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Studying the echo in the early modern period: between the academy and the natural world

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ABSTRACT

This article investigates the process by which the echo became one of the most prominent objects of study in early modern acoustics. Presenting a variety of scholarly work in seventeenth-century Europe, I argue that echo research in the period did not distance itself from the echo's place in mythology and natural history. On the contrary, the echo's existing function as an object of myth and curiosity helped it to attract attention in early modern scholarship. New methods of provoking, measuring, and calculating echo effects emerged, accompanied by descriptions of the echoes' local environments and representations of echo effects in books, journals, and questionnaires. As a much-discussed topic in the newly established scientific academies, echo research contributed to the formation of acoustics as a scientific discipline. Yet the echo remained an elusive object throughout the seventeenth century, driving questions on the nature of sound in a wide range of fields, and bringing together early modern fascinations with curiosity, mythology, and measurement.

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Introduction

The echo – the experience of hearing a sound repeated and altered – was a favourite theme in the early modern period. In works of music, theatre, and poetry, echoes were often used to create dramatic effects. At the same time, the echo was a pivotal object for studying the nature and movement of sound; it brought the early modern fascination with measurement together with mythology and curiosity. Since antiquity, numerous explanations had been devised for the echo, from the reflection of air atoms or spirits to comparisons with a bouncing ball or ricocheting missile. In the early modern period, explanations referred to mechanical, spiritual, atomistic, or magical forces. There was no consensus on what exactly creates an echo, how it is shaped, or how it relates to phenomena such as resonance and vibration. But this multiplicity of theoretical approaches did not prevent the echo from becoming a central object in the study of sound and, more fundamentally, the conceptualisation of sound as an object itself.

This article focuses on how the echo was shaped by its investigators, by tracing the methods, theories, and practices with which it was studied over the course of the

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seventeenth century. Throughout the century, the echo was not only an object of investigation but a tool to observe and experiment with as well. Scholars went out to produce sounds in their surroundings and observed any changes in the reflection, volume, speed, or even language of the sound they heard back. The echoes they heard thus informed them about acoustic phenomena as it helped them to understand their natural surroundings. In this dual capacity, early modern research on the echo forms part of an increasing empiricism in the sciences. Although the rise of empiricism in early modern Europe is typically connected to the visual realm, there was a similar effort to measure acoustical and musical phenomena, as the work of Floris Cohen, Penelope Gouk, and Benjamin Wardhaugh has shown (Cohen 1984; Gouk 1999; Wardhaugh 2008).

The sustained interest in the acoustical features of echoes in the early modern period allows an investigation of the changes in scientific methods and theories over an extended period of time. Of special interest here are the ways in which listening to sound was turned into a scientific experience. Historians of science and the senses have long devoted attention to the ways sensory experiences were made, corrected, and validated. Rather than advocating for a central role for sensory experience in science, most early modern scientists agreed that the senses were easily deceived and needed instruction. The senses needed to be guided by reason, instruments, procedures, and public witnesses. As Steven Shapin writes: "If experience was to play its foundational role in a reformed and orderly natural philosophy, therefore, it had to be controlled, monitored, and disciplined" (1998, 93–94; see also Shapin 1995). The echo research discussed in this article made use of similar strategies to control acoustical experiences, such as repetition, the inclusion of witnesses, techniques of visualisation, and measurement.

This paper starts at the moment when research on echoes became a field of study in its own right: in 1620, when the Italian Jesuit Giuseppe Biancani (1566–1624) declared "echometria" to be the study of echoes (1620). A few years later, Marin Mersenne likewise proposed a science to measure sound, "echometrie" ([1636] 1963). These works consolidated an already widespread interest in echoes, combining geometrical analysis with acoustical experiments. This approach was further elaborated in the works of Jesuit scholars Athanasius Kircher and Gaspar Schott. Tracing the fate of such experiments, we move to the activities of the Fellows of the Royal Society of London (founded in 1660). Echoes featured prominently in newly established scientific academies of the second half of the century. Members went out in the field and gathered observations of a wide variety of echoes. Over the course of this period, several continuities as well as changes, in terms of research methods and approaches, can be observed. Whereas Biancani's science of echoes aimed to describe the general course of nature, the Fellows at the Royal Society were much more interested in particulars. Although the echo remained an interesting acoustic phenomenon for scholars of sound, a clear shift takes place at the end of the seventeenth century. Whereas the echo was previously an exemplary object for studying sound propagation (and therefore one of the key research objects of the discipline of acoustics), its epistemic force had begun to decline. More and more, the nature of sound itself became the object of enquiry, rather than the effect of reflected sound.

In the popular imagination, echoes were often described as eerie or supernatural, but early modern scientists emphasised their predictability and regularity. In doing so, they participated in a larger discourse of anxiety and curiosity surrounding hitherto scientifically unexplored objects such as uncontrollable (female) voices. Building on the argument

of Gina Bloom (2007) and others, I trace the overlap of acoustical theories, mythology, and gendered discourses in echo research. Secondly, an essential part of echo research in the seventeenth century was of a joyful and curious nature. Historians have shown that early modern science was imbued with wonderment, or as Lorraine Daston puts it, curiosity became an "indispensable part of the militant empiricism of the late seventeenth-century natural philosophy" (1995, 400). Although curiosity in early modern science is most often seen as a predominantly visual phenomenon, I argue that research on echoes brought the same development to the world of sound. Researchers of the echo emphasised their curiosity about the phenomenon, and the echo itself was often described as an anomaly of nature. The multifarious nature of echo research in the early modern period, combining measurement, mythology, and curiosity, can help to illuminate why the echo attracted such interest.

By mapping and counting echoes, scholars made sound into an object that could be measured and – almost – captured.[1] The echo, like the scientific objects and processes in modern experiments described by historian of science Hans-Jörg Rheinberger (1997), was a driving force for theories and experiments with sound in the early modern period. Rheinberger's notion of "epistemic things" locates scientific knowledge at the conjunction of scientific objects and the experimental systems that investigate them. The knowledge surrounding epistemic things is thus always historically and contextually bound. The sound of the echo can be described as a sonic variant of the epistemic thing: always fleeting and beyond grasp, it shows how scientific objects can drive research questions, yet are not synonymous with knowledge itself. In the early modern period, many of the theories and tools to investigate sound coalesced around the echo.

"Echometria": a discipline of echoes

As Bruce Smith notes in *The Acoustic World of Early Modern England*, the early modern forests were "full of echoes" (1999, 77). Those uncanny sounds exerted an extraordinary fascination in the period. In recent research on the wide variety of ways in which early modern actors made sense of sounds,[2] the echo appears as a suggestive, often ghostly phenomenon. In his study of early modern England, historian Christopher Marsh emphasises the echo's supernatural potential: "Echoes were other-worldly and served to remind ear-witnesses of the deeper patterns that lay behind the merely physical" (2010, 11). Preoccupied hearers could be tricked by such phenomena. In *De Subtilitate*, for example, the sixteenth-century polymath Girolamo Cardano describes how an echo tricked a traveller at night: a clear and delayed reflection of sound can easily be mistaken for an original sound, and especially in the dark, echoes can "terrorize anyone" ([1560] 2013, 2, 948). The many scholars of the echo in the seventeenth century did not so much emphasise the uncanny nature of the reflection of sound but instead turned it into an attractive object of research, emphasising the echo's regularity based on the mathematisation of sound lines. In doing so, they turned the echo into a phenomenon that could be calculated and controlled.

As the Jesuit mathematician Giuseppe Biancani noted, the echo indeed has many "deceptive and deceitful" qualities, but those could easily be explained with the help of geometry (1620, 429). It turns out that echoes are not eerie, but follow the ordinary course of nature and can be explained by mathematics. Perhaps no one brought echoes to

scholarly attention more than Biancani, who announced the field of "echometria", or the study of echoes, in 1620 in the third book of his *Sphaera mundi* (Biancani 1620). The idea that the study of echoes should constitute its own field was only short-lived, lasting from 1620 until the second half of the seventeenth century.[3] But in those decades, the geometrical understanding of sound was considered an important framework for the study of acoustical phenomena, introduced by Marin Mersenne, Mario Bettini, and Athanasius Kircher. In these works, the pleasure of researching echoes is often highlighted. In his description Biancani details how he retired to the countryside with friends and musicians, determined to leave the business of philosophy in the city. While on a stroll, he and his friends encountered an echo and started to play with the reflecting sound. Infatuated with the phenomenon, Biancani chased echoes through valleys and woods comparing himself to the god Pan, in search of the nature of the echo.[4] Although first unable to explain the phenomenon, he eventually found a solution in the science of geometry. Not only could it explain the workings of light, geometry could now offer a model for studying sound as well: both can be explained by lines and angles (Biancani 1620, 416).

Several authors at the end of the sixteenth century had already suggested that sound was reflected in a similar way to light and that it could, therefore, be calculated similarly by using geometry. Giambattista della Porta (1535–1615), for example, mentions in his *Magia naturalis* that with the help of concave mirrors, one could hear a person speaking softly by holding one's ear at the point of the sound's convergence (see also Barbieri 2007, 162; della Porta [1589] 1658, 361). Geometrical acoustics is generally understood as a fundamentally different approach to sound than the wave metaphor that dominated the Middle Ages and Renaissance. Previously, the primary metaphor to describe the transmission of sound was the water wave. In this analogy, sound travels like the expanding ripples when a stone is dropped in a pond, moving in concentric circles from the centre in all directions. In the geometric understanding, sound travels in direct lines, like rays of light.[5]

Taking up this work, Biancani follows it to its logical conclusion, describing sound propagation as analogous to the propagation of light, importing theorems from optics and applying them to sound. Although Biancani's effort to describe sound as similar to light allowed for increased mathematisation, it also allowed for the greater role of personal experiences. But Biancani's "echometria" is not an "experimental science" in the modern sense. Within the Aristotelian-scholastic framework in which Biancani operated, singular experiences or experiments were hardly considered scientific. A single event would be difficult to adopt within the field of knowledge. The Jesuit mathematician François d'Aguilon (1567–1617) formulates this as follows: "For the single (sensory) act does not greatly aid in the establishment of sciences and the settlement of common notions, since error can exist which lies hidden for a single act" (Aguilonius 1613, 215–16; transl. in Dear 2003, 122; see also1995). Jesuit scholars like D'Aguilon and Biancani wanted to describe general principles of nature rather than describing what happens on a single occasion.

As such, the science of "echometria" aims to describe the general course of nature, what one can normally expect. When Biancani describes his experiments, they are not descriptions of what happened on a particular occasion but rather accumulated experiences over long periods of time. In his account, theoretical reasoning is always more appreciated than lived experience. For example, Biancani noted that sound is only

reflected by flat and solid objects, such as walls and cliffs, but not by uneven surfaces. For this he could rely on his many observations: rocks that were flat but not smooth do not reflect in such a way that is audible again for the observer. But even if this was not the case, according to Biancani, reason dictates that sound lines need a flat surface to reflect (1620, 420). It was hearing that needed to be corrected by reason, not the other way around.[6]

This geometrical understanding of echoes continued throughout the seventeenth century. The sound of an echo, Marin Mersenne wrote, is like light hitting a mirror (Mersenne [1636] 1963, 1, 18). In his famous *Musurgia universalis*, published in 1650, Athanasius Kircher put it even more strongly, recounting that when pursuing the echo, he found it could only be "caught" or understood through the geometrical rules of reflection. Since light is reflected by objects, so is sound (Kircher 1650, 9: 237, 9: 240). Kircher devotes many pages to the echo, making it a key to the study of sound. In the ninth book of *Musurgia universalis*, he gives general rules for studying the echo, shows how to investigate nature through architecture and its echoes, and explains how to build acoustical instruments with the help of sound lines derived from echoes (Kircher 1650: 237–308). The echo becomes the central object in unlocking the workings of sound, whether in instrument building, architectural acoustics, or the propagation of sound itself.

The use of geometry to study echoes exemplifies the intensifying efforts of the seventeenth-century mathematical sciences to account for individual experiences; the geometrical approach to sound not only mathematised the echo but also opened up a greater role for experiences and experiments. Individual echoes were now measured and described, such as the echo at the Villa Simonetta in Kircher's *Musurgia universalis*. Here, a single sonic effect (an echo that repeats the original sound more than 30 times) is visualised and measured, in this case by one of Kircher's assistants (Kircher 1650, 9: 289–291).[7] The acoustical marvel at the Villa is explained by measuring the relationship between the sound and the physical space, noting the location of the window and the distance of the walls. The calculation of echo angles thus became one of the few components of the study of sound that could be mathematised and became a central interest for mathematicians and natural philosophers (Darrigol 2010b, 248). Geometry, it seems, can demonstrate what is to be found in experience – sound reflects in angles and is returned to the listener when it hits walls, rocks, or cliffs.

The echo as a touchstone for theories on the nature of sound

The interest in and central role for the echo in the study of sound cannot solely be explained by the geometrical understanding of sound. Although dominant throughout the century, it was not without its detractors. As historian of science Olivier Darrigol points out, there was no single model of sound in seventeenth-century Europe capable of explaining phenomena as divergent as echoes and the sound of strings (2010a, 149). Instead, there were a variety of models based on Aristotelian, atomistic, and mechanic beliefs. The echo received a wide variety of explanations. This confusion was in part inherited from the ancient writers, who used a variety of metaphors to describe the reflection of sound. Aristotle had compared the echo to "a bouncing ball", Pythagoreans described sound as a missile-like motion of air, and atomists spoke of small globules or particles of sound (Aristotle 1964).[8] Whether sound and its perception

are transported by air, something spiritual, or something between the two was debated continuously. In the thirteenth century, for example, Albertus Magnus denied that the air itself is moved when an echo is perceived, describing the echo instead as a spiritual sound (Burnett 1991, 58).

The notion of "audible species" or "audible spirits" was still referred to by early modern theorists in order to explain how a sound can retain its shape when it is reflected by a wall. Francis Bacon, for example, saw the echo as "a great Argument of the spiritual Essence of Sounds" (1670, 73, §287). Sound must be made audible through little spirits; for if sounds were nothing but physical bodies, the echo would always be the same as the original sound.[9] Such arguments were increasingly criticised. One alternative was the atomistic interpretation of sound. Here again, the echo was put forward as a primary proof. The Dutch scholar and schoolteacher Isaac Beeckman argued (against Bacon) that the echo is evidence of the corporeal nature of sound, in which little voice particles bounce from another body and arrive at the ear in the same order, keeping intact the same word or syllable (1939–1953, 3, 55–56). Royal Society Fellow Walter Charleton held a similar view and derided those "who are persuaded that an Echo is made by the meer Repercussion of the Sound from the particles of the Aer" (1654, 212–13). Far from being a reflection of air, Charleton argued, the echo proved that sound was produced by corporeal particles, bouncing off other bodies, since otherwise words could not be kept intact. Although debates on the nature of sound continued, over the course of the sixteenth and seventeenth centuries, the notion of "audible species" slowly lost its explanatory force. Sound was increasingly described as a movement of air, arguing against the Aristotelian-scholastic view that identified sound as a quality that can be transmitted by air or another medium.[10] An important consequence of this change was that sound could now be studied as motion and as such quantified. And for many scholars, the echo was a central argument.

A survey of the acoustical literature in the first half of the seventeenth century demonstrates that many theoretical explanations centred around the reflection of sound. Depending on whose ears were listening, an echo could be the reflection of air, the movement of audible spirits, or the collision of sound atoms. By the second half of the century, the echo is less proof of a particular theory than an object of experimentation. Experimentation is here understood both as the observation, manipulation, and reporting of phenomena and as a social event. These experiments include an increasing amount of detail in the descriptions, part of a general fear of excluding any material in the experimental literature. In what follows, I focus on three different sources: Robert Moray's investigation of an echo in Scotland, Walter Charleton's report on echo experiments, and Robert Plot's *Natural History of Oxford-shire* (1677). Together, they represent the multiplicity of echo experiments among natural philosophers in the second half of the seventeenth century. After this discussion, I will trace the decline of the central role of the echo in the conceptualisation of sound and acoustics.

Describing echoes for the Royal Society: Robert Moray in Scotland

Echoes were widely discussed throughout the numerous academies and scholarly networks that flourished in early modern Europe. One example is the research associated with the Royal Society of London. Although the Royal Society's interest in music and acoustics is well

known, its echo research has received little attention.[11] Yet references to echo experiments began to appear very soon after the Society's establishment in 1660, stimulating multiple reports, letters, and drawings.[12] Later Fellows, such as Robert Hooke, George Sinclair, Robert Plot, and Charles Leigh, all investigated echoes, and at the end of the century Joshua Walker once again described echo experiments to the Society. Most of the echo reports were presented in the Society's early years, however. It was then that "the Baconian imperative to data-collecting" was most central to the institution's reasoning (Hunter 2007, 4): nature was to be studied inductively, through "careful, empirical observation and detailing of natural phenomena" (Carey 1997, 286). To collect data on sound in this same manner, Fellows of the Society went out into nature to observe and measure echoes or assembled reports from more distant echo observers. In the Royal Society accounts, one or more echoes are investigated and described, often illustrated by diagrams.

Robert Moray's paper on an echo near Rosneath in Scotland, presented in 1662, reports: "Having heard of a rare echo in the bay [at Rosneath], I engaged some acquaintance, one evening, when the air was serene and calm, to satisfy my curiosity in making a trial of it." Moray asked a trumpeter to come along and play "a tune of eight semibriefs". Just after the trumpeter ended, the echo repeated the tune three times, complete and clearly audible. Moray was unable to provide any more detail on what exactly had caused the echo: "I cannot venture to give any account of the precise places, whence the three several reflexions of the sound came, because I neither condescend upon the precise time of the duration of the tune, nor the exact situation, figures, and distances of the hills, rocks, houses, and woody places" (Birch 1756, 137). If the Society wished, Moray added, he could "employ a very skilful and curious person" to make precise measurements of the tune and the reflection of sound and to map the surrounding area. He did send in a sketch of the topography, together with the tune played by the trumpeter (Figure 1) (Moray 1662).

Moray's verbal description is particularly rich, which was necessary to convince his readers in London, but also because of the echo's uncertain origin. Referring to the map, he writes: "The first echo seemed to come from between B and C, the second from about D, and the third from between D and E." He describes the surroundings as "a rocky precipice, some ten or twelve yards high", "a house, all built of stone", and "a church, standing low upon the shore" (Birch 1756, 138). The different sources of sounds, the complex surroundings, and Moray's failure to carry out measurements all contribute to a sense of indeterminateness. Even though he was not able to locate where exactly the echo was coming from, or how it was able to resound the entire tune three times, the investigators had "great Satisfaction" in their research.

His discussion must have stimulated interest, however, since Isaac Barrow was requested next to report on an echo in Cambridge, and more experiments were to be performed by the Society in general (Birch 1756, 137, 138). Somewhat earlier, Henry Powle and Walter Charleton had presented accounts of whispering galleries and echoes to the Society (Powle 1662). The Fellows not only chased echoes through countryside and cloisters themselves but also circulated letters asking for rare examples of echoes. The Secretary of the Society, Henry Oldenburg, wrote to colleagues in Italy requesting echo observations.[13] Robert Southwell responded that he had heard an echo in Brussels that repeated a sound 15 times and that on experimenting with pistols at Villa Simonetta he had heard 56 reiterations but found it difficult to count the sound as it died away.[14] Similarly, Fellow Robert Plot used catalogues of questions to gather rare examples of

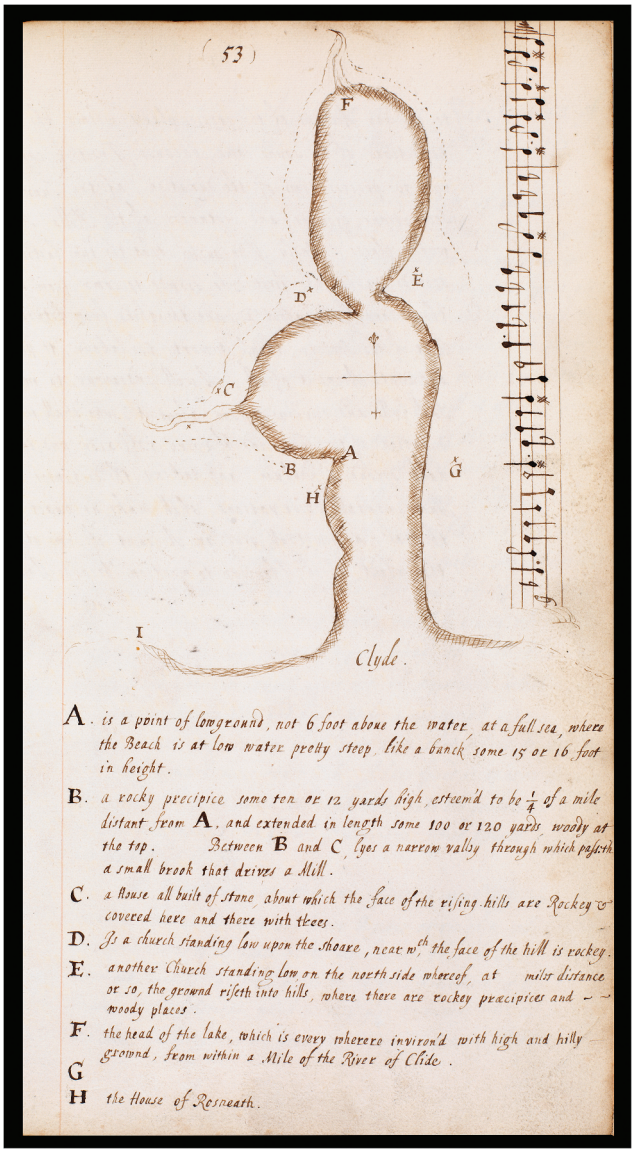

Figure 1. The echo at Rosneath Bay. London: Royal Society Archive, Register Book of "©The Royal Society". Volume 2(i). Dated 3 December 1662.

echoes.[15] Two of Robert Plot's lists have survived and both mention echoes. In Plot's first list, "Quaer's to be propounded to the most ingenious of each County in my Travels through England", he asks readers whether there is "any considerable Eccho in this County?" (Plot 1674, 19/93). In the second set of questions, he asks: "Know you of any considerable Echo in this County, is it articulat, or inarticulat?" (Plot 1679, 19/94). The echo was a central part to the Society's inductive investigations of the workings of nature.

Among the many bizarre and wondrous reports the early Society received, Moray's observation of an echo in Scotland does not seem particularly striking. But the extensive

description and drawing represent, however, a larger attention to a sonic effect and the reaction of its observers, making the echo part of the new culture of observation. As Lorraine Daston and others have observed, the seventeenth century saw an explosion in the amount of observations, questionnaires, and experiences.[16] Observations were widely shared among a larger community of scholars. In contrast to the more general echo science of Biancani, Mersenne, and Kircher, such reports are much more particular. As in Moray's report, they often describe only a single echo and its effect, in other words, a singular experience. As Peter Dear has shown, it was during this time that the notion of "experience" and "experiment" underwent great changes (1995). Whereas in the Aristotelian-scholastic notion (that Biancani was working in) experience meant accumulated experiences over long periods of time, in the second half of the century experience increasingly meant what happened on a single historical occurrence. Whereas Biancani wanted to search for the general nature of sound, Moray was interested in rarity.

Domesticating echoes: Robert Plot's natural histories

In her study of the voice in early modern England, Gina Bloom has investigated the subversive potential of the echo. The echo, as disembodied sound, violated early modern assumptions on the relation of voice, body, and selfhood (Bloom 2007, 160–185). Most early modern writers would still uphold the Aristotelian notion of voice as ensouled sound. Echoes, understood as voices without a clear subject, could be considered as disconcerting. The fact that the echo was traditionally seen as female speech that is difficult to control makes its subversive power clear.[17] Investigating the mythological and gendered discourses surrounding the echo, Bloom notes an increasing effort to divest echoes of their uncanny potential and turn them into easy to control and predictable sounds. The English scholar Francis Bacon, for example, "empties echoes of their eerie potential" by emphasising the similarity between the movement of sound and light (Bloom 2007, 176).[18] The curbing of the vocal potential of the figure of Echo thus stands for larger anxieties about female voices in the early modern period and the need for control in the creation of masculine identities.[19]

Continuing the Baconian project, perhaps no scholar exemplifies the tendency to make the echo an entertaining object of research more clearly than Robert Plot. Fellow of the Royal Society and first Keeper of the Ashmolean Museum, Plot introduces the echo in his *Natural History of Oxford-shire* (1677) with the goal of entertaining his readers with some "sports of Nature". As we can see in his use of questionnaires, Plot was most interested in extraordinary echoes – aiming to bring mythical accounts and practices of scientific measurements closer together. In Staffordshire, for example, he searched for "the best of the kind in the County", which he found in the town of Norbury near a little bank: the echo repeated 12 or 13 syllables spoken quickly (Plot 1686, 28–29). In his research, he describes similar methods we have seen before, moving around until he found a place where an echo replied regularly and he could locate the "vocal line".[20] With every echo, he looked for the "true *centrum phonicum*", the place where the speaker hears the best possible echo, detailing the distances in geometrical paces and emphasising the number of syllables he could hear with each echo. In Baconian fashion, Plot gathered such observations to come to a taxonomy of different echoes, such as "Tautological", "Polysyllabical", and "Tonical" echoes (1677, 7).

Mythology is a recurring topic in Plot's description of his echo research. For example, Plot used classical phrases in his experiments. With one echo near Woodstock, at night he could almost hear the entire phrase from Ovid's *Metamorphoses* – "Quae nec reticere loquenti, nec prior ipsa loqui didicit resonabilis Echo" – which he found "most remarkable" (1677, 8). In his illustration of this echo (Figure 2), Plot pictures the nymph herself in the clouds, chased by the god Pan, referring to the version found in Longus's *Daphnis and Chloe*. In this iteration of the myth, the nymph Echo avoids all contact with males, and Pan is so angered by this (and by her musical skills) that he incites the shepherds to tear her to pieces and scatter her still "singing limbs" over the earth (Longus 1989, 79, 161–63 [quotation 163]). Echo will continue to exist in this liminal state and repeat the sounds of "men, organs, and beasts". Pan, still angry, continues to chase the sounds – in vain. As we have seen, references to the mythological origins of Echo and Pan's hunt for the nymph abound in the acoustical literature of the seventeenth century (Biancani 1620, 415).[21] But in the work of Plot, the mythology of Echo receives a very local flavour: the pastoral surroundings of Oxfordshire. It is here that the echo needs to be "courted".[22]

Although in the myth, Echo continues to escape the grasp of Pan, in Plot's account he seems to exert great power over the acoustical phenomenon. Throughout his account, Plot emphasises his control over the different kinds of echoes, such as one at the park at Woodstock, which returns "very distinctly seventeen syllables, and in the night twenty" (Plot 1677, 7). Whereas the general population might be deceived by such sounds, Plot seems to have an almost virtuosic ability to hunt down and explain echoes. His self-fashioning as a gentlemen scholar, courting a mythical creature, played an essential role in turning the echo from an eerie phenomenon to a playful companion.

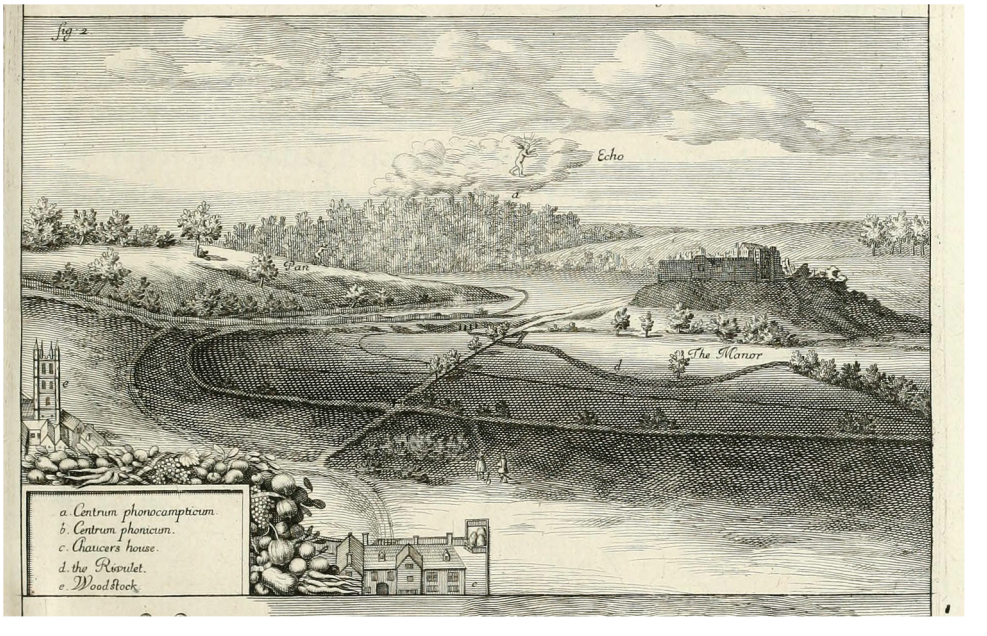

Figure 2. Echo research as depicted in Plot's natural history of Oxfordshire. Holding Institution: Research Library, The Getty Research Institute (archive.org).

Walter Charleton and the measurement of sound

A similar interest in mythology can be found in the echo writings of the physician Walter Charleton. Reporting on echo research for the Royal Society in 1662, Charleton alludes to Ovid's *Metamorphoses*: although "the nice thing [echo] hath often been courted to disclose her secrets" even the greatest philosophers had to conclude that Echo escapes "all embraces" (1662). The mythology of the elusive Echo coincides here with the Fellows' experience of their own echoes fleeing away. Charleton was less interested in the echo as a curious object, as in Plot's natural histories, and more interested in the echo as a tool for measurement. His paper presented to the Society does not include any research of its own, but rather summarises the methods of Biancani, Mersenne, and Kircher, highlighting the use of echoes to measure the speed of sound.

Charleton describes Kircher's method as follows: find a wall, rock, or any other solid object that produces an echo, mark the single echo, and start moving backward in a direct line, "at every 4th or 5th step pronouncing some fit syllable loudly" (1662, page 5 of manuscript). Marking the spot from which each echo was heard and measuring the distances, he explained, allowed one to measure the speed of sound and note how many syllables could be repeated at each distance. In this way Kircher came to the necessary distances for echoes with each possible amount of syllables; 190 Roman feet for a two-syllabic echo, 270 feet for a triple-syllabic echo. Biancani, Mersenne and Kircher had however all come to different conclusions on the necessary distance and the velocity of sound, Charleton pointed out. To bring an end to the various disagreements surrounding echoes, "new and lesse-fallible Experiments" were required (1662, page 6 of manuscript).[23]

Importantly, for example, the echo prompted observations on the influence of atmospheric conditions on sound propagation. Early modern scholars were still unsure about the effect of the time of year, time of day, weather, and temperature on sound, and despite being an unstable object itself, the echo enabled the measurement of these parameters through repeated echo experiments under different conditions. The reports of the Royal Society often detail the atmospheric conditions under which experiments were conducted. Joshua Walker included information such as "some Wind stirring, though not much" or "a clear calm Morning" when describing his echo measurements (1698, 435), and Plot recounted especially wondrous echoes created by weather conditions (Plot 1686, 28). These were no exceptions: Mersenne's *Harmonie universelle* already contains observations on the influence of the time of day, noting that in the afternoon the air was "too thin and weak to receive any impression of the echo".[24] Kircher ordered echo measurements to be made at four different times of the day to investigate the effect of weather and time of day (1650, 9: 245). Although such efforts would eventually lead to a better understanding of the influence of atmosphere on sound, the difficulty of standardising the data meant that it was difficult to generalise from them. There were echoes that seemed to disappear in winter; others could only be heard in the snow.[25]

Charleton's report demonstrates the central role of the echo in the approximation of sound measurements. By moving around, making sounds, and measuring distances scholars were able to make increasingly refined approximations of the speed of sound. Echo research as such led to an increasing number of observations on the speed of sound, executed at different times and under different conditions. In an effort to observe and

measure the natural world around them, measuring echo distances was of special interest to the Fellows in the early years of the Royal Society.

Echo science in decline

I have shown how researchers went about investigating echoes, by observing sounds in bays and churches and sending out questionnaires to collect rare examples. In the Royal Society's foundational years, the Fellows gave numerous reports on echoes, sent out letters asking for examples, and proposed improvements to experiments. But around 1700, a shift seems to have occurred and we find fewer references to echoes. This was not restricted to the sciences. In the aesthetic realm, as well, the taste for echoes was concentrated in the seventeenth century, whereas in the eighteenth, poetry, music, and theatre increasingly treated echo effects as childish gimmicks, not fit for the taste of the Enlightenment, as new standards of naturalism were implemented.[26] For scholars of sound, both the theory of geometrical acoustics and the practice of locating and mapping echoes seemed less fruitful than before and other subjects took a more central role.

An important reason for this new direction in the scientific study of sound was Isaac Newton's emphasis on the mathematical calculation of waves and air pressure. In what is often regarded as one of the most difficult parts of the *Principia*, Newton demonstrated that the speed of sound is dependent on the elasticity and density of air. Air is not propagated from a sounding object to the ear of the perceiver but conveys waves without itself moving. Newton followed the critique of René Descartes and others on the close relationship between sound and light lines, arguing that whereas light is propagated in straight lines, sound is not. What was new was that sound could now be related to measurable parameters of air (Newton 1990, 776–77). The echo experiments of Biancani, Mersenne, and the early Royal Society, which consisted in locating echoes and trying to measure the reflection of sound, could not be related to those parameters.

Around the same time, wider definitions of acoustics as a general field for the study of sound gained ground. Acoustics as a field became more firmly established and coherent; a separate discipline devoted to the investigation of sound rays, such as that of Biancani and Kircher, was no longer required (Gouk 1999, 191). Thus, in 1684, Narcissus Marsh divided the study of sound into "Acousticks, Diacousticks, Catacousticks" or "Phonicks, Diaphonicks, Cataphonicks", mirroring the division of optics but with no mention of echoes per se (Marsh 1684). Somewhat later, Joseph Sauveur contrasted "acoustique" – as the science of sound in general – to music ([1701] 1743, 299). The phenomenon of reflected sound, previously understood as a key to understanding *all* sound, began to take up a secondary position, both in the disciplinary formation of the study of sound and in theories of sound propagation. Echoes could be found anywhere, yet nobody could say why trees, rocks, waves, and clouds reflect sound in the way they do. Eighteenth-century acoustical writers often expressed their dissatisfaction with previous generations of researchers, who had spent much effort in locating wondrous echoes but had not provided a basis to explain their descriptions in terms of acoustical parameters.

That eighteenth-century scholars found the science of echoes lacking in evidential power becomes clear in a speech by Charles de Montesquieu for a competition held by the Académie nationale des sciences in 1718, dedicated to the explanation of the echo (Barrière 1951, 177–78). Montesquieu's speech introducing the winning paper pointed out numerous difficulties in echo research. Why do echoes repeat the same pitch and not sound higher or lower, for example? And how can uneven rocks reflect air without changing the sound? None of the submissions were able to answer these questions. Almost a century after Biancani initiated the field of "echometria", Montesquieu was not optimistic about its progress: "I feel the difficulty, and even more my powerlessness to solve it" ([1718] 1949, 13–14).

Several decades later, in his article on "Echo" for the *Encyclopédie*, d'Alembert complained that acoustical theories on the echo could explain neither why echoes occur at certain places and not others nor why flat or polished surfaces do not always produce better echoes. Moreover, the comparison between light and sound worked only to a limited extent: "sound propagates in all directions, light only in a straight line" (Diderot and d'Alembert 1755, 5, 263). The physicist Joseph-Louis Lagrange would later make similar comments, criticising the reliance of acoustical theories on optics and the imperfect efforts of echo scholars before him ([1759] 1876, 138). In the eighteenth century, research on sound would come to focus on the properties of air or the harmonic motion of strings.[27] The phenomenon of the echo was only secondary since it could not unlock knowledge about the medium of air in general.

Newton's emphasis on the study of air waves did not mean that he did not undertake echo experiments himself (1990, 765). He stood at the end of the northern colonnade at Nevile's Court, Trinity College, holding a pendulum. From this position, he either shouted, stamped his foot or clapped his hands and waited for the echo to return, using the pendulum to measure the time of a first return, around 0.35 seconds, that still can be experienced today.[28] The experiment did not stand on its own but was intended to corroborate Newton's mathematical calculations on the speed of sound in a particular medium. However, his experimental and mathematical results varied by 20%, too much to be convincing (Westfall 1973).

Perhaps because of this, in the second and third editions of the *Principia* (1713 and 1726), the account of his echo experiment is removed. By the time of the second edition, Joseph Sauveur and William Derham had published more precise observations on the speed of sound that did not rely on echoes. Sauveur compared the lengths of organ pipes with their pitches, and Derham used a telescope to observe a cannon shot (Sauveur 1700; Derham 1708–1709). Derham criticised the echo experiments on the grounds of the short distance between the object and its perception, which meant that the measurements were corrupted by the reaction time of the observer. He advised investigating sound at a distance, using a loud sound that could be observed aurally and visually – specifically, a cannon shot (1708–1709, 34). The echo experiments were increasingly viewed as flawed; a new era of precision in the study of sound had begun.

"Easily spoke with, yet known to few"

Research into echoes in the early modern period marks a remarkable chapter in the study of sound. Not only were new methods tested and measurements made, but the echo

became the symbol of the acoustical scholar trying to grasp sound, and curious echoes from the countryside were discussed at scientific academies in the capitals of Europe. This article has traced the circulation of echo descriptions, depictions, and queries, which, despite their ability to reveal an indeed infinite number of new examples, lacked evidential power for later generations. The echo, therefore, was not so much a stable object of research as a "sonic thing" that changed as it was studied.[29] Previously regarded as a key to the understanding of sound itself, the echo was now increasingly described as a property of air rather than a curious object waiting to be discovered. At the same time, the notion of acoustics as a discipline for the study of sound in general became more firmly established in the late seventeenth century, lessening the need for a special discipline of echo research.

Despite these changes in theoretical perspective, the history of echo observation shows a remarkable continuity as it was practised. Especially after Biancani's "echometria" of 1620, echo research took off in the seventeenth century, although many of Biancani's followers did not advocate the affinity between light and sound rays as strongly as he had done. The experiments Biancani described were picked up by numerous scholars from a wide variety of disciplines, within a broader culture of collective empiricism and a playful approach to scientific experiments. Scholars went out into the world, made and measured sounds, and surveyed their surroundings to understand how sonic effects were created. The echo's status as a curiosity here intersects with its status as an object or tool of measurement. Put another way, the variety of approaches in early modern acoustics had the same goal: to make an object of research out of something as elusive as an echo. In this process, our echo scholars found their mirror in mythology, comparing themselves to the god Pan himself as he chased for Echo through woods and mountains. The echo remained something elusive, as Robert Plot described, something "easily spoke with, yet known to few" (Plot 1677, 7).

Although the historical actors presented in this paper were constantly aware of the ephemeral nature of sound, they worked hard to capture the echo by mapping its surroundings and taking measurements. We may understand these efforts as a prehistory to narratives of "capturing sound" in the modern period (Sterne 2003; Katz 2010). Instead of sound recording, early modern scholars used drawings, numbers, and questionnaires to explore the echo as an object of research. The echo appears here as an ephemeral and constantly fleeing thing, engaging the imagination of centuries of listeners.

Notes

1. As historians of sound have pointed out, the desire to capture sound preceded technological developments; see especially Sterne (2003).
2. Of the very rich literature, see (Smith 1999; Rath 2005; Atkinson 2016).
3. One later example of an echometrical treatise is George Sinclair's *Tyrocinia Mathematica* (1661).
4. "Ego itaque veluti Pan alter, per saltus, per syluas, hac illac vociserans Echum persequi, & captare; ipsaque nostris votis respondente, ipsi" (Biancani 1620, 415).
5. Aristotle had already suggested that sound is reflected in a similar way to light, but this statement did not lead to a thorough understanding of sound as moving along geometrical lines.
6. "sensus enim auditus, sicuti & visus; nisi corrigantur ab intellectu, putant se per lineas tantum directas semper videre, & audire" (Biancani 1620, 431).

7. Kircher sent out one of his "well-trained" Jesuit students, Matthäus Storr, to investigate the echo at the Villa Simonetta near Milan (Kircher 1650, 9: 290).
8. The Aristotelian commentator Philoponus described sound as a form of writing into air, which can be reflected by walls (2009, 119). The atomist Epicurus considered sound "a current that is sent off by those who are shouting, making any kind of noise, or hitting surfaces" comprised of "shattered particles of similar shapes" (2005, 77). On debates in the Middle Ages, see Burnett (1991).
9. "For if it were Corporeal, the Repercussing should be created in the same manner … with the original Sound" (Bacon 1670, 73, §287).
10. See Finney (1962, 139–158). For example: Mersenne's "Livre premier de la nature et des proprietez du son" (Mersenne [1636] 1963, 2).
11. On the role of music in the Society, see (Gouk 1982; Miller and Cohen 1987; Wardhaugh 2008; Butler 2015).
12. For example, in 1661, Sir Charles Scarbuch was asked to present an account of an echo, and the Society's secretary Henry Oldenburg wrote to Italian colleagues requesting echo observations. In 1662, Jonathan Goddard, Walter Charleton, and William Croune reportedly experimented with echo effects. The same year, we find reports on echoes or whispering galleries by Robert Moray and Henry Powell. In a special report, Walter Charleton summarised the echo research of Biancani, Mersenne, and Kircher. For an overview, see Gouk (1982, 161–62).
13. Southwell to Oldenburg, 19 September 1661, in Oldenburg (1965, 1, 433–35). The use of a correspondence network to gather curious acoustical examples can be found in the works of other scholars, for example, the French scholar Marin Mersenne.
14. Southwell to Oldenburg, in Oldenburg (1965, 1, 434).
15. The questionnaire became a popular method for states and academies in early modern Europe to gather data on a region, whether newly discovered areas or already familiar land that was to be more thoroughly exploited. Travellers, professional scholars, merchants, and amateurs could all participate, methodically investigating each territory they came across (Hunter 2007; Leoni 2013). See also Carey (1997).
16. See especially Daston and Lunbeck (2011).
17. Bloom describes the echo as a "disembodied and uncontrollable voice" (2007, 161). For resisting female voices in Ovid, see also Enterline 2000).
18. For Bacon's statement, see Bacon (1670, 57, §249).
19. It is worth noting here the central role of Ovid, and Echo, in notions of early modern masculinity. As Danielle Clarke (2007) has argued, for many early moderns the story of Echo was about silencing women's voices, or at least making them complaisant.
20. "According to these grounds I carefully examined this Echo, and found, upon motion backward, forward, and to each hand, the true centrum phonicum, or place of the speaker, to be upon the hill at Woodstock towns end, about thirty paces below the corner of the wall aforesaid, directly down towards the Kings Majesties Manor" (Plot 1677, 10).
21. In his famous depiction of echo research in his *Musurgia universalis*, Kircher shows a variety of experimental constructions based on the echo; at the top of the page is the nymph Echo being chased by Pan. This image is discussed in detail by Jörg Jochen Berns in "Die Jagd auf die Nymphe Echo: Künstliche Echoeffekte in Poesie, Musik und Architektur der Frühen Neuzeit" (Berns 1990, esp. 77–79).
22. Since Carolyn Merchant's *The Death of Nature*, historians have pointed out that when early modern scholars made nature an object of study, they made it in particular a female object. The hunt for natural knowledge was increasingly described as a relationship between the male enquirer and female nature, often using metaphors of marriage, domination, or violence, and sound was no exception (Merchant 1990). A rich exploration of the role of gender and sound conceptualisations can be found in Rodgers (2016).
23. I would like to thank Julia Steinmetz for her help transcribing this source on the echo measurements of Marin Mersenne, see Hunt (1978, 95–98).
24. "Car à midy et à vne, deux, trois et quatre heures l'air eschauffé est trop fluet et debile, et ne sçauroit receuoir aucune impression de l'Echo" (Mersenne [1636] 1963, 1, 55).

25. For example, "I was told of another by the Reverend Mr. Masters Rector of the place, that near his Parsonage house, there was once an Echo that so strangely depended on Frosty weather, that it returned an answer at no other time" (Plot 1686, 28).
26. See, for example, "Echo" in Diderot and d'Alembert's *Encyclopédie*, which disparages echo effects in poetry: "ils ne peuvent se soûtenir contre le bon gout d'un siecle éclairé" (1755, 265).
27. It has been pointed out that the development of acoustics after Newton was increasingly theoretical, relying less on experimentation. See (Ullman 1984; Darrigol 2007).
28. See this 2016 recreation of the experiment: https://www.youtube.com/watch?v=Gy7HqToiBvo.
29. See the introduction of this volume.

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