the synchresis (Chion 2009: 492) of the visual and auditory to place sound at the heart of embodied interaction.

Bodily action in sound performance is also a relevant research area in the design and development of intuitive and expressive digital musical instruments (DMIs). Like digital sounding objects, they involve interactions with sound, but are more broadly defined as control interfaces used with digital sound generators or processors, rather than just physics-based synthesis models, in performance (Miranda and Wanderley 2006: 1). The act of music-making has itself been defined as enactive (Hayes 2015) and multimodal, and the design of human-computer interfaces sensitive to the needs of performing musicians (Emmerson 2000: 209) has raised some interesting challenges. Widely available human-computer interfaces, such as joysticks, were originally designed to minimise effort on the part of the user, and so do not present constraints to be overcome such as weight, roughness or stiffness – a stark contrast when compared with the properties of acoustic musical instruments. The need for a digital musical instrument to require effort on the part of the performer to make their interaction more meaningful (Ryan 1991: 6) has resulted in new design strategies, including augmentation with haptic technology to provide force feedback (Hayes 2013), and the exploration of complex and more meaningful mappings of control signals to the software system ((Hunt and Kirk 2000), (Rovan et al. 1997) and (Levitin et al. 2002)).

The construction of a digital 'sounding object' or a digital musical instrument presents a key design problem to researchers. How do we link human action to a resulting sound in a meaningful way? How can we offer the same possibilities for articulation of sounds in the digital realm that are available in the acoustic realm? How do we close the gap between simple actions and complex sounds in the digital world? Can digital sounding objects be as rich, intuitive and direct as non-digital sounding objects? We propose that this kind of problem has already been solved, in several instances, in the acoustic domain, by the designers of historical sound effects, particularly in the case of mechanical devices which weld a simple performance gesture to a complex sonic result in a natural action-sound coupling (Jensenius 2007).

While textual sources have revealed some useful knowledge, they may not be sufficient when examining the multisensory history of the design of sound effects objects and their use. Examining a specific object (Cross 2006: 26), or remaking a design (Elliott et al. 2012: 124), may be particularly useful in uncovering tacit knowledge accumulated as part of the design process. Through such making, sounds can be heard and materials can be touched and manipulated. Similar work has been undertaken in this area with Luigi Russolo's intonarumori family of early twentieth century noise intoners. Serafin and De Götzen (2009) studied the workings of the original devices and recreated them as a digital controller connected to a physics-based synthesis engine preserving the same action-sound coupling of the original instrument in a digital sounding object. Our own case study aims to use this method to uncover the tacit knowledge behind a particular historical sound effect design – a wind machine, which we study as an early interactive sounding object to uncover its potential as a model for new digital sounding objects.

INTERACTION IN THE ACOUSTIC DOMAIN: A CASE STUDY OF A WIND MACHINE

A wind machine consists of a wooden slatted cylinder mounted on a central axle, rotated by means of a crank handle. As the cylinder rotates, it rubs against a piece of cloth encompassing it. The friction of the wooden slats against the cloth produces a wind-like sound. A wind machine is particularly interesting to study given that it involves the coupling of a continuous action to a continuous sound, and it is operated through a gesture of rotation, which is a familiar paradigm to users of audio equipment for performance. As part of this investigation into the wind machine sound production and operation in performance, a fully acoustic version of the wind machine was built on the basis of existing designs which are described on a number of sources.

The earliest published mention of the wind machine can be found in Jean-Pierre Moynet's (1873) L'Envers du Theatre:

> Machines to imitate sounds of wind are of several kind. Most often used is this one. A very solid frame supports the axle of a cylinder placed on two bearings. The cylinder is constructed by placing side-by-side assembled sections, each cut to make a section of a circle and surmounted by projecting slats very similar to the teeth of a geared wheel. This forms projections on the exterior surface of the cylinder. There are ordinarily fifteen or twenty of these strips arranged on the apparatus. A strong silk fabric is fitted on the framework over the cylinder. Some small bolts clamp the free end of the fabric, allowing it to be stretched to desired tautness. When, by means of a crank handle, a revolving motion is imparted to the cylinder, the rubbing of the silk on the projecting strips produces a continuous swishing that imitates in a realistic manner the blowing wind sweeping into chimneys or passages. (Moynet et al. 1976: 135)

This method of creating a wind sound is consistently reported by practitioners, sometimes with reference to Moynet himself or the fact that it was originally a 'French' method. The wind machine design became a commercially manufactured device for a short time at the turn of the twentieth century (Yerkes 1911), and was still in use years later, despite the increased use of recorded sounds for performances. In his 1936 publication Noises Off: A Handbook of Sound Effects, Frank Napier advises his reader to use the instrument and learn to play it well rather than risking the obvious and ludicrous repetition of a recording of real wind throughout a show (Napier 1936: 50). The wind machine also continues to inspire the sound design for contemporary productions, including Ben Burtt's recent work on Wall-e (Stanton 2008).

The core principle behind the wind machine design, the creation of friction between a cloth and a rotating wooden cylinder, remains consistent across many historical examples. However, each version we have found has been slightly altered during construction according to the needs of the individual practitioner. A continual process of adaptation is at work, meaning that there are in fact as many different implementations of the design as there are examples:

> E. M. Laumann considered stage wind in Paris theatres in the 1890s 'a sharp whistle without variations' so he made some improvements. First, he released one end of the silk; still dissatisfied, he coated the silk with rosin and attached its loose end to a board which the operator held with his foot. By varying the tension in the fabric, this improved 'wind-machine' produced 'sounds, sharp or soft, such as those produced by real wind.
>
> (Culver 1981: 110 discussing Laumann's (1897) La Machinerie au Theˆ atre)

Mindful of the original design process of performative sound design practitioners, we chose four particular historical theatre wind machine designs by Moynet (1976: 135), Browne (1913: 50), Leverton (1936: 50) and Napier (1936: 51), and used their observations and advice to inform the construction of our own wind machine, so that we could evaluate it as an interactive sounding object (Keenan 2016). The construction of our wind machine (see Fig. 1) has revealed information about the significance of the choices made by designers, the kind of cloth and the smoothness of the wooden slats having a real effect on the resulting sound, for example.

The wind machine is simple to operate and its crank handle affords an obvious action (rotation) for the user. Performance using the wind machine gives a rich multimodal experience. The user experiences tactile (touch) and haptic (vibratory) feedback from the wind machine, as sound vibrates through the handle and can be felt in the hand during the performance. The machine is hand-built and therefore has a slightly imperfect coupling between the handle and the axle. Micro-movements sometimes give the sensation of 'wobble' in the hand during performance. The feel of the wooden handle and metal crank also contribute to the sensation. There is a requirement for the performer to 'do work,' by overcoming inertia and building momentum through the rotation, which changes the experience of force and weight over time. Our machine enforces a standing position on the performer, and engages the hand, arm and shoulder in the rotational gesture.

The wind machine gives reliable sonic feedback in performance. Sound is tightly coupled to the performer's action, and begins when the rotation begins. The sound source is positioned close to the performer and propagates from them rather than towards them from a loudspeaker. The machine produces a familiar everyday sound, which is recognisable as wind-like. There is the potential to develop expertise in playing; the machine can sound very repetitive and machine-like with regular rotational movement, but subtle shifts in the speed of the gesture create a continuously variable and natural wind, which is quite convincing to listen to, even as recorded audio. The wind machine also provides visual feedback to the performer, as the movement of the handle directly couples to the movement of the cylinder against the cloth, which can be seen during performance. The cloth can also be seen moving in response to the rubbing force of the slats.

THE WIND MACHINE AS A DIGITAL SOUNDING OBJECT

To preserve the tactile experience of performance with the acoustic wind machine while creating a digital version, we installed an Inertial Measurement Unit (IMU) sensor near its axle to generate data from the rotational movement. The IMU transmits angular orientation, acceleration and velocity in real time via a wireless transmitter and Arduino prototyping board to a computer running the MaxMSP software.

A digital synthesis engine was created in the visual programming environment, MaxMSP, using the Sound Designer's Toolkit (SDT) (Monache et al. 2010), a physics-based suite of objects for modelling interactions between objects in contact. We used the friction model available in the SDT for the digital wind machine. To emulate the machine's sound production, individual digital 'slats' were programmed to make sound when their acoustic counterparts made contact with the cloth. At any moment in time only seven slats of the total twelve are in contact with the cloth and contribute to the sound production. This was modelled by tracking the orientation data representing one slat, and positioning the others several degrees out of phase with the main data stream to represent the position of each slat in the cylinder. This preserves the workings of the acoustic machine in the digital domain. Transferring the irregular placement of the wooden slats to the software in this way also means the model can be adjusted to imitate other, differently scaled, wind machines. The acoustic and digital sounds can now be recorded simultaneously, facilitating a full examination of the same gesture performed with both systems.

Following an initial acoustical analysis and comparison of the acoustic and digital wind machines (Keenan and Pauletto 2016), the synthesis engine has provided promising results so far. The digital friction model produces a convincing wind sound in real-time performance, and work is currently ongoing to refine the synthesis engine and bring it closer to the acoustic sound to facilitate user testing of the acoustic and digital systems in an experimental setting.

A parallel piece of work mapped the digital synthesis engine to a simple digital crank controller based around a rotary encoder and Arduino (see Fig. 1). Tracking the orientation of this crank handle allows the digital synthesis engine to be activated in much the same way as it is with the IMU sensor data, however the digital crank controller offers quite a different sensory experience. During performance, sound does not vibrate through the crank handle, although the handle is metal rather than plastic, and the rotary encoder and Arduino are encased in a metal enclosure. Some micro-movements are present in the handle due to an imperfect coupling between it and the shaft of the rotary encoder, but the same sensation of 'wobble' from the acoustic machine is not present in the hand. There is no experience of inertia, momentum, force or weight. The handle is light, and given its size it completes a full rotation much more quickly than the wooden machine. Due to its size and portability the controller does not enforce a standing posture on the performer, as it can be freely positioned (lap, tabletop, tripod, handheld, etc.) and engage the hand and arm in a variety of sizes of rotational gesture. However, if it is placed on a tabletop and operated from a standing position, it can engage the hand, arm and shoulder fully in the rotational gesture much like the acoustic wind machine.

The digital crank offers reliable sonic feedback, as sound is tightly coupled to the performer's action, and begins when the rotation begins. This is dependent though on how effective the mapping of the rotary encoder movement is to the digital synthesis engine. The machine produces a familiar everyday sound, which is recognisable as wind-like. There is the potential to develop expertise in playing, but sonic responses to subtle shifts in the speed of the rotational gesture are also dependent on the quality of the mapping between the rotary encoder and the digital synthesis engine. In terms of visual feedback, the movement of the handle can be seen during performance, but there is no visual representation of the movement of the virtual slats against their cloth. There is no visual representation of the movement of the virtual cloth in response to the force of the slats, which would need to be provided by the computer.

Despite the less rich feedback in several modalities when compared with the fully acoustic system, the coupling of a gesture of rotation to a continuous wind-like sound is robust, and has the potential to feel rich, intuitive and direct even as an entirely digital performance. The experience of performing a wind sound with the acoustic wind machine gives a much more natural 'feel' by comparison, however. There is clearly a space between these two methods of performing a wind sound that requires further investigation.

What is significant about this case study is that we have a fully working acoustic wind machine available to us, and are starting from a new initial point. Rather than creating new mappings between digital sounds and controllers and then subjecting them to testing in an experimental setting, action and sound are already intuitively coupled together by means of a simple wheel-and-axle machine. This allows for a full examination of the sonic interaction in the acoustic and digital domain, and may allow us to discover which modality (touch, audition, movement) is most significant in how the action-sound coupling is perceived. Methodologies from digital musical instrument (DMI) design which facilitate a more fully embodied interaction such as the use of resistance (Bennett et al. 2007) could potentially be investigated as a way to bring the experience of performance with the digital crank and synthesis engine closer to that of the acoustic wind machine as part of this work.

In order to examine fully what the wind machine affords the user in performance, it is useful to compare it to other available methods for creating a wind sound. From our historical research, we have found that practitioners were aware of methods to create a wind-like sound through friction by rubbing a piece of cloth or paper against a surface (Fitzgerald 1881: 62); the wind machine is in fact an early performance interface which mechanises the friction in a complex way while still controlling it with a simple gesture. This puts a more complex sound into the hands of the performer, an early solution to a design problem. We can now frame methods for the live performance of a wind sound as a succession of stages that begin with the simplest modes of interaction with handheld materials and end with the use of sensors to generate data from free hand movements, charting the space from the most physical and tactile to the most 'virtual,' when the performer's hands themselves become digital controllers, and there is no experience of physical manipulation of an object or controller. We define this conceptual space of 'sounds in hand' in the context of our work as follows (see Figure 1).

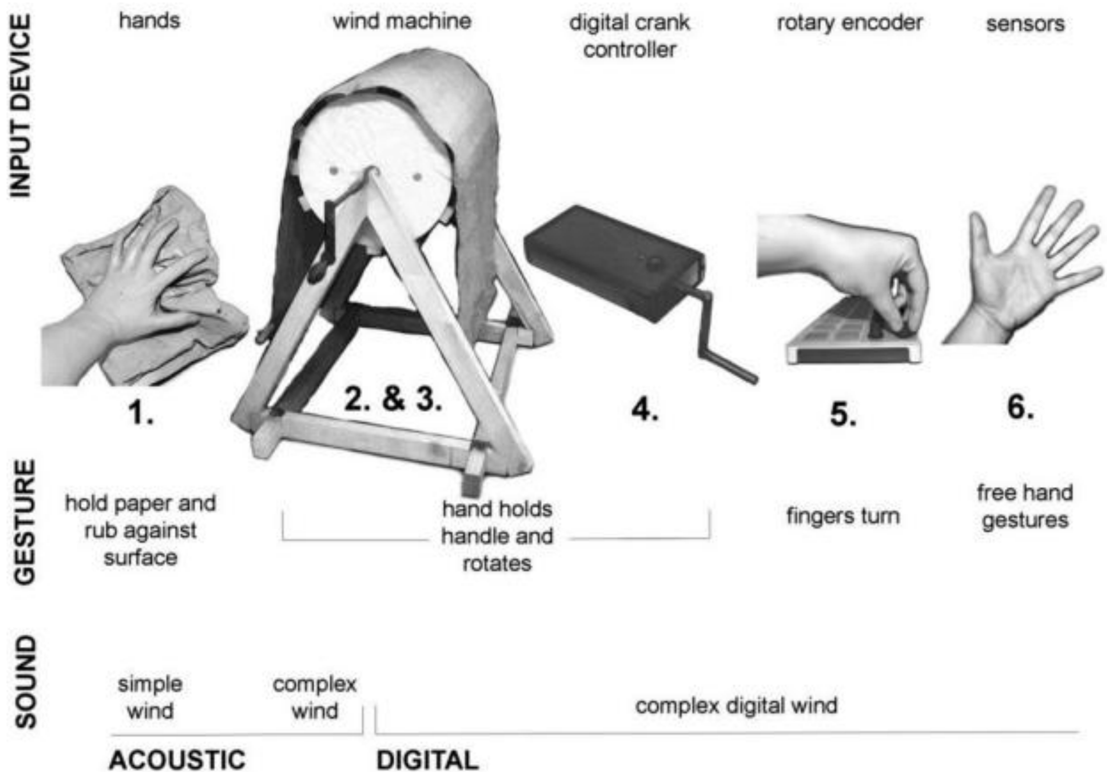

Figure 1: Putting the control of a wind-like sound into the hands of the performer.

1. A wind-like sound is created through friction by rubbing paper directly against a surface. The experience of sound creation is intuitive and direct, with multimodal feedback in performance.
2. This process is mechanised as an acoustic wind machine, and sound is created through a gesture of rotation, which creates friction between a wooden slatted cylinder and a rough cloth. The experience of sound creation is intuitive and direct, again with multimodal feedback in performance.
3. The wind machine is fitted with a sensor and used as an acoustic controller, and its motion drives data to a digital synthesis engine modelling its sound. The experience of sound creation is intuitive and direct, but relies on the mapping of sensor data to the digital domain to create the weld between the performer's action and resulting sound.
4. A small crank handle drives a rotary encoder, which plays the same digital synthesis engine to create a wind-like sound. The experience of sound creation is intuitive, but not as rich as the acoustic wind machine due to the relatively smooth and weightless rotation of the crank handle, which requires less effort from the performer. Augmentation of the crank controller, with a vibration motor for example, could potentially close this gap.
5. The digital synthesis engine is controlled with an audio controller with rotary encoders operated by the fingers. The gesture of rotation has become very small and subtle, and the possibilities for complex sound creation may be limited due to the range of movement this hand position is capable of, in comparison with the experience of rotating a crank

handle.

6. Free hand gestures, captured as data from sensors, control the synthesis engine. The experience of sound creation may not be intuitive, as the performer is unable to rely on the limitations of their own hand movements to establish the sonic parameters, and may require more rehearsal to 'play' the digital wind machine with this method.

Charting this journey from the physical to the virtual highlights the fact that the acoustic wind machine is not merely a sound effect device, but can also be considered as an early control interface. It represents the solution to a design problem, that of creating a complex wind sound capable of being controlled by one performer, the next iteration of a process that began with one pair of hands rubbing paper against a surface. The experience of performing with the wind machine, although introducing a handle into the process of friction generation, nevertheless allows the performer to hold the sound 'in hand' and experience a direct coupling between action and sound. At first glance, the gesture of rotation may seem repetitive, but as we have outlined this allows for subtle changes in speed that produce complexity in the resulting sound.

The action-sound coupling contained in the wind machine makes explicit that the sound of wind itself offers a sonic affordance and suggests a gesture of rotation to the user (Altavilla et al. 2013). Other continuous sounds created in the digital domain may similarly afford a gesture of rotation.

The difference between the acoustic wind machine and digital crank as controllers for the digital synthesis engine reveals the impact that the physical attributes of a device affording a gesture of rotation can have on a performance. It also suggests that a mechanical paradigm may prove to be an interesting methodology for mapping actions to sounds in the digital domain, as it replicates the causal link between gesture and sound in an intuitive manner for the performer (i.e. a continuous sound makes sense when performing a gesture of rotation). The use of simple gestures, such as rotation, as activating gestures for more complex virtual 'mechanisms' to control of digital sounds may make the affordances of those sounds more explicit, and their performance feel as rich, intuitive and direct as the manipulation of everyday objects.

CONCLUSION: 'GRASPING' THE DIGITAL

We have been investigating the space between these systems of sound performance in an attempt to define and close the gap between the physical and digital. We propose that the perceptual space between acoustic and digital control of sound production should be more fully investigated, and that historical sound effects devices can facilitate this, allowing the importance of each modality (touch, auditory and movement) in the interaction to be examined. Neither sound nor action should be privileged in the design of new digital sounding objects. Instead, we should start from an action-and-sound point of view at the prototyping stage in order to work within the possibilities of bodily gestures and sonic results in a meaningful way. The use of existing mechanical paradigms, or machines, that extend the body's capability to produce sound in an intuitive manner should be further explored, particularly in the case of the control of physical modelling synthesis. They make explicit some of the gestures afforded by certain sounds and this can be used in the creation of digital sounding objects for the same sounds. In the digital domain and through the use of physics-based synthesis models, new realisations of the sound effects machinery of the past and new interactions between materials are possible, thereby creating new possibilities for sounds. Simple gestures for the direct control of complex digital sound generation and processing have the advantage in that it is relatively easy to produce a convincing sound while still making space available for complex performances. We propose that a renewed focus on the kind of embodied performance inherent in the art of Foley in the domain of digital sound for film, and an understanding of how the affordances of digital sounds can be made explicit, will ultimately lead to the creation of new sounds and new methods of sound creation.

We have introduced the rich history of the design and performance of sound with acoustic materials and everyday objects as a useful source of knowledge for the creation of new sonic interactions and digital sounding objects, particularly in the case of early mechanical interfaces which couple a simple gesture to a complex sound. Through the discipline of Sonic Interaction Design (SID), we have presented a case study of one such device, a wind machine, and described ongoing work to calibrate a physics-based digital synthesis engine that models its workings. We have evaluated the potential of this work to inform new interactive methods for sound design and performance. We propose that this methodology has the potential to make explicit the affordances of the digital domain, and inform new interactive digital methods for sound design.

ACKNOWLEDGEMENTS

This research is supported by the Arts and Humanities Research Council (AHRC) through the White Rose College of the Arts and Humanities (WRoCAH) Doctoral Training Partnership.

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The New Soundtrack 7.1 (2017): 15–30, Edinburgh University Press,
DOI: 10.3366/sound.2017.0094