Visualizing the Invisible
Performing Chaos Theory

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Edward Lorenz, a pioneering figure in the field of chaos theory, coined the phrase “butterfly effect” and posed the well-known question “Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas?” In posing the question, Lorenz sought to highlight the intrinsic difficulty of predicting the long-term behavior of complex systems that are sensitive to initial conditions, for example, the weather and climate; these systems are often referred to as chaotic. Taking Lorenz’s butterfly as a starting point, the author’s science theater project Chaos Cabaret seeks to explore the nuances of chaos theory through performance and music.

CONTEXT OF SCIENCE THEATER
Science theater [1] has begun to attract interest from academics representing a range of disciplinary perspectives, including literary, performance, science communication and education perspectives, although the bulk of published work focuses on text-based analysis [2] or educational settings [3,4]. This has resulted in two dominant strands of literature: One is focused on more traditional, playwright-driven theatrical approaches, which, because they focus on the text, tend to explore the scientific content or position of science within the text. The other strand of science theater has focused on the potential of theater to provide alternative science learning experiences. This literature necessarily focuses primarily on science theater performed in institutions (schools, museums) with explicit pedagogical intent and aimed primarily at younger audiences. While there is much of interest in the educational literature, this paper explores the somewhat overlooked area of theater aimed at largely adult audiences. There has been relatively less focus on theatrical performances developed through approaches such as devised theater [5] or dramaturgical approaches [6], and few studies have explored adult audiences for science theater [7–9].

From a science communication perspective, there is, as Philip Ball [10] notes, a divide between “theatre writers looking to science, and scientists looking to theatre.” Playwrights may find inspiration, metaphors and stories in science but, as Ball points out, it is not easy to portray science well on stage, as a playwright cannot assume the audience is familiar with the subject matter or metaphor the writer is borrowing. For many playwrights the intent is usually not explicitly to educate but rather to explore ideas or the lives of their characters as a means of engaging with ideas [11]. Scientists, however, may turn to theater with more explicit pedagogical or communicative intent, seeking what Carl Djerassi has termed “science-in-theatre” [12]. This genre is one that makes more than passing reference to science and scientists, although science may still act primarily as a backdrop to the narrative, as in “My Galois” [13]. In reviewing a number of recent theatrical performances drawing specifically on mathematics, Robert Osserman [14] highlights particular problems in the representation of mathematicians, suggesting that audiences might conclude that mathematicians as a whole are women, neurodivergent and/or psychotic.

Postdramatic performances, where scientific concepts are embodied in theatrical productions, are also beginning to emerge [15]. Such plays challenge notions of binary oppositions and dichotomies “such as distinctions between thinking and feeling (binary of reason/emotion) and order and disorder (binary of order/chaos)” [16] in Tom Stoppard’s Arcadia. In Arcadia, Stoppard explores his apparently longstanding interest in unpredictability [17]. William Demastes argues that Stoppard believed in “a world that is in fact orderly—it is governed by cause and effect—but it’s also a world that has enough wiggle room to be unpredictable” [18]. Stoppard explores this unpredictability by presenting the past and the present together and illustrating the impossibility of interpreting and predicting either. Susanne Vees-Gulani [19] argues that he uses this device to explore “universal questions about the organisation and evolution of our world and our place and role within it.”

Infinities by John Barrow and Luca Ronconi [20] and Stoppard’s Arcadia [21,22] perhaps epitomize this shift to-
ward theater that weaves scientific concepts into the fabric of performance rather than drawing on them for other purposes, such as how Michael Frayn [23] borrows Heisenberg’s uncertainty principle to use as a metaphor for human psychology in Copenhagen. Stoppard, for example, uses themes such as sex and the garden to organize the structure of the play across time—acting like the strange attractors of chaos theory as points around which the plot evolves [24]. Thus, Vees-Gulani argues that like fractals “the more one thinks about Arcadia, the more levels and messages one discovers” [25]. Unlike the majority of science plays, which see science as a “supporting actor” [26], chaos theory is interwoven throughout Arcadia. Similarly, Barrow and Ronconi bring to life the slippery mathematical concept of infinity in five scenes that are linked but can be experienced in any order [27]. Hilbert’s Hotel, for example, explores the outer edges of infinity. In that scene, a hotel whose rooms are all occupied accommodates another guest by simply moving each guest along by one room (guest in room 1 moves to room 2, etc.). In another scene, the paradoxes of eternal life are explored in a nursing home for those who never die. This scenario explores the human implications of infinity. A further scene explores originality (or lack of it) to consider the implications of a universe where everything will happen, repeatedly. Two additional scenes explore other aspects of infinity [28,29]. Barrow and Ronconi sought to place the mathematical concept of infinity and challenges in conceptualizing it at the heart of the performance, giving infinity a central role in the structure as well as the performance of the play.

**CHAOS CABARET**

Chaos Cabaret, a theater performance that took chaos theory as inspiration, was an exploratory piece in which I was involved, along with author Frank Burnet, Angel Theatre Company and composer Jo Ives, and which the Science and Technology Facilities Council funded. Although Chaos Cabaret is experienced as a linear performance, we took inspiration from Barrow, Ronconi and Stoppard in our attempt to embed chaos theory in the fabric of the play.

Infinity is a concept some initially encounter in school, and many of us will have an intuitive grasp of its mathematical meaning: a number greater than any assignable quantity or countable number, although we may also attach colloquial meanings to the term, such as “limitless” or “boundless.” These are subtly different meanings, and a mathematician will have a different understanding of the term infinity than will a layperson. The same applies to the term chaos. In popular culture, chaos is usually linked to randomness, while as a scientific term it more closely maps to unpredictability [30].

This is a subtle difference, but a critical one when it comes to explaining chaotic systems. I refer to this as a “language challenge” in an attempt not to be normative about word meanings, and it was the stimulus for the development of Chaos Cabaret.

Edward Lorenz [31,32], who pioneered the field of chaos theory, was a mathematician. As he probed the unpredictability of weather systems mathematically, he discovered that while they are deterministic, they are nonlinear and not predicted by linear models. This means that “these systems evolve in different ways according to the given set of initial conditions and parameters” [33]. Lorenz originally called this the “seagull effect” but apparently listened to colleagues who suggested that “butterfly effect” was more poetic. In any case, many of us will make some link between chaos theory and butterflies, perhaps recalling the question posed in the title of Lorenz’s 1972 presentation to the American Association for the Advancement of Science (AAAS): Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas? Intriguingly, Lorenz points to Philip Merilees as concocting this title (apparently Lorenz failed to provide a title at all). Since the 1960s chaos theory has been applied in a wide range of scientific domains [34,35].

In developing Chaos Cabaret, we took this renowned question as a jumping-off point, as I explain below. However, before I dive into the performance itself, it is worth exploring chaos theory in a bit more depth. Lorenz used the question “Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas?” as a way of highlighting the intrinsic difficulty of predicting the long-term behavior of complex systems that are sensitive to initial conditions, for example, the weather and climate; these systems are often referred to as chaotic.

As Lorenz puts it:

> Our results . . . indicate that prediction of the sufficiently distant future [weather] is impossible by any method, unless the present conditions are known exactly [36].

In essence, what Lorenz is arguing is that even a very slight change in starting conditions can lead to widely divergent outcomes [37]. Thus, the flap of the butterfly’s wings represents this very tiny change, which could (in theory) result in some apparently unpredictable weather event (the tornado) in a distant and seemingly unconnected place (in this case, Texas). Or, as Lorenz supposedly puts it:

> Chaos: When the present determines the future, but the approximate present does not approximately determine the future [38].

Chaos Cabaret (see online supplemental materials), then, sets out to explore how small unknowns might lead to different outcomes. The performance is based on a hypothetical conversation between Lorenz and a young journalist who has trouble grasping the notion that tiny differences could produce widely divergent results and that we may not be able to describe a system fully, even though we appear to have accounted for all the essential conditions. This conversation is interspersed with vignettes that seek to visualize chaos theory for the audience and that are performed through dance, movement, sound and words by three actors and three musicians. For most of the performance, at any one time the audience’s attention is directed toward either Lorenz and the journalist or the actors and musicians, creating a separation between a largely expository and a largely narrative exploration of chaos theory. These two frames come together in a final whirlwind (tornado) in which the two worlds collide and merge.
If we take the different elements of the performance, we can uncover the ways in which, by drawing on both expository and narrative devices, the performance seeks to visualize the story of unpredictability that is chaos theory. Thus, we have didactic explanations from Lorenz, such as in this excerpt where he explains a “key dropping” experiment he performs for the journalist (two keys are held together and dropped but naturally do not land in the same place):

From the moment I released the keys the laws of physics took over subtly altering the way each key fell, that’s why one ended up over here and the other over there. So they started together in exactly the same place and ended up in different ones and that is because they were our very own chaotic system. One in which there was no way we could have predicted where these keys would end up, and that would be true however often I dropped them.

To counterpoise this didactic explanation we have a narrative ostensibly conceived by the journalist as he seeks to articulate his growing understanding of chaos theory. This narrative story is performed as a series of vignettes, whereby an initial set of conditions lead to a range of possible outcomes. For example, in this excerpt at the beginning of the performance, a butterfly being chased by a bee attracts the attention of a little girl called Emily:

The movement outside her window was noticed by Emily, a six year old girl who had been sent to her room for conducting an experiment that involved discovering what happened when you mix everything you can reach in the kitchen and put it in the oven for an hour.

Emily opened the window very carefully and a puff of wind may have:

[Music in background while performers act out the different options]
Blown the butterfly in
Made the curtain knock over a vase
Turned the page in a diary
Blown a picture of a bee to the floor

With the music ending, we move back to the expository sphere, where the journalist confirms his understanding of chaos theory:

So, the idea is that the direction of the journey will depend on what the puff of wind changes in the room. Is that OK?

This dialectic between the expository and the narrative is used throughout the performance to build a deeper understanding of the nuanced meaning of chaos in relation to chaotic systems.

AUDIENCE REACTIONS

Brief interviews with audience members both before and after the performance sought to explore ways in which audiences might engage with science theater. It was evident that many in the audience were attracted to the performance because they either knew the performers or had previously attended work by the Angel Theatre Company, while others were attracted by the topic (chaos theory), which they perceived to be an unusual topic for a performance, as this interviewee explains:

I thought it was a really unusual idea. How do you bring something like chaos theory, which is so dull, to life? (Int. 3)

Entwined in this response is a perception that science and mathematics in particular are in some way boring and irrelevant, which was not a view shared by all interviewees, many of whom “have always been interested in science” (Int. 1). Thus, the audience seemed to be composed of two quite different groups: on the one hand, those looking to feed an existing interest in science and who saw theater as just another venue in which to encounter science, and on the other hand, those primarily interested in theater who saw science as a curious challenge. This audience was culturally active, and many held existing interests in science; just over half had previously attended science-themed theater (56%, n=30). Interviewees also felt that the performance “was really good fun and it explained a lot of questions. Really in layman’s terms” (Int. 2). The majority of respondents felt that the science content of the performance added to the overall experience (87% agreed or strongly agreed, n=30), and 80% (n=30) felt that the performance had encouraged them to think about chaos theory.

There was one rather notable exception among the interviewees. Interviewee 8 had evidently attended the performance by accident, assuming it would “be more of a lecture” and who considered that “all this acting and poncing about is a load of rubbish” [39]. This audience member’s experience highlights the importance of expectations when attending live events; theater is not enjoyed or seen as relevant by everyone. As a genre that blurs boundaries and might be sited in unexpected venues (where either science is expected and theater is not, or vice versa), it has the potential to attract diverse audiences, but these audiences may be ill prepared for their experience.

DISCUSSION

Like the plays of Djerassi, Chaos Cabaret does have didactic content, and the vignettes—unlike in Ronconi’s Infinities—can only be experienced in one set order. In creating Chaos Cabaret, we drew inspiration from Stoppard, seeking to draw on both arts and sciences as modes of representation [40] with the intention of reassembling “various areas of knowledge” [41] to enable the audience to build new understandings. Arcadia moves between time periods—past and present—while Chaos Cabaret moves between narrative and expository speech. Both plays use these shifts in positioning as one means of weaving unpredictability (e.g. chaos theory) into the fabric of the performance. Audience responses suggested that the combination of narrative and expository elements was effective at engaging the audience with a topic that might otherwise have been seen as “dull”; audience responses also suggest that the concept of chaos theory was translated effectively into layman’s language [42]. For the majority of
audience members who were attending a theatrical event, they viewed it as a compelling way to encounter science, feeding their curiosity. However, the rather angry dissenting voice highlights the importance of audience expectations. While it may be hard to understand how an event advertised as a performance could be mistaken for a lecture, there are many ways in which an audience can be unprepared for science communication leading to dissonant experiences. (These dissonant experiences are not necessarily without value.)

Arcadia explores the ways in which chaos theory prevents us from ever fully understanding the past [43]. In a similar vein, Chaos Cabaret sought to visualize chaos theory through the performance of potential futures; in doing so, it points to the impossibility of predicting the future. In this way, Chaos Cabaret sought to enact and embody unpredictability. Performers’ bodies become our way to see the unseen and music becomes a means of signaling change. Through movement, music, narrative and expository dialogue, Chaos Cabaret engaged the audience with a topic some in the audience perceived as challenging. We designed the performance as a cultural collision—between performance, science and people. Such collisions offer challenges, but also opportunities for new meaning to be created.

References and Notes

1 There is also a field of theater related to health communication, health education and community development. This field is expansive in its own right and has some overlap with science theater in education. For the purposes of this article, it is considered a distinct field.


22 Vees-Gulani [19].


24 Vees-Gulani [19].


29 Coyaud [27].

30 Vees-Gulani [19].


35 Vees-Gulani [19].


37 Abdchiri et al. [34].


39 I should note that the performance was scheduled during a science festival in which much of the program was lecture or discussion based, but information on the program clearly stated that Chaos Cabaret was a theater performance.

40 Hooti and Shooshtarian [15].


43 Kramer and Kramer [21].

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