A Dramaturgical Framework for Interactive Performance: Sensitizing Concepts at the Intersection of Performance and Technology

Molly Nicholas

Electrical Engineering and Computer Sciences
University of California, Berkeley

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Thank you to my advisor, my committee, my esteemed and wonderful colleagues, my friends, my family, and most of all my husband!

A Dramaturgical Framework for Interactive Performance:
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by

Molly Jane Nicholas

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Professor Abigail de Kosnik
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To all my brilliant participants, whose collected knowledge could fill many wonderful dissertations

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Performances tell compelling stories, provide an escape from (or new perspective on) everyday life, help us connect with each other, and teach us about the world. In this work, I seek to identify, categorize, and expand existing notions of "performance" as it is operationalized within the world of HCI, and articulate the ways in which core HCI concerns — including identity, agency, immersion, self-presentation, social interaction — can and should be investigated through performance. Through 1) incorporating core theatrical values into the design of novel computer-mediated communication systems 2) designing, constructing, and deploying functional prototypes during long-term collaborations with expert theatre practitioners, and 3) designing creativity support tools that embody expert values in order to scaffold newcomers into sustainable creative practice, my work emphasizes the ways that HCI can shape and be shaped by rich understanding of and engagement with performance. I embrace 'performance' as an understanding of the way people present themselves (as performers) to others (an audience) and investigate this in technologically-mediated environments. This thesis seeks to "illuminate the specific ways in which performance might further enrich...HCI research" (Spence et al., 2013).

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Chapter 1

Introduction

Whether a theatre show, a musical concert, an impromptu street performance, or an animated film, nearly everyone has enjoyed at least one performance in their life. Performances tell compelling stories, provide an escape from (or new perspective on) everyday life, help us connect with each other, and teach us about the world. Performances are an important part of the human experience, and the field of Human Computer Interaction (HCI) has fruitfully sought to expand, support, capture, and re-imagine many aspects of performance.

The primary focus of most HCI research combining technology and performance is the performance itself - essentially limiting the design space to the specific time (and place) during which a ticket-holder would experience a formal, staged production. In this dissertation, I explore an inversion of these common constraints, identifying opportunities for technology engagement with a live performance at different times and in different places. My goal is to use technology to provide opportunities to engage with audiences outside of the context of a production, support reflective theatrical experience beyond the stage, all while embracing the affordances of theatre. In other words, my goal is to integrate tech *around* a theater experience rather than *into* it. I introduce an expanded understanding of time in relation to performance, considering not only the show itself but events and creative efforts that take place before and after (see Figure 1.1). I especially consider the extensive creative efforts that go into the early production process as well as the long-term reflection and engagement with a performance over time.

In this work, I seek to identify, categorize, and expand existing notions of "performance" as it is operationalized within the world of HCI, and articulate the ways in which core HCI concerns — including identity, agency, immersion, self-presentation, social interaction — can and should be investigated through performance. Through 1) incorporating core theatrical values into the design of novel computer-mediated communication systems 2) designing, constructing, and deploying functional prototypes during long-term collaborations with expert theatre practitioners, and 3) designing creativity support tools that embody expert values in order to scaffold newcomers into sustainable creative practice, my work emphasizes the ways that HCI can shape and be shaped by rich understanding of and engagement with perfor-

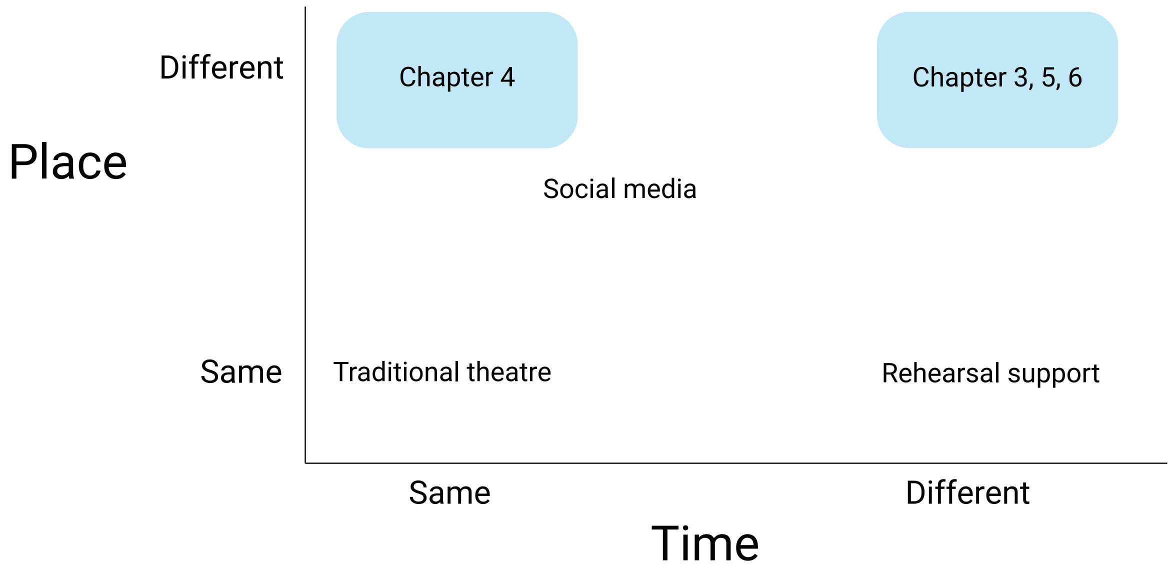


Figure 1.1: A visual categorization of how different performance approaches can be aligned in place and time. I include the work in this thesis, to further communicate the expanded design space I introduce. Chapter 3 presents these expanded notions in the context of a formal theatre production. Chapter 4 describes an experience-sharing system for camera glasses, and I recast social media as an informal form of performance. Chapter 5 introduces pre-production as another design space relevant to the performance context. Chapter 6 describes the design of a tool meant to support pre-production for animators.

mance. I embrace 'performance' as an understanding of the way people present themselves (as performers) to others (an audience) and investigate this in technologically-mediated environments. **This thesis seeks to "illuminate the specific ways in which performance might further enrich...HCI research"** (Spence et al., 2013).

1.1 An Expanded Notion of Performance

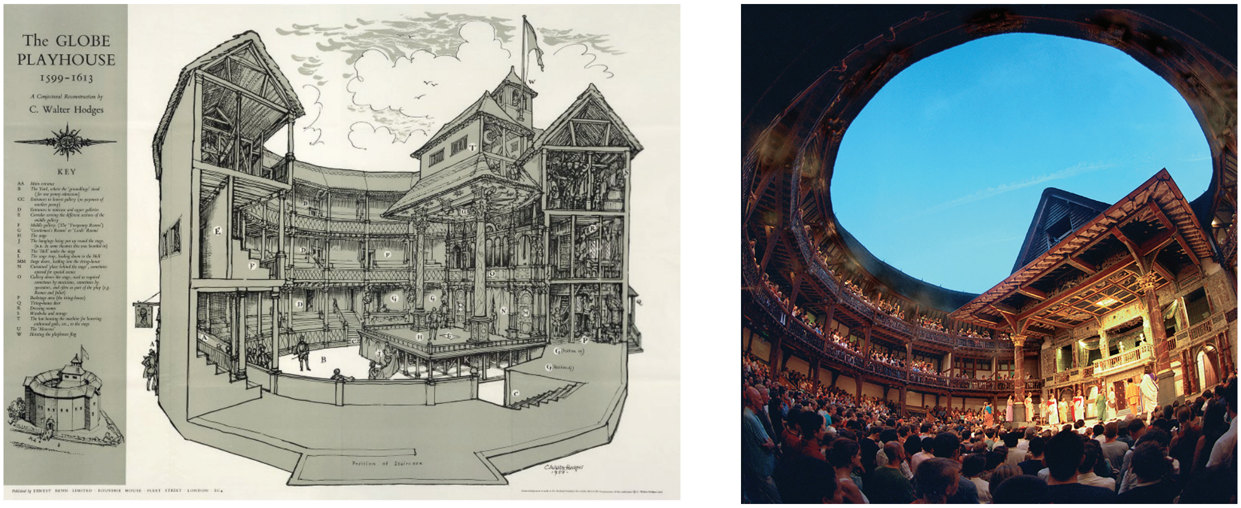
In addition to "formal" (rehearsed, planned, staged) forms of performance, myriad other aspects of our lives can be understood as a performance. I agree "there is more to performance than traditional theatre that is scripted to present a fictive, naturalistic representation of life" (Spence et al., 2013). Teaching a class, a first date, a job interview; these "everyday performances" happen online, offline, with close friends, strangers, co-workers, acquaintances, they may be planned or spontaneous. This expansive understanding of performance acknowledges, celebrates, and foregrounds the myriad ways performance shapes our everyday lives. In 1959, Erving Goffman's seminal work *The Presentation of Self in Everyday Life* (Goffman, 1959) provided a lens through which to understand the way people may 'perform' in their everyday life, making choices 'back stage' about how to present themselves in a 'front stage' personal interaction (Goffman, 1959). Goffman's work has been used to analyze both offline interactions (especially in the field of psychology) (Helm, 1982) as well as online interactions (Bullingham et al., 2013; Miller, 1995; Donath et al., 2004; H. Liu, 2007). In addition to a rich discussion of performance 'spaces' (front stage, back stage), Goffman's work uses theatrical and dramaturgical metaphors to understand the way identity is formed and how people engage in 'presentation of the self' (De Kosnik et al., 2019, p. 21).

In addition to Goffman, Marshall McLuhan provides a secondary viewpoint useful for theorizing how theatre relates to social media. For example, in "Is Twitter a Stage?" (De Kosnik et al., 2019, Ch. 1) De Kosnik applies McLuhan's analysis of another ubiquitous technology (the newspaper) to social media. De Kosnik observes that social media makes everyone a creator the same way that the new medium of "Xerox ma[de] everybody a publisher" (De Kosnik et al., 2019, p. 52). De Kosnik (De Kosnik et al., 2019, p. 22) defines the "McLuhanesque" approach as one where "there are no spectators but only actors" (McLuhan, 1974) and articulates the ways this perspective is useful to the analysis of new media (De Kosnik, 2015; De Kosnik et al., 2019).

In this dissertation, I follow a "performance-led research in the wild" (Benford, Greenhalgh, et al., 2013) process to iteratively construct, analyze, and evaluate performance-related computational systems, presented as annotated artifacts in the style of Research through Design (Stappers et al., 2017; Zimmerman et al., 2007). In this dissertation I a) describe the design of interfaces that support the audience's experience of formal performances by expanding the design space to include time before and after a performance (Chapter 2), b) show how embracing an understanding of the audience as agentic and empowered influenced the design of an image-based messaging system and results in higher self-reported levels of fellowship (Chapter 4), c) describe the design of a tool that incorporates creative strategies from the performance domain of puppetry into the world of animation (Chapter 6), and d) identify creative needs and strategies used by performers during the months and years of pre-production (Chapter 5).

1.2 History of Technology on Stage

Many common and familiar aspects of theatre today could be considered a kind of technology: from the lights and control board to illuminate the stage, the soundboard to control sound cues, to costumes and makeup. These elements of traditional theatre shape the experience for performers, technicians, and audience alike and are a normal and expected part of seeing a live show. Yet these core elements of a performance were not always part of a production. Like many productions before the invention of electricity, plays were staged during daylight hours, and there were no microphones or recorded sound effects (Gurr, 2022). Stages and amphitheatres constructed by the Romans and Greeks used the angle of the sun to light the stage: they were strategically designed on hillsides so as to direct the setting sun to the stage while leaving the audience in relatively lower light (Holmes et al., 2022; Gatto et al., 2018;



Sketch by C. Walter Hodges

Photographer: John Tramper.

Figure 1.2: Left: A conjectural reconstruction of Shakespeare's Globe theatre by C. Walter Hodges based on archaeological and documentary evidence (Hodges, 2022), and Right: a photograph of the recreated Globe Theatre (Trueman, 2017), highlighting the open-air design.

Eaton, 2022). Shakespeare's famous Globe Theatre, constructed in 1599, was a three-storey, open-air amphitheatre (see Figure 1.2) and similarly lacked electric lights. Going back even further, some scholars now believe the layered animal drawings found in the Lascaux cave are meant to create the illusion of movement when lit with a flame lantern (see Figure 1.3). In addition to lighting effects, stages have been carefully designed to strategically amplify sound (Chao, 2007).

Put another way, technology has always shaped the way humans perform and tell stories. In addition to shaping the kinds of narratives that are possible to tell, the technology shaped the audience experience as well. For example performing during the day allowed Greek and Roman actors to be seen, but the audience was equally well-lit, providing a space for visual displays from the crowd (Heim, 2015). Between the 17th and 18th centuries, audience onstage seating was common (Heim, 2015), where large groups were also on the stage: "up to 200 audience members would sit on the stage seriously impeding actors' entrances and exits, but also emerging as guest characters in the plays through their often audible dialogue, interactions and conspicuous costumes" (Heim, 2015). Indeed, up to the 1800s, audience were well-known for being "raucous, rambunctious, rowdy, and sometimes riotous" (Butsch, 2008).

In the 1880s, the introduction of electric lights and the shift to indoor productions gave theaters the sudden ability to dim the lights over the audience (Heim, 2015; Banham et al., 1995; Moigno, 1872). In combination with targeted efforts at encouraging audience restraint (see Heim, 2015; Sedgman, 2018 for details), this technology "abruptly terminated" the audience's ability to act as "performers in their own right" (Heim, 2015). This coincided with a

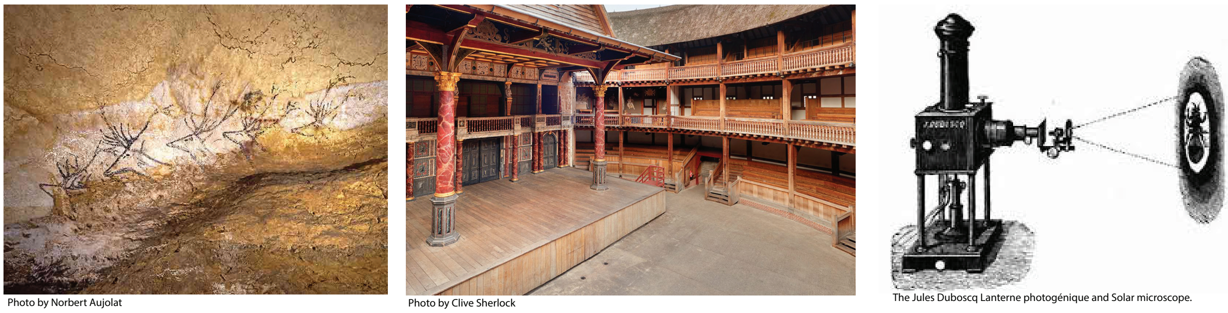


Figure 1.3: Left: A photograph of five stag heads in the Nave region of Lascaux cave, painted between 15,000-17,000 BCE, which some scholars believe is meant to depict movement (Azéma et al., 2012; Zorich, 2014). Center: A photograph of the recreated Globe Theatre based on the original 1599 structure (Trueman, 2017; Spaces, 2020), highlighting the open-air design. Right: An example of a lantern using Thomas Drummond's limelight technology, which generated a targeted circle of bright light and was used to highlight certain portions of the stage (Lauginie, 2015).

cultural shift, where art was separated into hierarchies: "'High' art was elevated over 'popular', 'legitimate' over 'vulgar', 'art' over 'entertainment' " (Blackadder, 2003). Together with these new categories came new expectations and cultural norms for behaviour (Sedgman, 2018). Specifically, Western audiences were suddenly strongly discouraged from 'performing' and encouraged instead to sit quietly in their seats and attend to the performers on stage (Heim, 2015).

As I will discuss next, this shift has far-reaching implications that influence our experience of theatre still today, and that have shaped the way we incorporate technology into theatre productions.

1.3 Performance in HCI

1.3.1 Audience Engagement

The history of performance lighting technology reveals a long tradition of technology shaping how performances are structured and experienced, beginning with the daytime productions where the audience was equally well-lit (Gatto et al., 2018; Eaton, 2022; Holmes et al., 2022; Gurr, 2022; Hodges, 2022; Trueman, 2017) and had their own performance space (Heim, 2015). When the new technology of 'dimmable' lights was introduced, theatre producers gained the ability to lower the audience space into darkness. Combined with other successful attempts to define new expectations around theatrical engagement, audiences learned a new form of 'appropriate' behaviour (Sedgman, 2018) which mostly persists today of sitting quietly in the dark and attending to the stage. An audience culture sometimes described as 'anesthetized' (Heim, 2015).

These new cultural norms were introduced at the turn of the 20th century. In response, theatre practitioners and scholars in the 1960's developed frustration with the idea that audiences were passive receptacles of an experience. In 1989 Marvin Carlson wrote "much theatre theory still regards the theatre performance as something created and set before an essentially passive audience" (Carlson, 1989). This belief lead to scholars critiquing passive audiences, and theatre practitioners attempting to "wake up" passive audiences. Bertolt Brecht is perhaps the most famous example of a theatre practitioner who incorporated unique narrative techniques into his productions to disrupt perceived audience passivity. Among others, these techniques included directly addressing the audience, episodic action, and leaving the lights up in the auditorium. Brecht incorporated these into his productions in pursuit of his goal of forcing audiences to question norms and expectations in the theatre, in order to get them to question norms and expectations elsewhere in their lives and to enact social change (Brecht, 2014).

Augusto Boal is another theorist and practitioner whose work has heavily influenced HCI. Boal introduced the notion of the 'spect-actor', often used to articulate specific view points on interactivity, agency, and empowerment (Coutrix et al., 2010; Dalsgaard and Hansen, 2008; Kuutti et al., 2002). Artists in the 60's, in particular Allan Kaprow sought to "thoroughly blur distinctions between audiences and performers and to make all attendees into actors", a core aspect of McLuhan's vision (De Kosnik et al., 2019). Many digital platforms implicitly seek to realize this goal in which all participants are actors, none spectators.

In response to this intellectual and artistic environment, Bennett applied literary response theories and theories of spectatorship to her analysis of theatre audiences in her classic book *Theatre Audiences* (Bennett, 1997). Bennett's core insight is to emphasize, appreciate, and understand the interpretative work done by the reader (or in this case, audience member) as they experience writing (or in this case, a performance). Yet even with such a conceptual shift, Bennett (and many theatre scholars) remained committed to the ideal of helping to create a "productive and emancipated spectator" (Bennett, 1997).

Emerging from this shared but somewhat ahistorical understanding of social norms associated with Western performances, in the 2000s scholars from the field of Audience Studies began to articulate a different perspective on audience behaviour. For example: Freshwater critically examines the idea that audience participation necessarily signals, embodies, represents, and enables political empowerment. Freshwater builds on Rancière, who writes that 'the act of watching should not be equated with intellectual passivity' (Rancière, 2021; Freshwater, 2009):

> “Spectatorship is not a passivity that must be turned into activity. It is our normal situation. We learn and teach, we act and know, as spectators who link what they see with what they have seen and told, done and dreamed.”
>
> *Rancière (2021) quoted in Freshwater (2009, p. 16)*

As Kirsty Sedgman writes, "the kind of silent absorbed attention mandated at more traditional theatrical events is something that requires active spectatorial work to achieve" (Sedgman, 2018). In other words, the unmediated theatrical audience experience is deliberately constructed by the audience, and does not need an extra layer of 'interactivity' layered on top in order to be a rich, interactive experience. See Kirsty Sedgman's work for thorough discussions about this concept (Sedgman, 2016; Sedgman, 2018), and James Frieze's collection for thoughtful critique of the widely perceived binary of active vs. passive and traditional vs. contemporary (Frieze, 2016).

In this dissertation, I articulate the benefits of incorporating such an understanding of the *engaged audience* into the design of augmented reality systems used by audiences attending a formal theatre production (Chapter 3), and how such a notion shapes the design of a computer-mediated communication system (Chapter 4).

1.3.2 Audience Agency and Empowerment

Some aspects of the original notion of the passive audience from the world of theatre studies seem to have been uncritically imported into HCI, and this has shaped the design of much existing research. Rhetoric motivating the design of performance-related technology frequently implicitly or explicitly reinforces the idea that the audience is passive and in need of activation. For example, consider the way these HCI research papers articulate their goals: "It is designed to *require active involvement*...of several of the visitors" (Friederichs-Büttner et al., 2012), "encourages audience members to *interact* with, and *contribute* to the performance" (Cerratto-Pargman et al., 2014), "*engaging* the audience in a *participatory, collaborative* creation" (Lee et al., 2019), (emphasis mine). Many HCI researchers contrast "interactive art" with "traditional" art that "keep the audience in a more *passive spectator* position" (Rostami, 2020, p. 11) (Edmonds et al., 2011). Each of these implicitly assumes or explicitly states that the audience is not engaged or does not contribute to the production without such a tool. Note that not all HCI researchers agreed. Laurel in particular reminds us that "the audience's audible and visible responses...are often used by the actors to tweak their performance in real time (this, by the way, reminds us that theatrical audiences are not strictly "passive" and may be said to influence the action)" (Laurel, 2013).

Yet even while these systems claim to give the audience control, and push them to be active, the suggested and allowed interactions are often carefully limited. Freshwater articulates these limitations: "Performances which seem to be offering audiences the chance to make a creative contribution only give them the choice of option A or option B" (Freshwater, 2011). Indeed, many of these "interactive" experiences "depend upon our familiarity with a vast network of unwritten scripts and ingrained social habitus" (Freshwater, 2011) and when it works, it may be because of social pressure, not any revolutionary sense of freedom. Anthony Jackson concurs:

> " Facile assumptions about being able to 'make a difference' in people's lives by the very act of engaging them in a participatory drama experience can all too easily lead to patronization, even to a certain kind of oppression. ... There are

> perhaps few worse experiences in this field of work than to find oneself belittled or one's dignity undermined within a supposedly participatory event from which there is no ready escape. ”
>
> *Jackson et al., 2007, p. 8*

De Kosnik articulates a similar perspective on the limitations to McLuhan's technodeterminism: "New media does not necessarily lead to new social movements", and any appearance of doing so is driven by "users' choices about how to use new platforms, not the platforms themselves" (De Kosnik et al., 2019). De Kosnik articulates McLuhan's technologically deterministic argument: "McLuhan assumes that because people *can* communicate faster ("at instant speeds") in the new global telecom systems than before, they *will* become actors and participants instead of (merely) audience and spectators. He anticipates that this 'public' will thus become active rather than passive and will 'program events'—will make historical moments—rather than only 'watch[ing] them' " (De Kosnik et al., 2019). Rosie Klich likens such performances to video- or role-playing games: "claims are often made for the empowering effects of immersive forms that allow spectators the freedom to choose their own path" but Frieze reminds us that "such claims must be tempered by the lack of agency implicit in the tightly controlled systems built by game designers and theatre makers" (Frieze, 2016).

I introduce this literature here as a way to help articulate the motivation behind my interpretation of "audience participation" in the context of designing both technology-mediated theatre experiences (Chapter 3), and computer-mediated communication systems (Chapter 4).

1.3.3 Dramaturgical Framework for Interactive Performance

As I show in this thesis, embracing an understanding of audiences as already active and engaged suggests new directions for interaction design. Integrating the Audience Studies perspective on audience engagement and audience empowerment requires a deep understanding of the roles we play during a performance, the way performances are spatially organized, and how these experiences exist in hybrid structures of space, time, and interactions — all questions typically addressed by a dramaturg. A dramaturg's role is to "learn as much as possible about the play (its structure, its language, its themes, etc.) and the context surrounding its creation, then to share that knowledge with the production team" (*Department of Theatre and Dance* 2020; *Dramaturg* 2022; *What is dramaturgy?* 2022). I introduce the role of "Dramaturg for Interactive Performance", whose focus additionally considers the technological context relevant to the production. The Dramaturgical Framework for Interactive Performance seeks to articulate an understanding of each of these three elements — space, time, and roles — and how technology can be incorporated into each in a cohesive framework to guide future designers working at the intersection of performance and technology. My exploration in this domain is guided by the following research questions:

RQ1: What tools, strategies, techniques, insights, and systems from the world of performance can — and should — inform the design and analysis of both new and existing technology?

Performance practice reinforces ways of engaging with the world that uniquely shape the final outcome of a performance, some of which may fruitfully inform the design of computationally-mediated systems. For example, embodied forms of creative exploration, sensitivity to the spatio-temporal structures of a performance, close attunement to the roles of participants (performers, audience, production team) are all important elements of creating a theatre production, and may be usefully applied to the design of computational systems. Theatre productions often rely on the skills of a dramaturge, whose job as part of the production team is to identify, research, analyze, and help construct the structures of the performance, primarily focusing on space, time, plot, and characters (Pfister, 1991). My work involves expanding the "dramaturgy of interaction design" by importing performer knowledge structures into the design of computational systems. I draw on existing bodies of literature across Performance, Theatre, and Audience Studies (Sedgman, 2016; Sedgman, 2018; Freshwater, 2009; Freshwater, 2011; Bennett, 1997; Brook, 1996; Carlson, 1989; Jackson et al., 2007; Keidan et al., 2015; Frieze, 2016; R. Goldberg, 2001; Abercrombie et al., 1998; Brecht, 2014; De Kosnik et al., 2019; Keidan et al., 2015; Heim, 2015; Butsch, 2000; Butsch, 2008; Blackadder, 2003; Murray et al., 2016; Carlson, 2013) - as well as collaborations with expert theatre practitioners and system evaluations to expand the design space for this Dramaturgical Framework for Interactive Performance.

RQ2: What new interaction techniques are suggested by the needs, goals, opportunities, and constraints of performance, and how can technology be used to expand existing notions of space, time, roles, and the creative process in the context of performance?

Just as HCI may be shaped by performance practice, so technology may also shape and influence narrative structures, temporal elements, spatial configurations, or other aspects of how performances unfold. I address these research questions through a Dramaturgical Framework for Interactive Performance, presented in-depth in the next chapter. Briefly, the framework provides:

1) an expanded understanding around what counts as a performance 'space' and a performance 'time' to include not just the production itself but pre-production, rehearsal, intermission, and post-show reflection (Chapters 3, 5 and 6),

2) a discussion about how designers can operationalize the 'roles' involved in a production, by embracing a particular interpretation of the unmediated and mediated audience experiences in the context of both a live performance (Chapter 3) and social media (Chapter 4), and

3) identifying and investigating challenges and opportunities related to designing creativity support tools that support the “behind the scenes” work of performers (Chapters 6 and 5).

In this thesis, I draw from extensive bodies of work across the fields of HCI, and Performance Studies to analyze, expand, critique, and extend existing discussions around the intersection of performance and technology.

1.4 Three Perspectives on Designing Computational Systems By and For Performers

The primary contribution of this dissertation is the design, engineering, evaluation, and analysis of these performance-related computational systems, following a Research through Design methodology (Zimmerman et al., 2007; Stappers et al., 2017). As I will discuss in Chapter 2, I embrace a broad definition of performance which encompasses not only formal productions (such as a music concert, a theatre show, or a dance performance), but also informal “everyday performance” (such as take place on social media, or in our daily lives), and the entire production pipeline (including pre-production creative practice such as a playwright writing a script, or character design early on in the creation of an animated film). I seek to explore technologically-mediated systems that support a range of roles and experiences from professional performers and audience members attending a formal staged production, close friends ‘performing’ for each other on social media, and creative practitioners working behind the scenes.

I operationalize the Dramaturgical Framework for Interactive Performance through the design and development of a broad range of performance-related technology systems: (1) a theatre playbill augmented with AR, (2) tangible interactive installations to support audience reflection, (3) an experience sharing system for camera-glasses, and (4) a creativity support tool for embodied character design. Each of these systems embody new ideas and opportunities for how we might incorporate knowledge, practices, techniques, and strategies from performance practice and performance studies into the design and deployment of technological systems. I briefly introduce each project below, and state which sensitizing concept I am exploring in each.

Produced performance – Through a co-design process with expert practitioners, we developed guidelines for designing experiences outside the *temporal* and *spatial* confines of a live theatre production. This allows us to explore a particular interpretation of the *role* of the audience. Following best practices for combining technology and performance (Gonzalez et al., 2012; Honauer et al., 2015; Saltz, 2001), we embedded within the development and deployment of a live performance with expert theatre practitioners to prototype technology-mediated experiences that extend beyond the stage. We constructed functional prototypes that use Augmented Reality to provide access to a digital layer of art related to a live production, and identify challenges and opportunities related to incorporating AR and technology into a formal production.

Informal performance – I recast livestreaming and social media as an informal form of performance, and introduce Friendscope, an instant, in-the-moment experience sharing system for commercial camera glasses that allows participants to engage in lightweight, rapid micro performances with an audience of close friends. Friendscope explores a concept called a *shared camera*. This concept allows a wearer to share control of their camera with a remote friend, making it possible for both people to capture photos/videos from the camera in the moment. This allows us to investigate the *roles* each participant engages in, and operationalize the notion of an active audience participant. Through a user study with 48 participants, we found that users felt connected to each other, describing the shared camera as a more intimate form of livestreaming. Moreover, even privacy-sensitive users were able to retain their sense of privacy and control with the shared camera. Friendscope's different shared camera configurations give wearers ultimate control over who they share the camera with and what photos/videos they share. We conclude with design implications for future experience sharing systems.

Behind the Scenes – Building on this expanded notion of *time* and *space* as a site for design for technology and performance, I explore the extensive planning, ideation, and creative work that happens in the *pre-production* stage before the show is even cast. I seek to identify community practices, strategies and techniques used by expert creative practitioners as they manage their own creative process, including managing version history. I draw from expertise across diverse creative practices to identify creative needs that may be unmet by current technological systems. Additionally, I design and construct a creativity support tool designed to be used extremely early in the production process, looking specifically at yet another kind of performance: animation. I introduce an authoring tool that combines the embodied nuance of a tangible interface (the HTC Vive controllers) with the accuracy, repeatability, and recording ability of a digital animation application (Blender). Both expert and novice animators have a need to engage in movement sketching – low-cost, rapid iteration on a character's movement style – especially early on in the ideation process. Yet animation tools currently focus on low-level character control mechanisms rather than encouraging engagement with, and deep observation of, movement. I identify "Found Object puppeteering" – where puppeteers manipulate everyday physical objects with their hands – as a creative practice whose use of material "jigs" is uniquely well-positioned to scaffold the novice animator's developing skills. In this chapter, I draw on the practice of an expert puppeteer practitioner to inform the design of a system that incorporates physical objects into the animation workflow to scaffold novices into diverse movement exploration while manipulating digital puppets.

These three perspectives have helped define the Dramaturgical Framework for Interactive Performance (see Chapter 2 for full introduction to the framework).

1.5 Methods

Sensitizing concepts can act as a lens through which to interpret data, can suggest entirely new research directions, and can draw attention to concepts and themes which may remain underexplored. Blumer, an American sociologist, introduced the term "sensitizing concept" (Blumer, 1954), contrasting it with a definitive concept (a key aspect of empirical scientific research):

> A definitive concept refers precisely to what is common to a class of objects, by the aid of a clear definition in terms of attributes or fixed bench marks...A sensitizing concept lacks such specification of attributes or bench marks and consequently it does not enable the user to move directly to the instance and its relevant content. Instead, it gives the user a general sense of reference and guidance in approaching empirical instances. Whereas definitive concepts provide prescriptions of what to see, sensitizing concepts merely suggest directions along which to look.
>
> *Blumer, 1954*

Such sensitizing concepts underlie most if not all research. As Gilgun (2002) writes, "Research usually begins with such concepts, whether researchers state this or not and whether they are aware of them or not" (quoted in (Bowen, 2006)). Others have argued that qualitative research is always organized around sensitizing concepts, and that such concepts shape theory generation (in contrast with the hypotheses seen in quantitative work) (Blaikie et al., 2019). Blumer writes that sensitizing concepts "can be tested, improved and refined" (Blumer, 1954), but researchers working in Charmaz' grounded theory tradition may instead simply seek to "discover, understand, and interpret" (Bowen, 2006; Charmaz, 2000) what is happening in a particular research context.

This qualitative research methodology shares features with a design research methodology well-known within HCI research: ambiguity. Gaver et al. articulate ambiguity as a "resource for design", writing that ambiguous systems can compel "people to interpret situations for themselves, it encourages them to start grappling conceptually with systems and their contexts, and thus to establish deeper and more personal relations with the meanings offered by those systems" (W. Gaver et al., 2003). Similarly, a sensitizing concept supports reflexive, reflective subjective engagement, and guides a researcher by highlighting particular ideas. A core difference is that "ambiguity is a property of the interpretative relationship between people and *artefacts*" (emphasis mine), whereas a sensitizing concept is an *idea* that can guide future research directions. Following a Research Through Design approach (Stappers et al., 2017; Zimmerman et al., 2007), we have created *artifacts* that embody sensitizing *concepts*.

I follow Charmaz, focusing primarily on rich descriptions of three perspectives on what I identify as the most important sensitizing concepts for researchers working at the intersection of performance and technology. As described in more detail in Chapter 2, I discuss how an awareness of the *roles* participants play as they navigate hybrid structures of *time* and *space* enables new configurations of engagement. My framework aligns closely with existing research across Performance, Theatre, and Audience studies, cross-pollinating expertise between these two rich domains of performance and HCI.

1.6 Overview

This dissertation explores the domain of technologically-mediated performance through a series of projects that embody complementary concepts. In Chapter 2 I first discuss definitions of performance, then describe existing approaches for 1) designing technology using performance as a metaphor, 2) incorporating technology on stage to be used by performers, 3) introducing technology to the audience during a production, and 4) interpreting social media as a kind of digitally-mediated performance. Next, I introduce research from the fields of Performance, Theatre, and Audience Studies (Sedgman, 2016; Sedgman, 2018; Freshwater, 2009; Freshwater, 2011; Bennett, 1997; Brook, 1996; Carlson, 1989; Jackson et al., 2007; Keidan et al., 2015; Frieze, 2016; R. Goldberg, 2001; Abercrombie et al., 1998; Brecht, 2014; De Kosnik et al., 2019; Keidan et al., 2015; Heim, 2015; Butsch, 2000; Butsch, 2008; Blackadder, 2003; Murray et al., 2016; Carlson, 2013), contrasting these approaches with those currently undertaken within HCI, and contextualize this extensive body of literature with a brief history. Finally, I introduce the Dramaturgical Framework for Interactive Performance, and discuss the ways such a framework can be operationalized when designing at the intersection of technology and performance. Chapters 3 - 6 embody elements of the framework, acting as exemplars through which to articulate this expanded design space.

In Chapter 3 I describe how embracing two elements of the Dramaturgical Framework for Interactive Performance: active audiences and expanded notions of 'performance space' resulted in the successful deployment of three Augmented Reality-based interactive experiences into a live theatre production.

In Chapter 4 I view social media as a site for performance, and explore the benefits and challenges when explicitly embracing the notion of the 'active audience' in this context. This chapter describes one way to incorporate this perspective on audiences into the unique digitally-mediated performance space of social media. I describe an experience-sharing system that runs on camera glasses, and the results of a user study evaluating the overall experience.

In Chapter 5 I move "behind the scenes", and describe the results of talking with expert performers about strategies and techniques used to manage their personal creative processes. I identify strategies related to creative and motivational management, and version control. I describe how tools could be designed to support these needs.

In Chapter 6 I introduce a novel authoring system for animation which incorporates some of the strategies and techniques described in Chapter 5. The tool provides a tangible interface for rapid motion sketching, designed to fit into the digital animation pipeline, in order to support novel and expert animators during the pre-production stage.

I conclude in Chapter 7, with a discussion of limitations, and a future vision for using the Dramaturgical Framework for Interactive Performance to design technology systems in the context of diverse performances.

1.7 Statement of Multiple Authorship and Prior Publication

This dissertation reflects work that was previously published in ACM DIS (*Expanding the Design Space for Technology-Mediated Theatre Experiences* (M. Nicholas, Daffara, et al., 2021)), ACM C&C (*Creative and Motivational Strategies Used by Expert Creative Practitioners*) (M. Nicholas, Sterman, et al., 2022) and PACM CSCW (*Friendscope: Exploring In-the-Moment Experience Sharing on Camera Glasses via a Shared Camera* (M. Nicholas, Smith, et al., 2022) and *Towards Creative Version Control* (Sterman et al., 2022)). Although I served as a first author and led the research and writing behind each work, the ideas, concepts, and artifacts were a product of a group effort and benefited greatly from the wide breadth of knowledge and expertise of the interdisciplinary Hybrid Ecologies Lab (including Sarah Sterman, César Torres, Rundong Tian, Christine Dierk, Katherine Song, Eric Rawn, Chris Meyers, and Kuan-Ju Wu).

The idea to expand the role of computational systems in the context of a live theatre show was formed during a collaboration with Sandra Woodall, Stan Lai, and Stephanie Claudino Daffara. For Friendscope, the technological system behind our prototype was developed jointly with Brian A. Smith, Rajan Vaish, Ilter Canberk, Jonathan Rodriguez, Maarten Bos, and others on the Spectacles team at Snap; the user study behind Friendscope was developed in collaboration with Brian A. Smith, Rajan Vaish, and Maarten Bos. The question of how expert creative practitioners use tools to engage with, structure, and manage their diverse creative practices was developed jointly with Sarah Sterman.

The freedom to begin exploring these concepts in depth was generously granted to me by both the Achievement Rewards for College Scientists (ARCS) and National Science Foundation Graduate Research Fellowship under Grant No. DGE 1752814. My advisor, Professor Eric Paulos, provided key insights, critique, directions, and advice on all projects detailed in this document.

Throughout this document, I use the collective we when referring to the reader or describing technical content. I use the first person when presenting concepts, arguments, evaluations, and discussions.

Chapter 2

Background and Related Work: Performance

> *"A vibrant and open society has a vibrant and open theater. A society without theater is like a tree that has dried up. It lacks a connective source that leads directly to the life force of the society."*
>
> — Stan Lai *2013*

An understanding of theatre and performance has shaped our relationship with society, gender, ourselves, crowds, history, the arts, government, and many other aspects of our world. Performing is a poetic celebration of the uniquely human, highlighting culture, connection, identity, and life itself. These everyday performances happen in different spatio-temporal contexts, and require and enable us to play different 'roles'. Various interpretations, understandings, and conceptualizations of "performance" have been leveraged within HCI research and practice, sometimes resulting in entirely new fields of study (including New Media, Media Studies) or new understandings of computer-mediated communication systems. I seek to identify, categorize and expand existing notions of "performance" as it is operationalized in HCI in part by drawing on domain expertise from the fields of Performance, Theatre, and Audience Studies. In this section I contextualize my work and existing HCI research with this body of existing literature, and introduce the Dramaturgical Framework.

2.1 Definition of Performance

There are many definitions of "performance". Peter Brook writes in his 1996 book *The Empty Space* (Brook, 1996) — which remains a classic in the world of theatre studies — that "I can take any empty space and call it a bare stage. A man walks across this empty space whilst someone else is watching him, and this is all that is needed for an act of theatre to be engaged." Helen Freshwater (Freshwater, 2009) agrees: "it is possible to do away with plot, character, costumes, set, sound, and script" but the one 'indispensable' aspect of performance is the relationship to the audience. This relationship has been explored, questioned, rejected, and re-imagined by performing arts practitioners for many years (Sedgman, 2016; Sedgman, 2018; Freshwater, 2009; Freshwater, 2011; Bennett, 1997; Brook, 1996; Carlson, 1989; Jackson et al., 2007; Keidan et al., 2015; Frieze, 2016; R. Goldberg, 2001; Abercrombie et al., 1998; Brecht, 2014; De Kosnik et al., 2019; Keidan et al., 2015; Heim, 2015; Butsch, 2000; Butsch, 2008; Blackadder, 2003; Murray et al., 2016; Carlson, 2013).

Such a definition allows us to embrace a range of experiences as performance: traditional theatre, improvisational theatre, flash mobs, live music productions, recorded shows, a post on social media, rehearsal, performance art, a walk in the park, a lecture, a conversation with an acquaintance. When discussing performance art, RoseLee Goldberg notes that 'performance defies precise or easy definition beyond the simple declaration that it is live art by artists' (R. Goldberg, 2001, p. 9). The 'happenings' of the 1960s represent another form of performance that "combined elements of dance, theater, music, poetry, and visual art to blur the boundaries between life and art and forge a path for new methods of artistic practice" (Cain, 2016). 1966 saw the "9 Evenings" production by E.A.T. (Experiments in Art and Technology), a group that "pioneered the way for the now-common practice of artists collaborating with practitioners from different fields" (Smithson et al., 2022). Cordeiro introduces definitions for the multitude of forms of interactive art, clarifying the difference between *participatory art*, where "the audience or visitors' participation is regarded as a necessary and fundamental element for the existence of the artwork", *collective art practice* where the larger community participates in art production as a means of community engagement and not an end, and *interactive art* which enables the 'audience' to influence and shape the content or form in real-time (Cordeiro et al., 2017) (but recall the earlier discussion about these definitions from Sections 1.3.1 and 1.3.2).

Fundamentally, the spatio-temporal aspects of performance can be understood as existing along the two axes: time and space (see Figure 1.1). Traditional theatre exists in the lower left quadrant, with the audience and performers in the same place at the same time for the production. In my research, we explored different locations within this design space, identifying opportunities for interaction design that reflect unique challenges and opportunities.

From collaborating with theatre-makers by incorporating technology into a live show to identifying patterns in the design of theatre shows that can be used to inform the design of computational systems, the world of HCI has shaped and been shaped by performance. In the following section, I describe existing research in HCI which seeks to either incorporate technology into a performance, design technology shaped by performance, or reconceptualize technology as a performance.

2.2 Performance in HCI

2.2.1 Technology Inspired by Performance

Researchers have long found value in viewing technology through the lens of performance (Laurel, 2013; Fizner et al., 1993; Benford, Giannachi, et al., 2009; Benford and Giannachi, 2012; Spence et al., 2013; Reeves, Benford, et al., 2005; Heckel, 1984). In his 1982 book *The Elements of Friendly Software Design* Heckel (1984) writes "When I design a product, I think of my program as giving a performance for its user." Heckel specifically identified techniques from another kind of performance – animation – in order to direct users' attention and provide visual cues for communicating how to interact with the computer. As Laurel describes in her 1991 classic, *Computers as Theatre* (Laurel, 2013) theatre and interface both "deal with the representation of action" (Laurel, 2013, p 14). Laurel goes on to articulate her goal to use theatre "not simply as a metaphor but as a way to conceptualize human-computer interaction itself" (Laurel, 2013, p 20).

Another example of the way an approach from the world of performance has been fruitfully cross-pollinated into HCI is the notion of *trajectories* from Benford, Giannachi and collaborators (Benford, Giannachi, et al., 2009; Benford and Giannachi, 2012). Originally part of the "cultural shift" in HCI — which involved a shift from a focus on usability to include "affect, sensation, pleasure, aesthetics, and fun" (Benford, Giannachi, et al., 2009) — the *trajectory framework* was developed to help HCI researchers, practitioners and designers understand and design "complex structures that extend across time and space", including computational systems.

Spence et al. (2013) introduced *performative experience design* (PED), a way to categorize work at the intersection of performance and technology that focuses on "a person or persons directly interacting with a digital system in order to express or present themselves to an audience." In 2005, Reeves, Benford, et al. (2005) produced a taxonomy of spectator experience drawn from performance studies: secretive, expressive, magical, suspenseful. Reeves wrote both a thesis and a book applying performance-related metaphors to the design of multiple technical systems (Reeves, 2009; Reeves, 2011). My thesis exemplifies how analyzing technology through the lens of performance can result in new and rich interaction techniques. Designers using immersive technologies such as VR have drawn on arts practices and performing strategies to enhance the experience of mixed reality performances (Rostami, Rossitto, et al., 2018). Each of these systems required identifying performance-specific concerns and applying them to the design of new technology.

Each of these approaches emerged from collaborations with expert practitioners, or deployed experiences managed by the researchers. For example, the original conception of the trajectory framework was developed through explorations of three mixed media performances. The authors describe both the development and deployment of these three performances, going into detail about both the performance itself, and also how each performance shaped the authors' understanding of what they call 'experience' design. The authors contribute an expanded discussion around the way theatre-makers might conceptualize and

Figure 2.1: Images from the 2003 *Uncle Roy All Around You* production done in collaboration with Benford, Giannachi, et al. (Benford, Giannachi, et al., 2009). Uncle Roy's office, car, and virtual city.

design multi-modal theatre experiences, and then map this understanding to the design of computational experiences. In doing so, they "demonstrate the relevance of trajectories to understanding how complex user experiences are designed and experienced."

The trajectory framework is comprised of four key elements: space, time, roles and interfaces. *Space* is defined as the structure or 'stage' upon which an experience takes place. This is typically a hybrid space combining physical and digital environments. For example, in the mixed-media production Uncle Roy All Around You (see Figure 2.1) participants were provided with a hand-held computer, allowing remotely connected observers a digital view of the city (digital environment), which they used to provide guidance to the participant wandering around the real city streets (physical environment). The multiple spaces, connected through various forms of technology, constitute the 'space' of that particular production. A more traditional theatre show might identify an actual stage as the Space. *Time* refers to the temporal structure of a given experience, making a distinction between the planned run-time, the actual run-time, and the perceived run-time of a show as well as the story-time and plot-time of the narrative. The *roles* include performers (what the authors call 'actors'), the audience (including 'participants' and 'spectators'), and the production team who manage the technology and logistics (called 'operators' and 'orchestrators'). Finally, the authors describe *interfaces*, organizing structures which connect the other three elements together.

The trajectory framework renews the focus on not only those four elements, but encourages a richer engagement with and understanding of how those elements interact with and shape each other as they unfold throughout an experience. For example, by considering continuity and transitions; hybrid structures of space, time, roles and interfaces; balancing participant and authorial control in interactivity; and interweaving trajectories (for more details see (Benford, Giannachi, et al., 2009; Benford and Giannachi, 2012)).

Figure 2.2: Images from a student production of *Twenty Thousand Leagues under the Sea* by Jules Verne, performed at Theaterhaus Jena in 2014. Honauer and Honecker (Honauer et al., 2015) describe interactive costumes incorporated into the production. From left to right: A) Octopus, B) Captain Nemo, C) all costumes together, and D) Diving Suit.

2.2.2 Technology On Stage

Work combining live performance and technology often involves incorporating technology into the performance itself, including interactive costumes (Honauer et al., 2015; Saltz, 2001; Karpashevich et al., 2018) (see Figures 2.2, and 2.3, or performer-controlled sets, lighting or sound (Bluff et al., 2017; Bluff et al., 2019; Latulipe, Wilson, Huskey, Word, et al., 2010; K. Goldberg, 2006; SF Opera, 2006; Paulos, 2000) (see Figure 2.4). These approaches focus on enriching the experience of the performance as it occurs on the stage, staying within the borders of the theatre, and within the time limits of the production.

Collaborations between technologists and performers often involve layering technology on top of the on-stage performance. Saltz (Saltz, 2001) presents a thorough taxonomy for incorporating technology into theatrical productions, all of which involve the technology appearing "on stage" in some manner. Saltz articulated two primary goals for his work: "1) to incorporate digital media into theatre without compromising the spontaneity of live performance and 2) to make the media dramaturgically meaningful—in other words, to use the media only insofar as they enhance the meaning of dramatic texts." These goals make sense in the context of creating technology that will appear on-stage during a live production. Saltz' primary dramaturgical goal was to "bring the audience into the minds of the characters". In *Hair* — a rock musical from 1968, performed by Saltz' group in 1999 — the production team projected computer-generated animations and digital video onto the backdrop in as a form of digital set design. In the 1999 production of *Kaspar*, Saltz considers technology integral to the play, and incorporated computers into the production to generate sounds, projected images, track sensor data, and manage LEDs embedded into costumes. While most technology for both *Hair* and *Kaspar* productions was primarily controlled by off-stage technicians, some of the on-stage sensors were instead directly manipulated by the on-stage performer. Lastly, Saltz describes the design of the character Ariel in a production of *The Tempest* from the year 2000:

Figure 2.3: Images from productions at the University of Georgia (Saltz, 2001). Saltz describes three productions from the Interactive Performance Laboratory (IPL) at the University of Georgia: Left: The Fall 1999 production of *Hair*. Center: The Spring 1999 production of *Kaspar*. Right: Rehearsal for the Spring 2000 production of The Tempest.

> “ The live actress [playing Ariel] performed in full view of the audience with sensors strapped to her head, wrist, elbows, hands, waist, knees, and ankles. These sensors transmitted detailed information about the actress’s movements to a computer that produced the three-dimensional animations of Ariel. These real time animations were projected onto either the large screen behind the sound stage or onto a smaller screen (4’ wide by 5’ high) inside Prospero’s cell. Voice recognition software matched the actress’s phonemes in real time, allowing the animation’s lips to move automatically in sync with the actress’s voice. The only aspect of the animated Ariel’s performance not directly under the live actress’s control was its facial expression, which an offstage operator controlled. ”
>
> *Saltz, 2001*

Saltz describes his notion of “interactive media”, contrasting it with linear media such as a recorded musical track or video file. He emphasizes the importance of flexibility and variability, aligning the design of technology with the needs of a live theatre production:

> “ Now consider the impact of injecting linear media into a live theatrical performance. Imagine an extended scene between a live actor and a videotaped actor. Unlike a live partner, the videotape will be unforgiving of any errors the live actor might make (for example, missing a cue) and will never adapt to variations in the rhythms or dynamics of the actor’s delivery. The medium forces the live actor to conform rigorously to it. Such a performance combines the worst of both theatre and media: it lends the live performance a canned quality without endowing it with any of film or video’s advantages, such as the ability to select the best takes, edit out the mistakes, or apply camera movement or jump cuts to the live actor’s performance. ”
>
> *Saltz, 2001*

Figure 2.4: Physical performers with the interactive stage elements. Left: The interactive platypus from *Dot and the Kangaroo* (Bluff et al., 2017) Center: Berries of understanding from *Dot and the Kangaroo* (Bluff et al., 2017), Right: Particles respond to performer movements in *Encoded* (Bluff et al., 2019).

Saltz's use of technology within these productions embodied his notion of interactive media: he designed systems that allow "random access" and "an arbitrary link between trigger and output", both of which enable the performers and backstage technicians to maintain the spontaneity and variability he valued in a live production.

Years later, Bluff and Johnston developed a system for using "motion-tracked human performers in real-time" to control backgrounds and animated graphics projected onto the stage during live shows (Bluff et al., 2017). They describe how both this system and the performers have co-evolved over time (Bluff et al., 2019). See Figure 2.4 for images from their productions.

Latulipe and collaborators have done extensive work combining dance and technology on stage (Latulipe, Wilson, Huskey, Word, et al., 2010; Latulipe, E. Carroll, et al., 2011; Latulipe, Wilson, Huskey, Gonzalez, et al., 2011; E. A. Carroll et al., 2012). See Zhou et al. for a thorough retrospective of how technology has been incorporated into dance in HCI over the last two decades (Q. Zhou et al., 2021). Karpashevich et al. (2018) describe the impact of restrictive costumes inspired by Oskar Schlemmer's Triadic Ballet on dancer movements (see Figure 2.5).

What these approaches have in common is a focus on incorporating technology into the performance as it occurs on the stage. My work emphasizes the benefits and opportunities that arise when we view the entire production process as a site for exploration and design.

2.2.3 Technology for the Audience

In addition to creating technology for the stage, to be used by the performers onstage or by technicians backstage, technologists have explored the impact of providing the audience with technology. This is typically framed as a way to make the art "interactive". Cordeiro introduces definitions for the multitude of forms of interactive art, clarifying the difference

Figure 2.5: Images from the 2018 reimagining of Oskar Schlemmer's classic *Triadic Ballet* from the 1920s (Paret, 2014; Conzen et al., 2014). Left: Original Wire Costume (Oskar Schlemmer, Draht-Figur 1922). Right: Interactive costume from production done in collaboration with (Karpashevich et al., 2018). Right: Group photo of all figurines in Oskar Schlemmer's *Triadic Ballet.* (Karpashevich et al., 2018).

between *participatory art*, where "the audience or visitors' participation is regarded as a necessary and fundamental element for the existence of the artwork", *collective art practice* where the larger community participates in art production as a means of community engagement and not an end, and *interactive art* which enables the 'audience' to influence and shape the content or form in real-time (Cordeiro et al., 2017). Similar to Cordeiro (Cordeiro et al., 2017), Edmonds et al. (2011) (2012) define interactive art "by its dynamic 'behaviour' in response to external stimuli, such as people moving and speaking", which "requires an audience's active engagement with the artwork" (Rostami, 2020) (but see critique of this framing as summarized in Sections 1.3.1 and 1.3.2). Laurel goes on to first introduce and then reject the notion of "audience-as-active-participant", arguing that when comparing computer users to theatrical audiences "it's not that the audience joins the actors on the stage; it's that they become actors — and the notion of 'passive' observers disappears."

As a few examples of so-called interactive art, Cerratto-Pargman et al. (Cerratto-Pargman et al., 2014) and Owen et al. (Owen et al., 2013) both designed systems that allow audience members to use mobile devices to shape the outcome of the production. Lee et al. describe a system that facilitates such audience participation during a musical performance (Lee et al., 2019). Rostami et al. identified opportunities for bio-sensing and body-tracking technology that span many forms of interactive performance (Rostami, McMillan, et al., 2017). Works like these often focus on "blurring the distinction" between audience and performance. A huge variety of work has explored interactivity in live performances across many domains, including music (Lee et al., 2019; Webb et al., 2016), theatre (Saltz, 2001; Cordeiro et al., 2017; Cerratto-Pargman et al., 2014; Barkhuus et al., 2016; Owen et al., 2013; Friederichs-Büttner et al., 2012; Koleva et al., 2001; Paulos, 2000; Smithson et al., 2022),

Figure 2.6: Systems that allow audiences to interact with or control on-stage behaviour. Left: *ADA FTW*'s stage at the Royal Dramatic Theatre (Cerratto-Pargman et al., 2014) Center: Image from *Transitions* performance (Owen et al., 2013), Right: *Crowd in C* facilitates audience engagement with a musical performer (Lee et al., 2019)

sporting events (Ludvigsen et al., 2010; Esbjörnsson et al., 2006), games (Seering et al., 2017; Glickman et al., 2018; Maynes-Aminzade et al., 2002), and audio-visual (McCarthy, 2016) to select a few.

Researchers have also looked at spectators beyond the stage, and designed systems for crowds at various other events (Reeves, Sherwood, et al., 2010; Esbjörnsson et al., 2006; Ludvigsen et al., 2010). Zhou et al. also considered spectators in their design of Astaire, a collocated hybrid VR dance game (Z. Zhou et al., 2019).

In contrast with this framing — common in HCI — scholars in Audience Studies would claim all performances require "audience or visitors' participation" (see Sections 1.3.1 and 1.3.2). In that sense, all theatre is 'participatory', and needs no additional mediation to create an 'engaged' or 'active' audience. This is the perspective I embrace as I describe the Dramaturgical Framework for Interactive Performance.

2.2.4 Social Media as Performance

In his 1982 address as president of the American Sociological Association, Goffman implied that conversations held over technology were an inferior version of 'the primordial real thing' (Goffman, 1983), 'a departure from the norm' (Goffman, 1964), a 'marginal' form of social interaction (Goffman, 2017, p. 70). Goffman's original framing was focused on unmediated, co-present, face-to-face social environments (Goffman, 1959; Laughey, 2007), and some have argued that Goffman's work is outdated and should not apply to any form of mediated social interaction (Arundale, 2009). However, the ubiquitous communication technology when Goffman generated his original framework was the telephone, which could not provide the same richness of interaction due to limited visual cues for managing interaction. As computer-mediated communication (CMC) systems have evolved to include video, image-based communication, emojis, digital avatars, and other rich forms of self-expression, researchers have argued that Goffman's work remains relevant and applicable (Jenkins, 2010; Laughey, 2007; Jacobsen, 2009; Miller and Arnold, 2009; Bullingham et al., 2013). As one example, Bullingham interprets offline behaviour as Goffman's 'backstage' — a private, unobserved space in which no performance need take place — and online interactions as 'front stage', or the locus of performance. De Kosnik articulates one interpretation of the way Goffman's approach maps to social media:

> The "techniques" of performance preparation that Goffman claims we all employ on a daily basis, such as "dramaturgy," "stagecraft," and "stage management," are also evident in our social media use: in how we thoughtfully prepare and craft our posts in advance; how we create content to share; how we strategize (even if only with ourselves) about the timing and impact of the release of our content (in other words, we ask ourselves when would be the best time to post a particular piece of content to attract the greatest possible response); how we launch and participate in hashtags; and how we work to attract clicks, views, likes, reblogs, retweets, and upvotes.
>
> *De Kosnik et al., 2019, p. 21*

Others have articulated similar analyses of social media as performance. Besides Goffman, Marshall McLuhan represents a secondary viewpoint on how theatre relates to social media. For example, in "Is Twitter a Stage?" De Kosnik et al. (2019, Ch. 1) articulates "Theories of Social Media Platforms as Performance Spaces", and applies McLuhan's analysis of another ubiquitous technology (the newspaper) to social media. De Kosnik observes that social media makes everyone a creator the same way that the new medium of "Xerox ma[de] everybody a publisher" (McLuhan, 1974, p. 52). Additionally, De Kosnik et al. (2019, p. 23) analyzes the way that social media's focus shifts from "figure" to "ground" in the way McLuhan described "new journalism":

> "Old journalism," McLuhan argues, was about figures—that is, important or prominent people or events. "New journalism," in contrast—and I suggest that we can add or substitute "social media" for this term—is concerned with "ground" rather than "figure" (McLuhan here uses terms borrowed from Gestalt psychology), in that newer ways of reporting on events are invested in being on the ground, reporting on the experiences, opinions, and perspectives of the mass or crowd. McLuhan writes that "new journalism" (and, again, I view this term as equivalent, in our current moment, with "social media") consists of "immersion in situations which involve many people simultaneously"
>
> *McLuhan, 1974, p. 51*

Abercrombie and Longhurst introduce the notion of a 'diffuse' audience, arguing that evolutions in CMC tools have transformed everyone into a constant audience:

> “So deeply infused into everyday life is performance that we are unaware of it in ourselves or in others. Life is a constant performance; we are audience and performer at the same time; everybody is an audience all the time. Performance is not a discrete event.”
>
> *Abercrombie et al. (1998) (quoted in Freshwater (2011, p. 70))*

Together, these works represent an interpretation of social media as a site for performance. I embrace this framing; Chapter 4 goes into detail about the system we constructed which embodies this approach.

2.3 Summary of Previous Approaches in HCI

The focus of most HCI research combining technology and performance is the performance itself - essentially limiting the design space to the specific time (and place) during which a ticket-holder would experience a production.

In this dissertation, I explore an inversion of these commonly accepted constraints, identifying opportunities for technology engagement with a live performance at different times and in different places. My goal is to use technology to provide opportunities to engage with audiences outside of the context of a production, support reflective theatrical experience beyond the stage, all while embracing the affordances of theatre. In other words, my goal is to integrate tech *around* a theater experience rather than *into* it. I introduce an expanded understanding of time in relation to performance, considering not only the show itself but events and creative efforts that take place before and after. I especially consider the extensive creative efforts that go into the early production process as well as the long-term reflection and engagement with a performance over time.

2.4 Introduction of Dramaturgical Framework for Interactive Performance

Returning to the definition of a ‘sensitizing concept’, I embrace Blumer’s original construction (Blumer, 1954), which emphasizes the importance of celebrating unique observations:

> “We do not cleave aside what gives each instance its peculiar character and restrict ourselves to what it has in common with the other instances in the class covered by the concept.”
>
> *Blumer, 1954*

In this work I introduce three perspectives which allow me to enrich, extend, and embody existing conceptualizations of performance-related technology. Specifically, the Dramaturgical Framework for Interactive Performance highlights the importance of *roles*, *space*, and *time* in the design of interactive performance technology. The framework expands the discussion around each element through an engagement with the 'peculiar character' of each project.

In this section, I present the Dramaturgical Framework for Interactive Performance. This framework builds on existing approaches and has been shaped by my experience collaborating with expert practitioners, designing, and evaluating performance-related exemplar prototypes, presented in Chapters 3 - 5. The Dramaturgical Framework for Interactive Performance discusses the importance of considering roles, space, and time in the context of both "on stage" and "back stage", and identifies three guiding principles for designing at the intersection of performance and technology: 1) spectatorship is active, 2) performance experiences extend beyond the stage, 3) performance occurs in daily life. Working closely with expert theatre practitioners during the deployment of a live production presented in Chapter 3 allows us to deeply examine the *roles* in a traditional performance environment, and our prototypes embody the Audience Studies understanding of an active *audience* (Freshwater, 2009; Freshwater, 2011; Sedgman, 2016; Sedgman, 2018). By embracing this interpretation of the audience, we additionally expanded the design space around how *time* and *space* are considered in a traditional performance experience. Continuing to explore the active audience *role*, Chapter 4 explores the same concept outside the formal production context. Moving backstage, Chapters 5 and 6 articulate the benefits of identifying strategies and techniques used by performers into the design of creativity support tools. The Dramaturgical Framework provides sensitizing concepts to guide and support future designs at the intersection of performance and technology (see Figure 2.8).

2.4.1 Roles

Many research projects that combine technology and performance choose terminology and definitions for audience members that imply passivity: "the [spectators] are waiting their turn, do not wish to directly take part, or are just passing through the locality" - this frames these spectators or bystanders as not engaged, not active. Instead, the Dramaturgical Framework for Interactive Performance emphasizes the importance of embracing the framing of audiences from Audience Studies (see Sections 1.3.1 and 1.3.2) which understands audiences as always actively engaged, and purposefully co-constructing the performance together with performers and backstage technicians. Embracing an understanding of the inherently active engagement of any observer shaped the design of the three prototypes in the theatre project (see Chapter 3), and the design of our computer-mediated communication system (see Chapter 4). In both chapters, I discuss how this perspective fundamentally respects the existing audience experience as 'active' and did not seek to 'activate' it through the incorporation of technology, or interactive experience design (like participatory theatre).

In addition to this understanding of audience behaviour, we can identify other relevant roles (which HCI researchers might call 'stakeholders'). In addition to the performers on-stage, and the audience (who may also sometimes be on-stage), it's important to consider

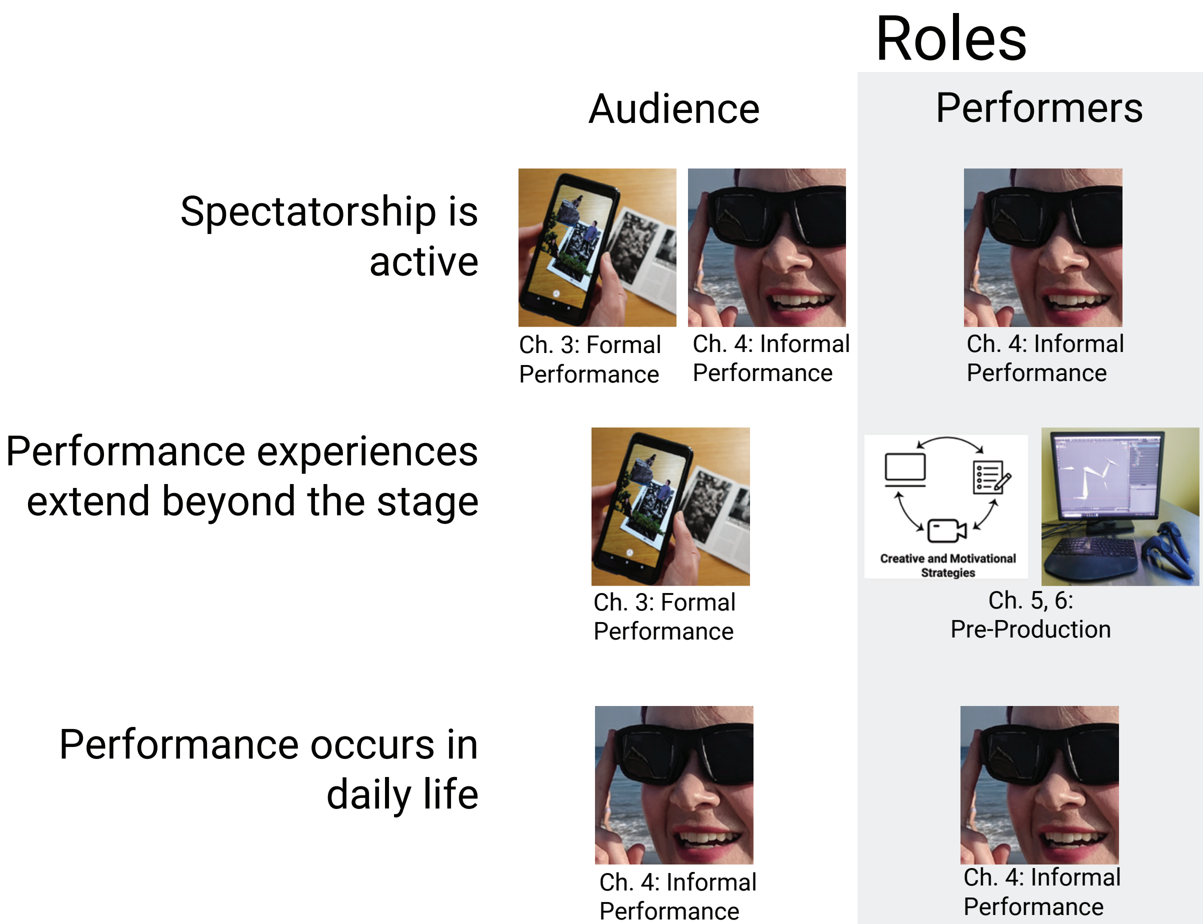


Figure 2.7: When designing at the intersection of performance and technology, what roles do we need to consider?

and design for the production team (including the director, stage manager, costume designer, and so on). The trajectory framework (Benford, Giannachi, et al., 2009) helpfully lists the core roles involved in a production: performers (what the authors call 'actors'), the audience (including 'participants' and 'spectators'), and the production team who manage the technology and logistics (called 'operators' and 'orchestrators') (see Figure 2.7). Each represent potential future users of technology in the context of theatre and technology. I discuss opportunities and challenges when designing for these additional roles in Chapters 6 and 5.

2.4.2 Time

By embracing the agentic audience, and drawing from my own experience as a performer, as well as my extensive collaboration with expert theatre practitioners, I identify *time* as another element of the framework that benefits from an expanded perspective. Performances

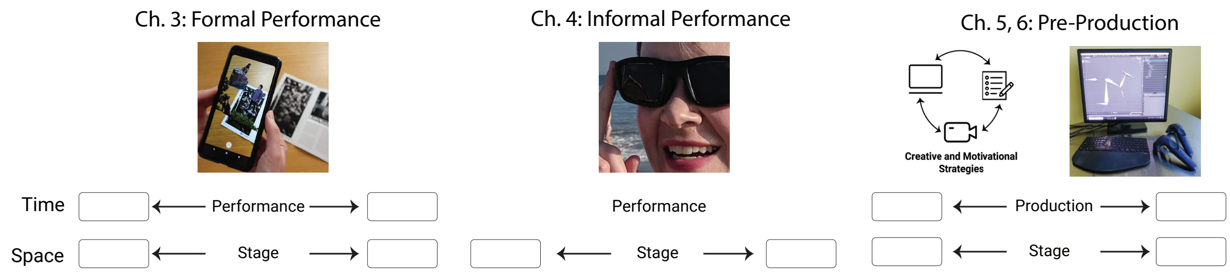


Figure 2.8: When designing at the intersection of performance and technology, what kind of new opportunities and challenges emerge out of an expanded understanding of space and time?

have an extensive pre-production stage, which begins months or even years before the cast gets together for the first rehearsal. This extended life-cycle of production occurs in some form in nearly every kind of production, from a traditional theatre show, to an improvised production, to self-expression on social media, to an animated movie. Consider first a typical theatrical production. The first step along the journey to creating the final show begins with members of the production team identifying the story they want to tell. They may start with an already completed script or they may be writing and generating an entirely new script. In both cases, the production team (which may include the director, the dramaturg, the production manager, the set designer, the choreographer, the band leader, the costume designer) first engage in a creative exploration of the elements that will ultimately make up the show. Together, they may define the visual language, the overall look and feel, the sound design, or other aspects of the production. Throughout this process the production team may be shifting between levels of abstraction (ideal artistic vision with no costs considered, vs highly practical decisions around total production cost), and considering each choice from the perspective of multiple stakeholders (future audience, theatre sponsors, personal storytelling goals).

All of this work happens months or even years before any other aspect of the production becomes a reality. I argue that embracing an extended definition of *time* reveals new opportunities for design at the intersection of technology and performance, and I show how embracing this has resulted in the design of compelling systems incorporated into a live show (Chapter 3), an additional understanding of the creative process throughout the pre-production stage (Chapter 5), and a creativity support tool that supports the creative process that happens during early pre-production (Chapter 6).

2.4.3 Space

Space plays an important role in the experience and design of a production, it was part of the motivation behind attempting to reconstruct Shakespeare's original Globe theatre:

> The basic justification for attempting to reconstruct the Globe in a faithful version of the original is that it can be used to learn more about Shakespeare's plays. The Globe was Shakespeare's machine, financed and built by the company that intended to use it. How it worked and what it produced have a great deal to offer to students of Shakespeare's plays... Everything that has been wrung from [Shakespeare's plays] in the last four centuries is enhanced by a better knowledge of Shakespeare's original [theatre] concept.
>
> *Gurr, 2022*

The definition of 'space' from the trajectory framework similarly emphasizes the environment in which a performance takes place. This could include both physical locations (a stage, a city) and also digital ones (a 3D map of a city, an online forum). Additionally, our expanded understanding of *time* related to a performance now includes pre-production and post-production, both of which may take place in entirely new locations beyond the stage. For example, most rehearsal doesn't take place on the formal stage where the final production will happen, but in a rehearsal room: Dancers rehearse in a dance studio, singers may practice in a practice room, and actors may run lines or learn blocking in a variety of locations. All of these locations represent underexplored sites for design.

Additionally, even if we limit our design process to the performance itself, from the audience's perspective the stage is viewable but generally unreachable, while the lobby represents another location that provides an opportunity for design. Expanding our understanding of performance to include social media, work presentations, first dates, games; anywhere can be a 'stage' (see earlier discussion about Abercrombie and Longhurst's notion of "diffuse performance"). In addition to an expanded notion of how *time* is relevant, the Dramaturgical Framework for Interactive Performance foregrounds an expanded conceptualization of what *spaces* are relevant to our experience of performance.

2.4.4 Core Sensitizing Concepts

Considering these expanded definitions of role, space, and time as described in the Dramaturgical Framework for Interactive Performance, the technologically-inclined dramaturg additionally needs to consider the following core sensitizing concepts. While the relative importance of each concept may vary depending on the exact context, each is worth taking into account when designing technology for a performance-related experience.

Liveness

In the context of performance, notions of 'liveness' are key. Saltz (2001) described the importance of liveness and spontaneity when incorporating technology into a live production (see Section 2.2.2). Many researchers have explored the impact of technology on 'liveness' as experienced in the theatre, including Webb et al. (2016), who introduced the term *dis-*

tributed liveness as part of their exploration of the role that networked technologies can play in traditional forms of performance. Throughout this thesis, I rely on Couldry (2004)'s definition, which emphasizes the shared social reality between participants who are experiencing an event in real-time, and especially the way "liveness guarantees a potential connection to shared social realities as they are happening".

As part of this exploration of liveness, Chapter 3 describes the process of incorporating technology into a live theatre production, where we decided not to incorporate any technology into the show itself, in part to avoid disrupting the sense of liveness and immersion as experienced by the audience. Chapter 4 introduces Friendscope, an experience sharing system for camera glasses which enables instant sharing of videos and photos from the wearable camera interface, and supports quick responses immediately viewable on the wearable camera interface. These two projects find the balance between liveness, and social and technical constraints.

Immersion

Immersion plays a major role in our experience of diverse media forms. From reading a book (Weibel et al., 2010) to listening to music (Chamberlain et al., 2018), to playing a game (Jaakko et al., 2011; Brown et al., 2004), to watching a show (Machon, 2013), or existing in Virtual Reality (Rostami, 2020; Mestre et al., 2011) feeling 'immersed' is a compelling concept which has shaped much research in HCI (Morgan, 2012; Machon, 2013; Broadhurst et al., 2006). Immersion is very important to the experience of a live show (but plays less of a role in the expanded definition of roles, space, and time described in this thesis).

Aesthetics

Because performance concerns itself with how something is perceived by others, aesthetics plays a very large role in the artform. The importance of aesthetics not only impacts the final outcome, but also can shape the entire design process. For example, best practice for 1) technologists working with theatre-makers (Honauer et al., 2015), 2) eliciting early feedback while managing limited resources (Sauer et al., 2009), 3) participatory design practices (Muller, 1991), and 4) prompting innovation and exploration (Wulff et al., 1990; Claes et al., 2017) typically involves building low-fi prototypes. A low-fi prototype may be defined as ranking relatively "low" on all five of McCurdy's dimensions (McCurdy et al., 2006). Throughout my collaborations with expert theatre practitioners, I specifically avoided polishing our early demos, hoping to encourage richer feedback, as recommended by HCI researchers (Coyette et al., 2007; Virzi et al., 1996; Wulff et al., 1990; Claes et al., 2017; McCurdy et al., 2006; Landay et al., 2001). As I describe in more detail in Chapter 3, this strategy was not effective. In fact, aesthetic refinement was a key element of our successful collaboration. Additionally, as I describe in Chapter 5, aesthetics can play a motivating role for practitioners as they engage in their creative practice.

Agency

How might the notion of the active audience shape the design of a computational system? How might we ensure that "spectatorship is not a passivity" (Rancière, 2021)? The Dramaturgical Framework for Interactive Performance explicitly embraces this notion, and encourages the dramaturg to consider how each element — role, space, and time — can shape the "parameters" of experience (Spence et al., 2013) while still fundamentally respecting the agency in each audience member.

Embodiment

Audiences "bring their whole bodies with them into the auditorium" (Freshwater, 2009). Performers often develop and use their body as their instrument. Within the world of theatre studies, much of this framing around the audience's experience was shaped by the philosophy of Maurice Merleau-Ponty, who discusses the way our embodied experiences shape every aspect of perception (Merleau-Ponty et al., 1962). Banes and André Lepecki (Banes et al., 2012) describe the way performances have creatively explored senses beyond sight and hearing, and suggest the ways we can expect 'modes of attention' to change as technology enables 'new forms of perception' (Freshwater, 2009).

An understanding of how embodied experiences shape tool-use has long suffused HCI as well. Consider Dalsgaard's notion of *instruments of inquiry*, an understanding of the way the creative process "intertwines" and "co-evolves with" the environment and tools. This Deweyan pragmatist perspective, which underlies Dalsgaard's philosophy, elucidates the way a performer might leverage tools to augment her own cognition and creative process (Dalsgaard, 2014). For example, we can frame the use of tools as 'knowing-through-action': combining expertise as a professional performer with the tools at hand together to produce output – a scene, a character, a line reading – that is meaningful and that moves the design process forward. This 'knowing-through-action' arises as the creative practitioner leverages different tools throughout her process. Distributed cognition (Hollan et al., 2000) presents a similar lens for understanding this concept, which also embraces the larger context of her working environment as part of her cognition. In other words, her creative process is an emergent property of the interaction between her own skills and the camera or the journal.

Seen through the lens of *instruments of inquiry* (Dalsgaard, P., 2017) or distributed cognition (Hollan et al., 2000), we can see the importance of understanding how closely enmeshed the creative behavior is with the tools at hand. This philosophy resonates with earlier work on tangible tools that tap into muscle memory and tacit, embodied forms of knowledge (Klemmer, Hartmann, et al., 2006), further motivating the design of tools that span modalities and mediums.

2.5 Summary

In this section I have introduced the Dramaturgical Framework for Interactive Performance, which consists of expanded definitions of **roles**, **time**, and **space**. I have also introduced five core sensitizing concepts for any dramaturg seeking to design technologically-mediated theatre experiences: liveness, aesthetics, agency, immersion, and embodiment. I argue that work at the intersection of performance and technology may benefit from drawing on the extensive literature in the field of Performance, Theatre, and Audience Studies (as described in detail in sections 1.3.1 and 1.3.2). By cross-pollinating perspectives from these existing fields, I identify roles, space, and time as the most important elements to consider when designing technology in, around, and for performance.

In the next chapters, I describe three perspectives on this framework, through the design, creation, and deployment of multiple interactive systems. Specifically, I report on 1) a 4-month collaborative process with expert theatre practitioners where we explored the benefits of expanding the discussion around what counts as a performance 'space' and a performance 'time' to include not just the production itself but pre-production, rehearsal, intermission, and post-show reflection, 2) a within-subjects user study of our system that allows both the 'performer' and the 'audience' to have equal access to the generation of a shared experience, and 3) identify and investigate how designers can construct tools that support the many "behind the scenes" processes that take place early on in the life cycle of a production, including , especially the way embodied creative exploration shapes a performance throughout the life cycle of a production in the context of designing animated characters.

Chapter 3

Formal Performance

"The show begins when you first hear about it, and only finishes when you stop thinking and talking about it."

— Lyn Gardner, *2019*

Work combining live performance and technology often involves incorporating technology directly into the performance as it occurs onstage, including interactive costumes, or performer-controlled sets, lighting or sound. As I described in Chapter 2, putting technology on the stage, or providing audiences with technology implies a particular perspective and understanding of where and how technology can and should be incorporated into a production. In this work, I invert this common approach, developing technology-mediated experiences outside the temporal and spatial confines of a live theatre production. This approach aligns philosophically with how Audience Studies researchers often discuss the role of the audience (Sedgman, 2016; Sedgman, 2018; Freshwater, 2009; Freshwater, 2011; Bennett, 1997; Brook, 1996; Carlson, 1989; Jackson et al., 2007; Keidan et al., 2015; Frieze, 2016; R. Goldberg, 2001; Abercrombie et al., 1998; Brecht, 2014; De Kosnik et al., 2019; Keidan et al., 2015; Heim, 2015; Butsch, 2000; Butsch, 2008; Blackadder, 2003; Murray et al., 2016; Carlson, 2013).

In this chapter, I describe the 4-month co-design process with expert theatre practitioners, and detail how we iteratively developed design guidelines for incorporating technology into a live, formal theatre production. In the style of research through design, I present three annotated prototypes: the Augmented Playbill, the Prayer Wheel, and Tarot Cards as well as accompanying AR applications to convey the decisions we made and the philosophy we iteratively developed throughout the project. In particular, by embracing a particular understanding of the **role** of the audience – as already active, engaged, and agentic – this project lead us to extend the design space for technology-mediated formal theatre experiences into the **times** before, and after the show itself, as well as the **spaces** around a production.

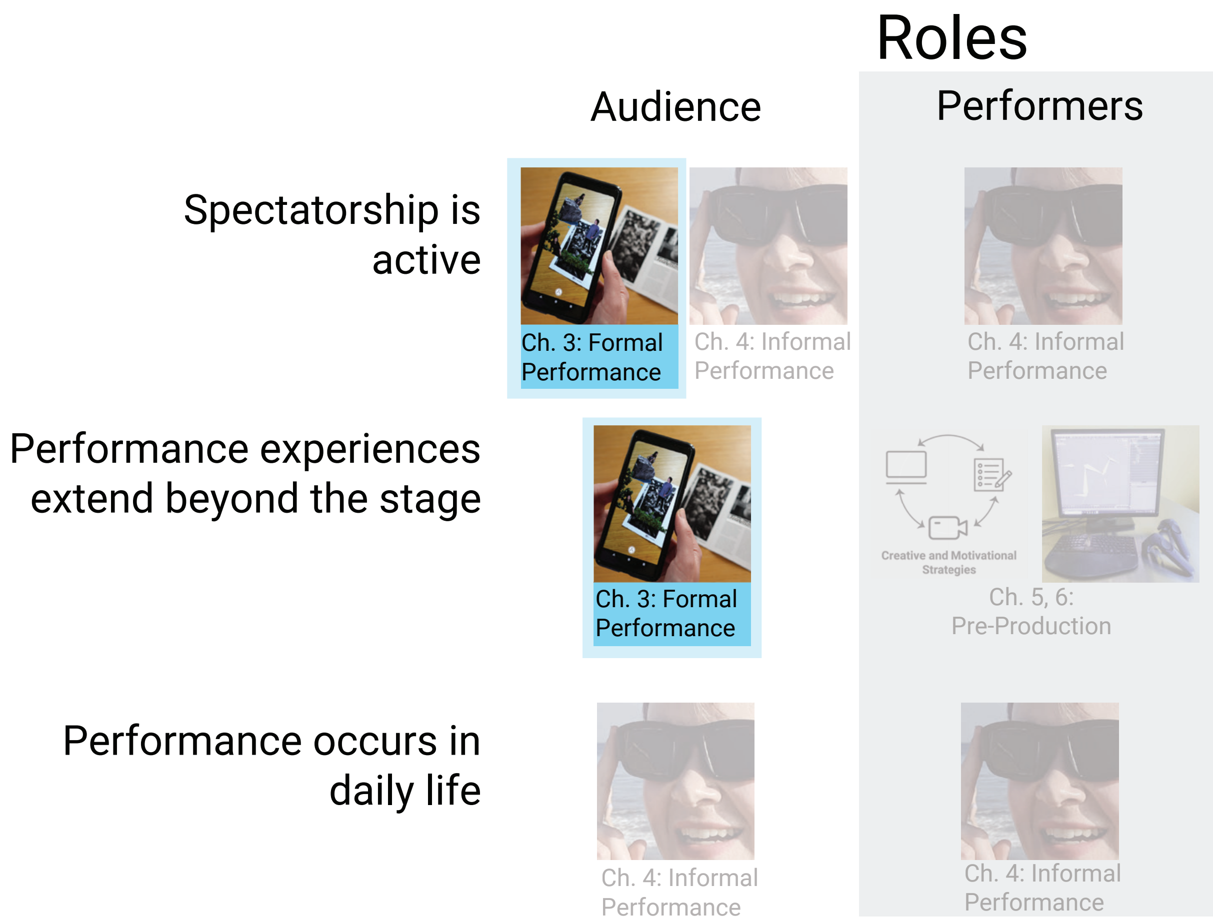


Figure 3.1: In this chapter, I described the way considering the role of the audience can embody two of my design guidelines, and describe the way this understanding of the audience lead us to expand our understanding of both time and space as related to performance.

3.1 Introduction

Work combining live performance and technology often involves incorporating technology into the performance itself, including interactive costumes (Honauer et al., 2015; Saltz, 2001), or performer-controlled sets, lighting or sound (Bluff et al., 2017; Bluff et al., 2019; Latulipe, Wilson, Huskey, Word, et al., 2010). These approaches focus on enriching the experience of the performance as it occurs on the stage, staying within the borders of the theatre, and within the time limits of the production. In this work, we explore an inversion of these constraints, identifying opportunities for technology engagement with a live performance at different times and in different places. Our goal is to use technology to provide opportunities to bring characters to life outside of a production, support reflective theatrical experience beyond the stage, all while embracing the affordances of theatre. In other words, our goal is to integrate tech *around* a theater experience rather than *into* it (see Figure 3.3).

Figure 3.2: Our three prototypes, embodying the six design guidelines for incorporating technology into a formal performance that we iteratively developed throughout the four month co-design process. Left: Augmented Playbill, a familiar artifact from the world of theatre, augmented to extend the narrative of the production, prompt reflection on the themes of the show, and provide privileged access to behind-the-scenes information. Center: Prayer Wheel, constructed out of lasercut wood, the prayer wheel resonates with motifs from the play. When scanned, each side reveals audience and cast-member reflections about the themes of the play. Right: Tarot Cards, each depicting a character from the play, which launch an augmented reality scene when scanned by our app.

People enjoy creating auxiliary experiences around stories that they love and often enjoy thinking of characters as existing outside the official 'canon' of an author's work. Through a co-design process with expert practitioners, we developed guidelines for designing experiences outside the temporal and spatial confines of a live theatre production. Following best practices for combining technology and performance (Honauer et al., 2015; Saltz, 2001; Gonzalez et al., 2012), we embedded within the development and deployment of a live performance with expert theatre practitioners to prototype technology mediated experiences that extend beyond the stage. In this chapter, I describe the 4-month intensive co-design "performance-led research in the wild" process (Benford, Greenhalgh, et al., 2013), identify challenges and opportunities for collaborating with professional theatre-makers, and describe how our design guidelines developed throughout the rehearsal process.

In the style of research through design (Stappers et al., 2017; Zimmerman et al., 2007), I also present three annotated prototypes: the Augmented Playbill, the Prayer Wheel, and Tarot Cards as well as accompanying AR applications. Together, these convey the decisions we made and the philosophy we iteratively developed throughout the project (W. Gaver, 2012). These artifacts also embody six design guidelines for incorporating technology into a formal staged theatre production: *resonant affordances*, *extended narrative*, *reflective interaction selective reveal*, *personalized experience*, and *privileged access*. We evaluate the overall experience with core stakeholders – the Director and the Production Designer, the two most important decision-makers in the theatre production itself – and identify new opportunities for technological engagement within live performance.

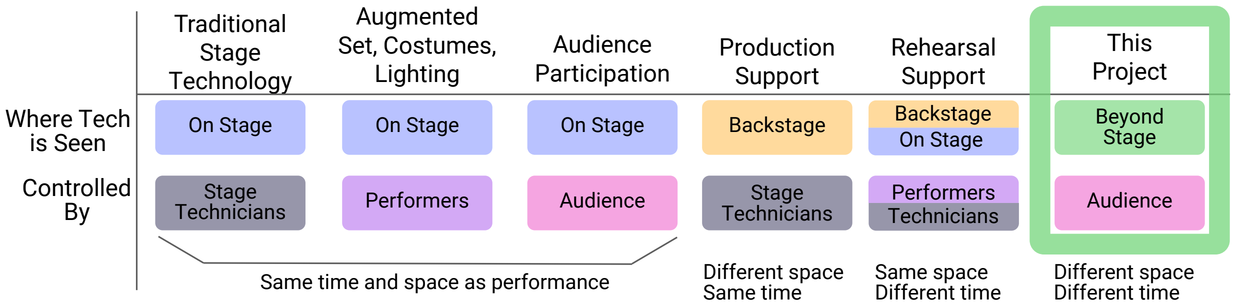


Figure 3.3: Technology-mediated theatre experiences can be understood in terms of *where the technology is seen*, and who it is *controlled by*. This work explores a central, but under-explored aspect: supporting the experience of audience members beyond the onstage experience. Note that both Production Support (technology used by stage technicians backstage during the show) and Rehearsal Support (technology used by performers or stage technicians outside the scope of the show) represent other design spaces that are also underexplored in the literature, though I do not discuss them in this chapter.

3.2 Related Work

3.2.1 Technology On Stage

Collaborations between technologists and performers often involve layering technology on top of the on-stage performance. Saltz (Saltz, 2001) presents a thorough taxonomy for incorporating technology into a theatrical production, all of which involve the technology appearing "on stage" in some manner. Bluff and Johnston developed a system for using "motion-tracked human performers in real-time" to control backgrounds and animated graphics projected onto the stage during live shows (Bluff et al., 2017). They describe how this system and the performers co-evolve over time (Bluff et al., 2019). Latulipe and collaborators have done extensive work combining dance and technology on stage (Latulipe, Wilson, Huskey, Word, et al., 2010; Latulipe, E. Carroll, et al., 2011; Latulipe, Wilson, Huskey, Gonzalez, et al., 2011; E. A. Carroll et al., 2012). See Zhou et al. for a thorough retrospective of how technology has been incorporated into dance in HCI over the last two decades (Q. Zhou et al., 2021). These approaches focus on enriching the experience of the production at the time of the performance and on the stage. In contrast, we seek to extend the experience beyond the timeline and the location of the live show. The project most conceptually related to our work is *Magicface*, an AR mirror that operates in the backstage of an Opera performance and enables audience members and performers to "step into the character" of a show, enhancing the overall experience (Javornik et al., 2017). While our work also expands the experience beyond the stage, our work differs from *Magicface* because our artifacts were meant to be kept by audience members and experienced as they continue to evolve over time.

3.2.2 Interactive Live Productions

A huge variety of work has explored interactivity in live performances across many domains, including music (Lee et al., 2019; Webb et al., 2016), theatre (Saltz, 2001; Cordeiro et al., 2017; Cerratto-Pargman et al., 2014; Barkhuus et al., 2016; Owen et al., 2013; Friederichs-Büttner et al., 2012; Koleva et al., 2001), sporting events (Ludvigsen et al., 2010; Esbjörnsson et al., 2006), games (Seering et al., 2017; Glickman et al., 2018; Maynes-Aminzade et al., 2002), and audio-visual (McCarthy, 2016) to select a few.

Cordeiro helpfully summarizes the multitude of forms of interactive art, clarifying the difference between *participatory art*, where "the audience or visitors' participation is regarded as a necessary and fundamental element for the existence of the artwork", *collective art practice* where the larger community participates in art production as a means of community engagement and not an end, and *interactive art* which enables the 'audience' to influence and shape the content or form in real-time (Cordeiro et al., 2017). As a few examples of interactive art, Cerratto-Pargman et al. (Cerratto-Pargman et al., 2014; Owen et al., 2013) designed a system that allows audience members to use mobile devices to shape the outcome of the production. Lee et al. describe a system that facilitates audience participation during a musical performance (Lee et al., 2019). Rostami et al. identified opportunities for bio-sensing and body-tracking technology that span many forms of interactive performance (Rostami, McMillan, et al., 2017). Works like these often focus on "blurring the distinction" between audience and performance.

Building technology directly into a live production is clearly an incredibly rich design space for creating compelling experiences. In contrast, we understand the unmediated theatrical experience as *already interactive*. As Kirsty Sedgman writes, "the kind of silent absorbed attention mandated at more traditional theatrical events is something that requires active spectatorial work to achieve" (Sedgman, 2018). In other words, the unmediated theatrical audience experience itself is deliberately constructed by the audience, and does not need an extra layer of 'interactivity' layered on top in order to be a rich, interactive experience. See Kirsty Sedgman's work for thorough discussions about this concept from the field of Audience Studies (Sedgman, 2016; Sedgman, 2018), and James Frieze's collection for additional details of the historical context, and thoughtful critique of the widely perceived binary of active vs. passive and traditional vs. contemporary (Frieze, 2016). In this work, we focus on opportunities for design that extend that rich experience *beyond* the moment of the production, rather than inviting audience participation *during* the show.

3.2.3 Collaborating with Theatre-makers

When designing technology for live productions, researchers often develop new ways of collaborating throughout the rehearsal process. Barkhuus et al. (2016) describe the rehearsal process for an interactive theatre production. Honauer et al. (2015) present a practice-based case study with a local theatre house developing interactive costumes. Their recommendations mirror Gonzalez et al.'s principle of *Integrated Process* (Gonzalez et al., 2012); both emphasize the importance of close collaboration and co-designing aesthetics. Following their recommendations, we were present throughout rehearsals and production to maintain synergy with the aesthetics of the production, and to provide support for any implemented prototypes. We describe additional collaboration recommendations, especially around what types of prototypes are useful for communicating with theatrical professionals, who are accustomed to highly refined aesthetics.

3.2.4 Technology Inspired by Theatre

Spence et al. clearly articulate the differences between various understandings of "performance" as they related to HCI, making a clear distinction between projects that embrace the "theatre of dramas" (as ours does) and those that engage more with the "postdramatic" practices of performance art, which maps more directly onto concerns of HCI. See their paper for thorough and clear discussion (Spence et al., 2013). Reeves, Benford, et al. (2005) produced a taxonomy of spectator experience drawn from performance studies: secretive, expressive, magical, suspenseful. Their work describes how these spectator experiences can influence the design of technology. Z. Zhou et al. (2019) also considered spectators in their design of Astaire, a collocated hybrid VR dance game. Designers using immersive technologies such as VR have long drawn on arts practices and performing strategies to enhance the experience of mixed reality performances (Rostami, Rossitto, et al., 2018). Researchers have also looked at spectators beyond the stage, and designed systems for crowds at various other events (Reeves, Sherwood, et al., 2010; Esbjörnsson et al., 2006; Ludvigsen et al., 2010).

3.3 Design Process

To better understand the perspectives of multiple stakeholders and goals, and values spanning the lifecycle of development of a live performance, we embedded ourselves within the creative team of a stageplay. We worked directly with actors, directors, and the production team throughout the creation of the production. In this section we detail that process. The final prototypes emerged from our evolving process; we adjusted strategies and techniques as we discovered the best way to work together. We describe both the process and designs simultaneously, describing how each stage shaped the final design guidelines.

3.3.1 Production details

Collaboration logistics: Embedding into traditional structure

In a typical theatre production, the production design team includes costumes, set design, sound design, props, lighting, and graphic design. Following best practices for technologists collaborating with artists, in order to stay integrated with the production process (Honauer et al., 2015; Gonzalez et al., 2012), we joined this set of teams as the 2-person AR design team. Throughout the 4-month creation period, at least one member of each design team, including the AR design team, always attended every rehearsal and production meeting. This kept us in close contact with the evolving artistic production.

Collaborators

Working as part of a team, the main people involved in the design of these prototypes are the following 4 people:

- Director - the internationally acclaimed author of over 40 plays, and is a veteran director of theatre, film, and opera. While he was the final decision-maker for all show elements, he was less involved with daily design aspects.
- Production Designer - a world-renowned designer, she led the vision and execution of the Set, Costume, Lighting, Sound, and AR Design teams. She was the primary day-to-day contact for design discussion and decisions. The Production Designer was also particularly interested in using Augmented and Virtual Reality technologies, because it resonated with the themes of the show.
- Developer/Co-author 1 (D1): previously toured as a professional performer, then worked as a software and hardware engineer, now an HCI researcher.
- Developer/Co-author 2 (D2): a creative technologist and engineer with a background in film, virtual/augmented reality and HCI research.

The descriptions below are taken from notes taken during the rehearsal process, as well as ongoing interviews and discussions among all the collaborators.

Production details

This production was the world premiere of the Director's latest production. The play begins in a small mountain village near the Himalayas, following the local people's daily lives. Some characters then move to New York, and adjust to life in the big city. The play in its entirety is conceived to be a 4.5 hour performance in four acts. The production involved 28 actors, 6 assistant directors, and 8 designers (one of which was D1, the head AR designer).

The show was performed for three, sold-out nights. A total of 85 audience members saw the production.

3.3.2 Initial Meeting: Shared philosophy

Our first meeting with the production designer occurred one month before rehearsals started. In this early meeting, expressing our own ambivalence about how and when it's appropriate to incorporate technology into a live show helped to build rapport. Consider this excerpt from an early email D2 sent to the Production Designer:

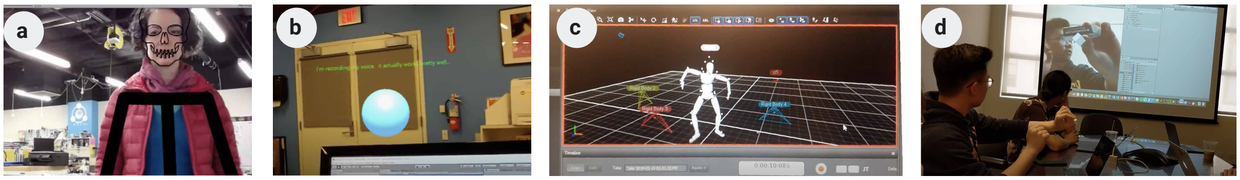


Figure 3.4: Screen captures of a subset of the lo-fi prototypes D1 and D2 put together during the prototyping stage (see Section 3.3.4). a) OpenPose skull prototype, which does full-body and face-tracking. The virtual skull overlaid on top of the camera feed represents the Buddhist notion of awareness of death. b) Hololens voice recording demo, showing the impressive capabilities of accurately capturing speech in a noisy room. c) Motion capture, using a full-body setup and mounted trackers. d) A live demo of Vuforia target tracking and interaction.

> *Before using a new technology just for the sake of using it you should ask yourself, what is the goal? Who is this experience for and when should they experience it? Why? What value does this interactive piece add to the overall spirit of the performance?*

Thoughtfulness around when and why to incorporate technology was a theme in early discussions. At D1's first meeting with the Director, he quickly shared his reluctance around incorporating technology into any theatrical show. He was especially concerned that using phones would distract audience members. We emphatically voiced our agreement, emphasizing our own skepticism about technological solutions in general. Building on his concerns, we discussed potential difficulties with getting folks to learn a new technology, download an app, our shared desire to minimize the 'necessary evil' of instructional signage (Cordeiro et al., 2017) and other potential challenges around comfort and battery life. Instead of enthusiastically declaiming the potential benefits of technology, we acknowledged potential downfalls, and reframed the production as an experiment.

Takeaway: Understand Ambivalence, Build Rapport

By openly embracing our own ambivalence around technology, we built rapport with our collaborators. Discussing potential issues and downsides early on allowed us all to embrace the production as an experiment, and set our first design guideline: we wanted the ***affordances*** of any technology to ***resonate*** with existing norms and expectations of theatre (this became our first design guideline, *Resonant Affordances*). Our approach is an interesting twist on Honauer and Hornecker's recommendation to have an enthusiastic proponent of technology within the organization (Honauer et al., 2015). Instead, both developers bonded with the Director over skepticism around technology. Of course many theatre-makers embrace new technology in different ways! We encourage designers to embrace the complex implications of introducing any piece of technology into theater, and led with openness to support a discussion about how to make it work well in their context.

3.3.3 First week: Technology Enumeration

During the first few weeks of the design process, we purposefully maintained a sense of openness about what kind of technology we might be able to use, and how we might incorporate it into the production. By collecting a list of existing technology, we thought we'd be enabling an open but grounded conversation around the technological possibilities. While we wanted to stay open to any design options, we were also eager to converge on a specific technology quickly, so that we could finish any implementation early enough that it could be incorporated into the rehearsal process if necessary, as recommended by both Gonzalez et al. (2012) and Honauer et al. (2015). We particularly wanted to be able to iterate on designs beyond the lo-fi prototyping stage, since we expected aesthetics to play an especially large role in the final experience. At this point we expected our technology to be part of the actual production, used by the performers.

Our generated list included devices with a high likelihood of working for the show (such as the Hololens), and devices we thought wouldn't work at all (such as the HTC Vive, which is expensive, unwieldy, and requires a full desktop setup). We also included practical information about cost and details about the user experience including field of view, battery life, and wearability. Our design process at this point could be understood as 'problem-solution co-evolution', whereby the designer both a 'problem space' and a 'solution space', with each informing the other (Ball et al., 2019).

Takeaway: Build a Shared Understanding

While helpful from a logistical point of view, it became clear very quickly – within a few meetings – that there was a lack of shared understanding around what each technology could do, and our lists didn't translate into familiarity with existing options for both the theatre-makers, and the technologists. At the same time, some technology that was new and exciting to us – such as projection mapping – felt like old hat to the Production Designer. The Production Designer also wanted to stay away from any technology that she saw as likely to be co-opted as a cost-saving device (such as using projection mapping to save money on scenery). Instead, she repeatedly emphasized how the technology should ***extend the narrative*** of the production, leading to our second design guideline, *Extended Narrative.*

3.3.4 Month One: Lo-Fi Prototyping

Following our own prior experience and best practices for 1) technologists working with theatre-makers (Honauer et al., 2015), 2) eliciting early feedback while managing limited resources (Sauer et al., 2009), 3) participatory design practices (Muller, 1991), and 4) prompting innovation and exploration (Wulff et al., 1990; Claes et al., 2017) we opted to build lo-fi prototypes (i.e., they rank relatively "low" on all five of McCurdy's dimensions 2006, but especially on visual refinement and richness of interactivity). Our goal here was two-fold: verify what a given technology option could do, and act as a discussion prompt with the

Figure 3.5: Left: An iOS app called Peck Peck's Journey (*Peck Peck's Journey: A Picture Book That Spawns Virtual Life* 2015) that served as inspiration for our augmented playbill. Right: An image of the *Unreal Garden* (*The Unreal Garden: Multiplayer Mixed Reality* 2018), a Hololens-based augumented reality art exhibit we attended along with the Production Designer. When we visited the *Unreal Garden*, we were still considering designing an experience that the audience would use during the show, possibly while wearing the Hololens. While we had shown the Production Designer several lo-fi demos that used the Hololens, experiencing a *polished* version end-to-end helped the Production Designer develop a clearer understanding of both the limitations and opportunities, and helped us as a team better articulate a shared vision and goal for the project (see Section 3.3.5), which helped us develop our design guidelines (see Section 3.4), and ultimately led us away from an experience where the audience would wear the Hololens and towards the final prototypes (see Section 3.5).

theatre experts. We believed building prototypes would be a helpful way to build a better shared vocabulary.

Throughout the first month of the rehearsal process, we built and shared four primary lo-fi prototypes as part of the brainstorming process. See Figure 3.4 for a subset of our early proof-of-concept, low-fidelity prototypes. We specifically avoided polishing our early demos, hoping to encourage richer feedback, as recommended by HCI researchers (Coyette et al., 2007; Virzi et al., 1996; Wulff et al., 1990; Claes et al., 2017; McCurdy et al., 2006; Landay et al., 2001).

Takeaway: Lo-Fi Prototypes Failed to Build Shared Understanding

While these technical demonstrations were helpful to the technologists as proofs of concept, they proved less useful for communicating with the rest of the design team. Even while examining a functional prototype, the Production Designer frequently asked us to clarify what was possible to implement. Believing that the prototype correctly conveyed both the limitations and possibilities of the technology, we'd optimistically respond "anything", meaning “anything within these limits”. What became clear after several such conversations was the lack of shared understanding for what a prototype meant, as well as a lack of clearly articulated goal.

Fundamentally, this represented a lack of shared understanding of what the technology was capable of, a lack of shared vocabulary, and lack of shared vision behind incorporating technology into theatre. Prototypes, while helpful from a technologists perspective, were not helpful for overcoming these barriers. The lack of aesthetic refinement, meant to encourage thoughtful critique, was so off-putting to the Production Designer that she hesitated to respond to or critique our work at all. We frequently turned to Youtube, looking for polished and complete examples of similar technology or experiences (see Section 3.7.2 for further discussion).

3.3.5 Month Two: Experiential Immersion

Once we realized that lo-fi prototypes were failing to help us overcome these barriers, we sought out ways we could experience polished, finished experiences. Wanting to go beyond watching Youtube videos, we found several well-executed AR applications we could experience together. Two had a particularly large impact on our final designs and overall collaboration experience: Peck Peck’s Journey, an AR-augmented book (*Peck Peck’s Journey: A Picture Book That Spawns Virtual Life* 2015; *Peck Peck’s Journey Home* 2015); and the *Unreal Garden*, an experience for Hololens (*The Unreal Garden: Multiplayer Mixed Reality* 2018) (See Figure 3.5).

Peck Peck’s Journey

Peck Peck’s Journey is a simple AR Book experience which uses a mobile phone and a physical book. When a page is scanned with a phone, AR characters appear on the page as viewed through the phone, and they interact with digital elements of the on-page scenery. The AR characters can also be interacted with using your finger on the touch screen. The story progresses as the user flips the book’s pages, scanning each page (See Figure 3.5). The simplicity of the experience, coupled with the highly polished aesthetics, immediately resonated with the Production Designer. We began to see the possibilities of embedding the AR experience into a familiar theatre artifact: the playbill.

Unreal Garden

By far the most impactful experience in terms of shaping our designs was the *Unreal Garden*. The *Unreal Garden* was billed as an “interactive, multiplayer mixed reality experience blending a beautiful, psychedelic forest landscape, multiple layers of sound, responsive projections, haptics, and augmented reality. Visitors are immersed within a magical world blending art and entertainment, and inhabited by fantastical flora and fauna” (*The Unreal Garden: Multiplayer Mixed Reality* 2018) (see Figure 3.5 for images).

	Resonant Affordances	Extended Narrative	Reflective Interaction	Selective Reveal	Personalized Experience	Privileged Access
Augmented Playbill	✓	✓	✓	✓		✓
Prayer Wheel	✓		✓			✓
Tarot Cards		✓		✓	✓	

Figure 3.6: To investigate the whole range of our design guidelines, we instantiated each into more than one prototype. This diagram shows which guidelines were built into each prototype.

Participants are welcomed to the indoor space, a tall-ceilinged room decorated to look like a lush cave, filled with fake plants, a stream, and dramatic lighting. As a group, we were instructed in the use of Hololens headsets, and then allowed to explore the “interactive” AR exhibit at our own pace. The specifics of the exhibit aren’t as relevant as our own discussions afterwards.

Immediately following the experience, we sat down in the lobby for what became an intense, multi-hour discussion about the value of theatre, and how augmented reality might fit into that world. In sharp contrast to earlier discussions, which had felt tentative and polite, the Production Designer immediately launched into a thoughtful, nuanced critique of the entire experience, and Augmented Reality as a medium.

The Production Designer is passionate about the potential of theatre to have an emotional impact, and feels that theatre is one of the only places where people can really “expand their perception”. For her, the *Unreal Garden* was a disappointment; more of a beautiful museum-like display, or “eye candy”. She said: “The whole intro, the front door, the ticket setup, everything of the *Unreal Garden* sets you up for entertainment, not an emotional experience”. She went on to emphasize the difference between a theatrical experience which “has a lot of space for imagination” and AR, which she understood as primarily focusing on “showing something more.” She described her personal favourite theatrical experiences, which have “so much implied and so much space” to “give room for our own interpretation and our own perspective to it.” This discussion became another design guideline, one focused on helping audience members deeply engage in the themes of the production and how it impacted their own life: ***reflective interaction***.

For the Production Designer, the way technology in general, and AR in particular always *added* content to the world was a barrier to embracing it for theatre [1]. She articulated her

[1] We also discussed using AR to remove or block elements from the live on-stage production, a form of “diminished reality” she found extremely compelling, but the post-*Unreal Garden* discussion led us away from audience members wearing individual headsets due to their isolating nature.

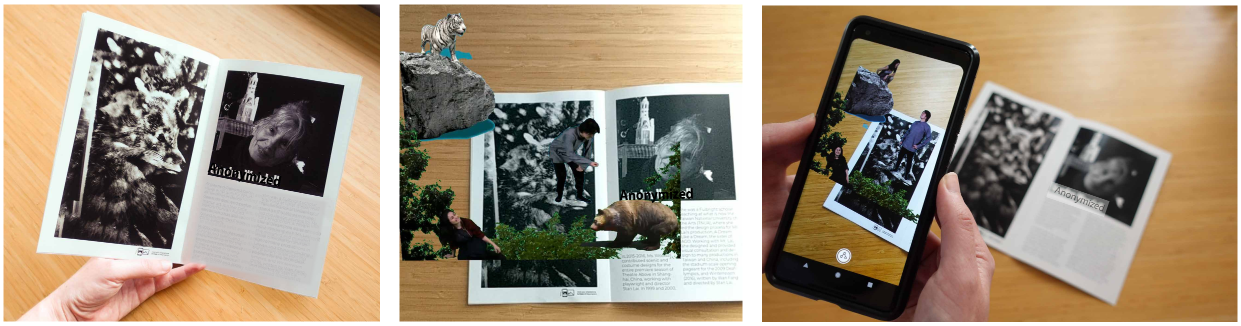


Figure 3.7: Demonstrating how one particular page of the Augmented Playbill shows a scene from the play when scanned by the phone app, including effects and costumes we were unable to achieve in the live, stage production itself.

concerns beautifully:

> **Production Designer:** What do artists do? We focus attention, while leaving space for imaginative leeway. Theatre is about creating something tangible to respond to. But wearing [a Hololens] or having an iPad is "more real" than what's on stage, and this can then feel like an imposed sense, not belonging to me.

She compared the capabilities of AR with existing theatre tech: "Sure, we can imagine flowers blooming suddenly on stage but well-designed scenery and lighting can already do this." After experiencing the *Unreal Garden*, she found herself questioning whether AR was appropriate for theatre at all. She wondered if there was "a way to use AR in a way that invites imagination rather than illustrat[es] a secret." This led to another of our design guidelines, ***selective reveal***.

Takeaway: Hi-Fi Prototypes Are Better In Some Contexts

The polished aesthetics and immersive experience of both Peck Peck's Journey and the *Unreal Garden* launched a series of much richer discussions. Over the next few weeks, we developed a more complete shared philosophy around the purpose of theatre, and how technology should fit into that, shaped by our shared experiences with these two events, and our own backgrounds. Our experiences suggest that in certain contexts, it may be important to adjust the default methodology, and question existing recommendations that emphasize the value of "low-fi prototypes" for cross-disciplinary collaborations. We found instead that highly polished, aesthetically refined, complete experiences best supported the collaborative experience in this context (see Section 3.7.2 for further discussion on this).

3.4 Design Guidelines

Here we describe the design guidelines we generated throughout the collaborative process in greater detail. Our overall guiding principle, succinctly stated by the Production Designer: “We want something that’s a continuation of theatre, not a contradiction.”

3.4.1 Resonant Affordances

It’s important for the technology to enhance and extend the aesthetics and affordances of the production, not “fight” it. We see this as the “off-stage extension” of Gonzalez et al.’s *Aesthetic Harmony* (2012). Gonzalez et al. focused on how technology can augment the on-stage production. In contrast, our focus was on the audience experience before and after the show. The notion of *resonant affordances* encourages designers to take into account not only the themes of the show, but the existing norms of theatre spaces broadly speaking, and how those can influence not only the content, but the interaction techniques used. For example, personal phones are naturally distracting, and using them during the show would break the common theater norm of keeping phones hidden. Maintaining these norms was important for this particular production team, but might be useful to break in another context. We did not expect the audience members of this particular production to be familiar with head-mounted displays such as the Hololens, but for another audience that might be reasonable.

This guideline emphasizes allowing the themes and design of the show to help inform the interaction with the technology. For example, if the production is not interactive, the post-show experience doesn’t need to be, and doing so might be confusing or jarring.

3.4.2 Extended Narrative

Characters and elements of the show should have a life beyond the production. The content of any technological artifacts should be deeply connected to and extend the existing narrative. Tech should expand opportunities for interaction at either end of the production, and should take advantage of existing theatrical and storytelling techniques for introducing characters and building on the story.

The technology should take the story further than would be possible otherwise. A key element of this for the Production Designer was that the technology should go beyond “just marketing” - she felt very strongly that anything we create should ultimately serve the story. She was particularly drawn to the idea of the character having a life even when you’re not looking at it.

3.4.3 Reflective Interaction

While some forms of theatre are meant to be pure escapism, both the Director and the Production Designer emphasized the importance of long-term reflection on and engagement with the themes of the show. As the Production Designer put it:

Production Designer: Reflection completes the idea of theatre.

We wanted to prompt reflection on the personal experience of the show, while supporting lightweight engagement between audience members. By reflection, we don't necessarily mean a serious, focused accounting of one's personal experience. Writing fan fiction about the show, or creating cosplay[2] of a character would both be activities that could be supported in reflective interactions (though we didn't necessarily expect those to happen for this production because it is so new and had a limited 3-day run; those types of fan-based behaviours take time to establish).

3.4.4 Selective Reveal

The Production Designer emphasized the importance in theatre of leaving some details to the imagination: "We want something that's *charging* your imagination, not illustrating everything."

Putting a show on stage is all about choosing what to display and what to keep hidden. Hidden or ambiguous details allow audience members to "complete the story" with their own interpretations - in this way, the Production Designer considers all of theatre a co-created art form, constructed in collaboration with an audience. We wanted our designs to embrace this mindset, and to explicitly invite audience members to add their own experiences to the story.

3.4.5 Personalized Experience

In all theatre, there's a tension between the shared experience of watching a live show together, and the individual experience we all have as humans. Personalizing experiences is a very strong theme in D2's AR/VR work. The more personal an experience feels, naturally the more immersed a user becomes. Since AR and VR are typically viewed through an individual viewer (headset or mobile device), it is an optimal platform for those forms of tailored experiences, but the medium can also be isolating. Broadly speaking, there are two ways an experience can be personalized: 1) the user chooses what they want to interact with and therefore personalizes their own path and 2) the developer knows who the user is because of tracking and tailors the content of the experience to that particular user. We chose to embrace the first option, feeling that this resonated with the sense of agency and personal choice that the Production Designer and Director hoped to engender in the audience. We also sought ways to balance the personalized, individual experience that's often implicit in AR/VR while still supporting the social experience that's core to theatre, see Section 3.7.3 for further discussion.

[2] Cosplay is defined as the practice of dressing up as a character from a movie, play, book, or video game.

Figure 3.8: Left: One page of the playbill showed the cast thanking the Director, Production Designer, and backstage crew. Center: Another page of the playbill, which shows cast-member and assistant director interviews when scanned. Right: The cover of the program, which had the same design as the advertisement posters. When scanned, both show the Director inviting the viewer to the show.

3.4.6 Privileged Access

There was a strong tension between the audience desire to have access to process and the artist's desire to fill any available space with more art. In contrast with the Production Designer's primary goal of extending the show's narrative, both D1 and D2 felt that the project represented a unique opportunity to provide access to behind-the-scenes information such as interviews with performers and the director. This stemmed from our own experiences as dedicated fans of shows - we have participated in cosplay, created our own fan fiction, and otherwise engaged in various fandoms[3]. The Production Designer initially felt that including "behind the scenes" information was not a novel use of the program. We eventually agreed that dynamically updating the program over time with "the latest" behind-the-scenes shots curated by the performers, including (for example) pictures of the audience from the specific night they attended represented a unique twist on the typical "behind the scenes" documentary: a much more personalized, targeted, and potentially memorable experience.

3.5 Three Prototypes

Using the design guidelines described above, we developed three artifacts: the Augmented Playbill, the Prayer Wheel, and the Tarot Cards. We describe them below, as an annotated portfolio (B. Gaver et al., 2012), focusing on the functionality, aesthetics, practicalities of production, motivation, and audience. We explored each design guideline in different ways in each artifact, and covered the entire design space through the instantiation of the artifacts.

[3] A fandom is a subculture composed of fans characterized by a feeling of empathy and camaraderie with others who share a common interest.

Figure 3.9: Left: The Prayer Wheel being used and experienced by a cast member. Each side displays a scannable image, containing a question prompt. Once scanned, recordings left by other audience members appear as flames situated in the 3D coordinate position around the prayer wheel, mirroring the unique 360° layout of the production. Each flame can be selected, playing the associated recording (shown in yellow). In this image, the flames are added digitally for clarity. Right: Early draft of the Prayer Wheel prototype.

3.5.1 Augmented Playbill

Theatrical productions typically provide an informational booklet known as a 'playbill' to audience members as they enter the theatre. These playbills typically contain information about the production including short blurbs about the performers, a note from the director, dramaturgical information and relevant history behind the production. Our design goes beyond this, adding a layer of technology to provide access to additional content.

Implementation

The Augmented Playbill is a printed booklet that acts as both a traditional playbill, and additionally reveals 3D scenes when scanned by a handheld smartphone. Audience members download and install a free app to their phone to access the extra Augmented Reality functionality. The playbill itself contains instructions for downloading and using the application. The phone application automatically recognizes the image on the page and pulls the video data from a remote database. This video then plays as an overlay on top of the physical playbill. (See Figure 3.7 and Figure 3.8).

Design

Mapping to our design guidelines described above, using a playbill helped us embrace existing norms around the classical theatre experience, since playbills are typically only used before the show, during intermission, and after the show. By embedding the technology experience into the playbill, the **affordances** of this new interaction **resonated** with expected behaviour in theatre. A recurring theme of the show was seeing across layers of reality, so using Augmented Reality to reveal a new "layer" to the familiar playbill was another **resonant affordance**.

The augmented playbill **extended the narrative** of the production by showing scenes that had been cut from the final show enjoyed by the audience, and effects that weren't possible in the show - like snow falling, or characters morphing into animals. We also updated the content of the Augmented Playbill each week by changing the videos that would launch when a certain page of the playbill was scanned. The goal here was to further **extend the narrative**, and provide a potentially surprising moment of **reflective interaction** for those who scanned the program after some weeks had passed. By combining the Augmented Reality technology with the playbill — usually experienced as static memorabilia — the augmented playbill was designed to enhance the experience of the audience member long after the performance ended.

The Production Designer wanted to ensure the audience members developed a sense that the characters lived rich lives and continued to evolve even after the show ended, which required finding the right balance of details to **selectively reveal** through the playbill. For example, although some details of the background of a certain main character were known to the Director, we did not include those in the playbill. Maintaining some mystery was key to a rich experience.

Being theatre fans ourselves, we know how much the audience appreciates having access to behind-the-scenes information. We incorporated some interviews with cast members, recordings of rehearsals, and speeches from the Director into the playbill. This **privileged access** to behind-the-scenes information is what most audience members expect from extra content. We additionally wanted to include more personalized content, including pictures of the audience (taken from back-stage, or on-stage) on the specific night each person attended, or a curated message from the cast on each given night. Our system did not support sending personalized messages like this, but we hope a future version of the project can support these more targeted and potentially more memorable experiences.

3.5.2 Prayer Wheel

This prototype was meant to emphasize **reflective interaction** with the story, the characters, and the creation of the play. Using motifs from the play we built a model of a Tibetan Prayer Wheel. Prayer wheels are meant to be spun as part of a meditation and prayer practice in the Tibetan culture that was depicted in the show. It was displayed in the lobby and rolled into the main theatre area during intermission (see Figure 3.9).

Implementation

The Prayer Wheel prototype is composed of a physical prayer wheel and an accompanying augmented reality application. The prayer wheel was built out of laser cut wood, a bicycle wheel, and paper. Before and after each performance we installed the Prayer Wheel in the lobby of the theater.

The prayer wheel has six sides with one question written on each side. The questions on the prayer wheel were carefully selected to both guide audience members to reflect about their own life as well as on their experience watching the play. This represents a **reflective interaction**. Both Developers generated a set of six questions in collaboration with the Production Designer, including questions such as "Is your best day ahead of you or behind you?", "What will you remember about this production tomorrow? In a year?" and "What's the best thing that happened to you today?". The questions were closely tied to the themes of the play.

To trigger the AR experience, audience members first spin the wheel, scan a question with the tablet device, and record or listen to an audio message responding to that question. Audio messages appear in the AR scene as virtual candle flames. Once a question is scanned, the flames appear in the 3D coordinate position that the audience member is standing at in relation to the prayer wheel. The end result is that after scanning a question, the audience member is surrounded by the thoughts and reflections of other audience members or performers (see Figure 3.9 for details). Spinning the prayer wheel happens in 'public' - visible to everyone in the lobby.

Design

Because part of the production takes place in Tibet, having a prayer-wheel in the lobby shows *aesthetic harmony* (Gonzalez et al., 2012) with the overall production and helps to set the scene for the audience members. The prayer wheel was placed in the lobby to signal that interaction is appropriate, since using it won't interrupt the show, a **resonant affordance**. Additionally, the fire icons that appeared in a 360 degree layout around an audience member mirrored the unique layout of the production, and reiterated that the production existed in 360 degree space around the audience. All of these represent the **resonant affordances** of the prayer wheel.

In addition to the audience, the Director and performers also responded to the questions on the prayer wheel. Their recordings were then made available to the audience members, played over the tablet's speakers. This provided audience members **privileged access** to **reflections** from the actors on both their own personal lives, as well as their experiences playing their scripted character.

3.5.3 Tarot Cards

Each tarot card depicts a character from the play, printed on high-quality cardstock. The same way that audience members might keep memorabilia of events they attend such as a ticket stub, a poster, or a flyer, we gave audience members a physical item that they could take home. Each card also launched an AR scene when scanned with our app. The AR scene displayed the life of the characters before and after the duration of the play.

Implementation

The Tarot cards were printed on high-quality, cardstock paper. The cards were accompanied by an AR application built in Unity that would play a unique 3D animation upon scanning a card. After many thorough readings of the script, conversations with the actors about their characters and with the play's designer, we generated scenes that the character might have lived in before and after those already in the script, such as a dream-like scene where one character called Caiyun is crying in the snow. We captured the data for these animations during rehearsal. First we took 3D body scans of each actor wearing their character's costume using the iOS app itSeez3D. Then we cleaned up each mesh using Meshlab by first removing any garbage points from the point cloud, then adding a sampling filter (Poisson-disk Sampling). Next, we computed normals for point sets, and finally ran a surface reconstruction filter. Next, we added animations to the fixed mesh using Adobe's Mixamo.

Lastly, we designed and modeled scenes and animations for each character using Unity. We built a custom Unity app using our own code wrapper on top of ARKit and ARCore. This allowed the software to run on any AR-enabled iOS or Android device. Each character had its own Tarot card that served as an image marker that would launch a particular scene when scanned.

Design

Each tarot card launched a window into unseen moments with the characters outside the timeline of the play. This supports our design principle of **extended narrative** by giving each character a deeper story beyond what was shown in the show. Later, the physical card would not only remind audience members of the performance itself, the scenes would also act as a continuation of the character. The scenes that were launched from the Tarot cards could be changed over time, showing more details of the characters. We were careful to **selectively reveal** "just enough" information about the characters' backstory, choosing to let audience members' imaginations fill in many details. For example, we did not include any dialogue in the AR scenes so that most of what the characters were actually thinking or saying was still left to the imagination of the audience members.

Many actors chose to the Tarot card that represented the character they had played home as a souvenir, because this represented their own **personalized experience** of the show.

Figure 3.10: Left: Four of our Tarot Card designs. Each card has details and imagery that depict that character's trajectory throughout the play. Right: The animation scene that plays after scanning the "The Giver" Tarot card, shown in Unity.

3.6 Evaluation

In our ongoing post-production correspondence, all collaborators have discussed what was successful and what wasn't. Both the Director and the Production Designer highly valued the Augmented Playbill and the Prayer Wheel over the Tarot Cards. The Director described the Prayer Wheel as "extremely effective, being an object that reflected on the contents of the play itself, while utilizing the spiritual aspects of the play to bring the audience into a separate but related experience". He also instructed his production company to incorporate the Augmented Playbill into the professional production that was staged in Shanghai. The Production Designer found the Prayer Wheel "extremely meaningful and appropriate...simple and effective and well-executed". She felt the Augmented Playbill "represented a powerful use of [AR], one that was exciting to me, in that it worked with the audience to create the poetic furthering of the themes of the piece". All of us agreed the Tarot cards were the least successful, perhaps because they are the least familiar in the theatre context.

Theatre has existed as unmediated live performance for thousands of years. Of course, there is "technology" in theatre but it is integrated into the show, and doesn't mediate the experience for audience members. Developing a rich shared philosophy about the purpose of theatre, technology, and our personal purpose behind combining the two led us to the design of three artifacts whose affordances resonate with theatre itself, but have technology embedded within them and which can then extend and enhance the overall theatrical experience rather than change it.

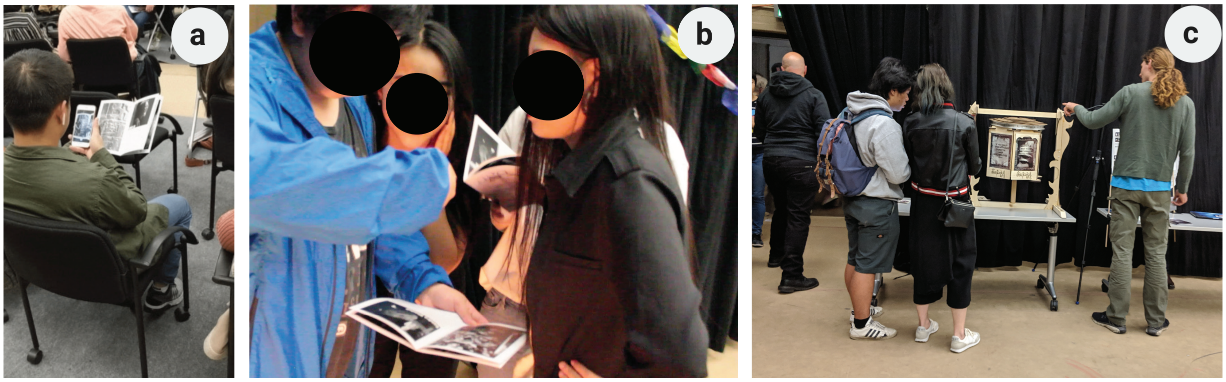


Figure 3.11: (Left) While we observed prototypical program usage (individual, prior to the show or during intermission), we also (Center) observed social behavior where attendees would gather in groups to explore the program and (Right) prayer wheel together.

3.7 Discussion

Although this work discusses, explores, and expands the role of technology in theatrical productions, we see these insights and principles guiding the design of experiences beyond the stage.

3.7.1 Applications Beyond Theatre

Outside of traditional theatre shows, we see opportunities to expand the design of personalized, reflective, tangible technological artifacts in many other contexts. For example, during special theatrical events (a special page in the playbill that is only "unlocked" if an audience member attends a staged reading); a backstage tour (uploading a photograph with a cast member taken at the stage door within the augmented playbill itself for a highly personalized memento); improving the experience of waiting in line for an amusement park ride (a 'passport' that interacts with exhibits as people wait in line, or a premium feature that automatically displays the photographs taken on each ride); in other forms of entertainment (augmenting the ticket stub from a sports game); or book readings (recording a message from the author directly onto the cover of a book rather than getting their signature). Many of these ideas relate to and extend Benford & Giannachi's concept of the 'trajectory' (Benford and Giannachi, 2012).

3.7.2 Implications for Creative Collaborations

While each step in our collaborative process was fruitful, productive, satisfying, and built rapport and trust even if it didn't directly affect the final design outcome, by far the most impactful was the shared experience of the high fidelity "artifacts", especially the *Unreal Garden*. While a serendipitous finding, and not something we expected to explore, this aspect of our collaboration contributes to the broader discussions within HCI about the roles of high- and low-fidelity prototypes and cross-discipline collaboration. Low-fidelity prototyping is a well-validated and valuable method for quickly and inexpensively gathering a great deal of information, frequently used to validate designs and and generate insight (Sauer et al., 2009; Muller, 1991; Wulff et al., 1990; Coyette et al., 2007; Virzi et al., 1996; McCurdy et al., 2006; Claes et al., 2017). Compare the prototypes we described in Section 3.3.4, which score low on all of McCurdy's dimensions of fidelity (McCurdy et al., 2006), with the *Unreal Garden*, which is a fully-realized, paid experience, but is also an extremely high-fidelity prototype[4] that scores high on all five dimensions. For the Production Designer, a highly accomplished costume designer accustomed to working with extremely aesthetically polished projects, the low level of visual refinement (McCurdy et al., 2006) may have played a particularly large role in her negative experience. In our ongoing discussions, she said that she was unable to separate the "content of the demos from the affordances of the technology".

While more work is needed to fully explore this, we speculate that when collaborating with stakeholders that are 1) from disciplines that value highly polished or refined visual aesthetics (costume designers, luthiers, etc) and 2) have less familiarity with the proposed technology in use, a mixed-fidelity prototype that scores high on visual refinement, richness of interactivity, and breadth of functionality (McCurdy et al., 2006) may be the best way to introduce new, unfamiliar technology. But the specific implementation may also matter - the similarity with the final potential use-case. In her own words:

> **Production Designer:** The Unreal Garden worked better [than the lo-fi demos], not because the use of the technology was more effective. What worked, what really worked, was having the chance to see the piece with you [D1] and with [D2].

In other words, we agree that it wasn't simply the high level of visual refinement of the *Unreal Garden*, nor the richness of the interaction (e.g., the fact that the installations there made use of the gesture interaction on the Hololens) – if that were the case, trying *any* polished application on the Hololens would have prompted this form of deeper discussion. Instead, we speculate that it was the "theatre-like" aspects – the **resonant affordances** – of the Unreal Garden (arriving at a venue, entering into a special location, the shared experience) that allowed us to reach a much richer place of mutual understanding. This may also be related to the context in which a prototype is evaluated (Salovaara et al., 2017). Ultimately this represents one collaboration in a specific context, and more research is needed to identify best practices for cross-disciplinary collaboration, especially in a theatrical and performance-related context.

[4] According to the developers, who we met at the venue and engaged in an interesting "behind the scenes" discussion.

3.7.3 Social Experiences in AR/VR

While in-person AR/VR experiences can isolate participants from their local environment due to the affordances of the current – mostly head-worn – technology, one of the ways this isolation has been mitigated for mobile AR is through tangible interfaces (Claudino Daffara et al., 2020), a known technique to aid in collaboration and cooperation between participants (Klemmer, Hartmann, et al., 2006). Both the Augmented Playbill and the Prayer Wheel took advantage of this, and we observed social behavior where attendees would gather in groups to experience the content in both artifacts together (see Figure 3.11). Especially in the case of the Prayer Wheel, which is physically large, and highly visible, particularly lends itself to interaction by multiple people.

The time outside the dimmed lights of the theatre is more overtly and explicitly social than inside the venue when the house lights are down. The rush of emotions as an audience member emerges into the world again and becomes no longer part of an audience but a person separately living their lives is an underexplored opportunity for compelling, enriching technologically-mediated experiences, which we sought to enrich with our prototypes.

3.8 Limitations and Future Work

For the purposes of this initial collaboration, we focused on the co-design process rather than the audience experience. Our plans for future work include building the Prayer Wheel's *reflective interaction* into the playbill, and allowing audience members to record and listen to messages in the privacy of their own home. However, that introduces concerns about audience members recording vulgar or inappropriate messages such as advertisements or personal attacks. Like Cerratto-Pargman et al. (2014), we'd need to add a moderator to manage the input. Our Prayer Wheel design instead had people record their messages "in the open" rather than creating a private sound booth because we hoped that the environmental context of the theatre would strike a balance between socially appropriate behaviour, while still allowing vulnerability in the expression of inner thoughts (However, Helen Freshwater discusses the way these kinds of social affordances inherently limit audience choice in "interactive experiences" (Freshwater, 2011)). The playbill also introduced changing content, but didn't clearly signal those changes to audience members - finding playful ways to indicate that the stories are evolving would be an interesting next step.

Ultimately our design seeks to expand notions of authorship beyond the Director or Playwright. However, not all authors appreciate or value this form of engagement with their characters and stories. Enabling forms of authorship and engagement by fans may not be appropriate or welcome in all productions, but in cases where authors seek to encourage this form of engagement, we hope these guidelines can shape compelling experiences.

The Production Designer describes her vision for future work: "To me, the next question to address, for scholars, is to investigate the ways that [a] new tool influences the piece — possibly by influencing the question that's asked, possibly by influencing the path of

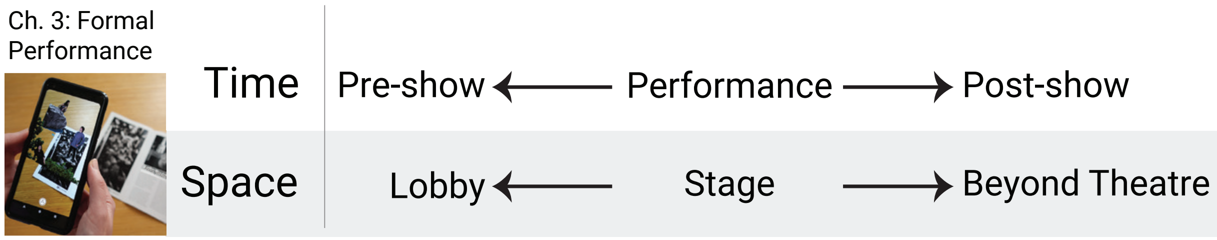


Figure 3.12: This chapter identified design opportunities for expanding the notions of time and space in the context of a formal production.

exploration, possibly both. (In costume design an example would be using material to express the content of the piece, then seeing what's revealed, how the costume influences and *augments* the piece's exploration of its question)". In other words, giving designers new tools during the design process and exploring how their process and output evolves would be a fascinating next step.

3.9 Summary

This chapter explores possibilities for incorporating technology into a formal, staged, theater production. In collaboration with theatre professionals, we developed three prototypes that demonstrate how technology — in this case, AR — can expand the experience of attending a theater performance while still resonating with existing theatrical affordances. Throughout the rehearsal and co-design process we developed six design guidelines that can be further explored when combining emerging technologies with theater.

Most importantly, this chapter identified the benefits of expanding the design space around incorporating technology into performance. Seeking to design experiences that resonate with existing theatrical affordances, and avoiding the urge the "disrupt" or "awaken" the **role** of the audience lead to the expanded notions of **time** and **space** that make up the Dramaturgical Framework for Interactive Performance. The design guidelines of "extended narrative" and "reflective interaction" both relate to these expanded notions of **time** from the Dramaturgical Framework for Interactive Performance.

Additionally I identified the importance of refined visual *aesthetics*, especially for high-fidelity prototypes used during the pre-production stage. I also shared some initial observations around opportunities for designing more social Augmented Reality and Virtual Reality experiences.

I hope this chapter can help future designers and practitioners motivate their own projects incorporating technology into and around theatrical productions, including production support, rehearsal support, and experiences for audiences that extend beyond the stage (see Figure 3.3).

Chapter 4

Informal Performance

"All the world's a stage,
And all the men and women merely players"

— William Shakespeare *1623*
from As You Like It. Act 2, Scene 7
spoken by Jaques

Scholars have applied both Goffman and McLuhan to the analysis of social media as a site for performance. Goffman is used to analyze how we prepare content 'backstage' before posting it 'onstage' (De Kosnik et al., 2019). Where Goffman is often used to discuss identity formation (De Kosnik et al., 2019; Donath et al., 2004; H. Liu, 2007), McLuhan "calls for more attention to be paid to performances by collectives" (De Kosnik et al., 2019), and what happens when "everyone [is] a creator" (McLuhan, 1974). De Kosnik et al. (2019) emphasizes the McLuhanesque way in which social media emphasizes the 'ground' (the collection of "thousands of people's experiences of, and perspectives on" an event) rather than any particular 'figures' ("individual people or isolated occurrences"). Abercrombie and Longhurst also discuss the way ubiquitous computer-mediated communication has transformed everyone into both a performer and audience all the time (Abercrombie et al., 1998). Together, these aspects of social media have expanded the world of informal performance to inconceivably broad levels: more 'performers' have more access to more 'audience members' than ever before in human history. If everyone participating in social media is playing both performer and audience roles all the time, how might the notion of the active audience shape the design of a computational system? How might we ensure that "spectatorship is not a passivity" (Rancière, 2021)?

This chapter explores the notion of the **role** of an active audience in a different context: social media, which I recast as a type of informal performance. While in Chapter 3 I argued that there is no need to provide formal performance audiences with tools to "activate" them or "prompt engagement" during the show, because audience members are already active. In this chapter, I describe a system where we again embrace the idea of "active observers", and

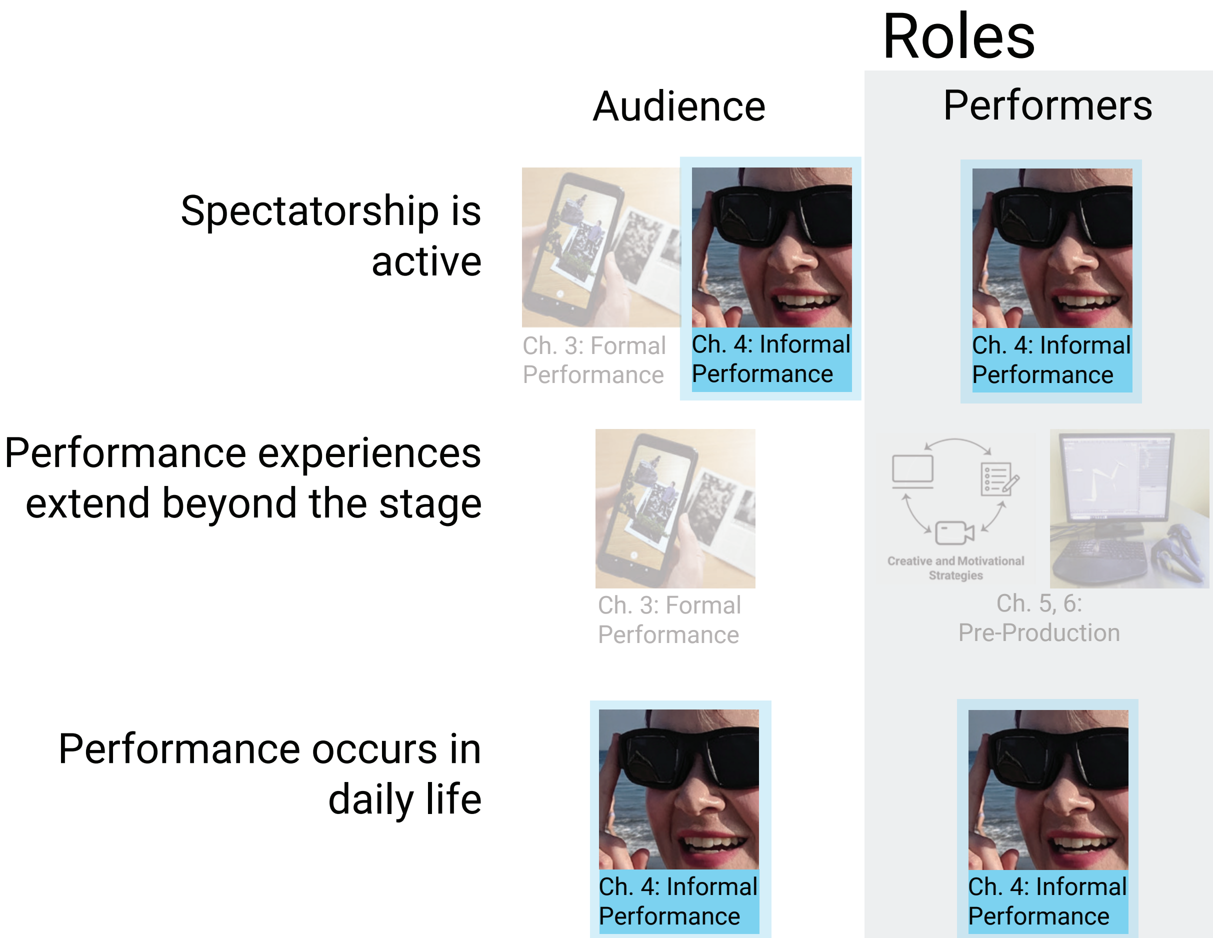


Figure 4.1: In this chapter, I recast social media as a site for performance, and describe the way considering the roles of both the performer and the audience represents two design guidelines.

do provide a system that allows and supports active interaction.

As part of this exploration, I introduce Friendscope, an experience sharing system for camera glasses that allows both the camera wearer and their remotely connected friend to have similar levels of control over a shared camera. Friendscope enables instant sharing of videos and photos from the wearable camera interface, and supports quick responses immediately viewable on the wearable camera interface. This balances the importance of liveness and immediacy for even an informal performance on social media with current hardware constraints that limit the ability of most smart glasses to stream constantly. Friendscope explores a concept called a *shared camera*. While not new – TeleActor was a Multiple Operator Single Robot system that allowed a a group of online users to view and vote on the movements of a single mobile camera (K. Goldberg et al., 2002) – this concept allows a wearer to share control of their camera with a remote friend, making it possible for both people to

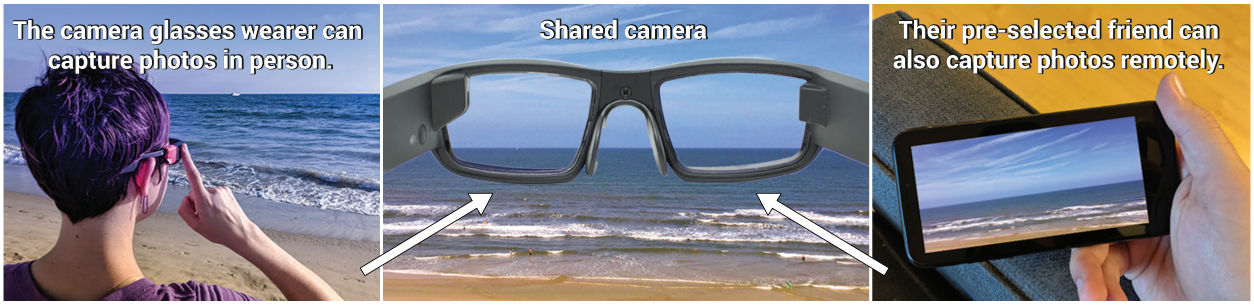


Figure 4.2: Overview. Friendscope's key innovation is its *shared camera*, which enables wearers to share control of their camera directly with a pre-selected friend so that both of them can capture photos/videos. The friend is therefore able to receive photos/videos on demand, anytime, as if they are viewing the experience live.

capture photos/videos from the camera in the moment. These features of Friendscope allow us to investigate the sensitizing concepts of *liveness* and *agency*.

In addition, by analyzing social media — especially on a wearable platform such as camera glasses — as a form of informal performance, I again expand the **space** context to include "wherever people wear camera glasses" (which, as others have shown, is extensive (Bipat et al., 2019)). One element I keep consistent in this exploration is **time** - Friendscope seeks to maintain the sense of 'liveness'. I embrace Couldry's (2004) definition, which emphasizes the shared social reality between participants who are experiencing an event in real-time, and especially the way "liveness guarantees a potential connection to shared social realities as they are happening". Our experience-sharing system, Friendscope, emphasizes liveness through the shared camera.

Through a user study with 48 participants, I found that users felt connected to each other, describing the shared camera as a more intimate form of livestreaming. Moreover, even privacy-sensitive users were able to retain their sense of privacy and control with the shared camera. Friendscope's different shared camera configurations give wearers ultimate control over who they share the camera with and what photos/videos they share. I conclude with design implications for future experience sharing systems.

4.1 Introduction

With their light weight, first-person perspective and hands-free form factor, camera glasses have the potential to become a valuable platform for real-time experience sharing. As defined by Bipat et al. (Bipat et al., 2019), camera glasses are glasses with image or video capture functionality only, without the full set of hardware that smartglasses have. Snap Spectacles (Snap, Inc., 2018), OhO Waterproof Video Sunglasses (OhO sunshine, 2018), and Kestrel Pro (Zetronix Corporation, 2019) are some examples of camera glasses. They look and cost similarly to sunglasses (see Figure 4.3), and they are one-tenth the weight of full-fledged smartglasses such as Microsoft HoloLens (Microsoft, 2021) and Magic Leap One (Magic Leap, Inc, 2018).

In their recent investigation of camera glasses usage, Bipat et al. (2019) found that camera glasses wearers ("Wearers") use camera glasses for outdoor experiences such as hiking, skiing, and traveling. Notably, Wearers expressed a strong desire to share these experiences with remote family and friends (their "Friend"), so that they can "see what [the Wearer] is seeing and feeling" and it can be "like they went on the trip with [the Wearer]" (Bipat et al., 2019). Currently, however, camera glasses primarily support a delayed form of sharing: the Wearer can only share their experience *much later* rather than *in the moment*, and the Friend must simply wait for the Wearer to share highlights from their excursion later. The Wearer needs to (1) record videos, (2) wirelessly transfer them to their phone later, and then (3) send the videos from their phone to the Friend (Snap, Inc., 2021; Snap, Inc., 2018; Constine, 2018). As a result, both the Wearer's and Friend's sense of togetherness suffers.

In this chapter, I introduce *Friendscope*, a system for probing how in-the-moment experience sharing on camera glasses might work. Through Friendscope, I explore how the concept of a *shared camera*, impacts a sense of *agency* for the remote viewer, and how such a system can be designed to support *liveness* (see Figure 4.2). This *shared camera* concept allows the Wearer to share control of their camera directly with a remote Friend. By doing so, Friendscope makes two things possible: the Wearer can capture photos/videos and send them to the Friend instantly, *and* the Friend can capture photos/videos themselves and receive them instantly, on demand, as if they are viewing the experience in the moment. As a result, both the Wearer's and Friend's sense of togetherness can improve.

Friendscope consists of three components that, in tandem, allow the Wearer and their remote Friend to feel connected through the shared camera. Two components are for the Wearer, and one is for their Friend:

- *Camera glasses app (Wearer)*: Allows the Wearer to (a) send photos/videos to their Friend, and (b) receive *trigger requests* (requests to capture photos/videos) from their Friend. The interface does not require a screen, and displays trigger requests using a flashing mock LED. The screenless design minimizes power consumption and makes the app compatible with camera glasses, which do not have screens.

- *Companion smartphone app (Wearer)*: Allows the Wearer to manage the shared camera configuration. Three sharing modes are available: (i) Auto Approve, which automatically approves trigger requests to send photos/videos unless the Wearer declines them; (ii) Manual Approve, where the Wearer must manually approve trigger requests in order to send photos/videos; and (iii) Shared Camera Off, which disables trigger requests entirely.

- *Messaging app (Friend)*: Allows the Friend to send trigger requests to the shared camera and view photos/videos returned from it. Friendscope is compatible with any text messaging app. For this chapter, we created our own messaging app.

Figure 4.3: Examples of camera glasses, Friendscope's target devices. Bipat et al. (Bipat et al., 2019) defined these as lightweight, screenless sunglasses with a very limited set of hardware, typically including a camera, microphone button, and LEDs. These devices are very different from smartglasses, which are more feature-rich and often heavier. Top left: Spectacles (Snap, Inc., 2018). Top right: Kestral Pro (Zetronix Corporation, 2019). Bottom left: zShades (Zetronix Corporation, 2017). Bottom right: OhO Waterproof Video Sunglasses (OhO sunshine, 2018).

With Friendscope, we wanted to understand how different shared camera configurations — Auto Approve, Manual Approve, and Shared Camera Off — lead to different types of experiences for users in terms of fellowship, privacy, and sense of control. Shared Camera Off represents our baseline condition, where there is no shared camera at all and only the Wearer can initiate sending photos/videos. This baseline enables us to study the affordances and behaviors that the shared camera and trigger requests bring.

In our main user study with 48 participants, both Wearers and Friends emphasized the sense of being directly connected to each other — in the moment — when the shared camera was enabled (Auto Approve or Manual Approve modes), and described Friendscope as a more intimate form of livestreaming.

Between the three shared camera configurations, Wearers preferred Manual Approve mode the most because it struck the right balance between giving them a sense of fellowship with their Friend and maintaining their own sense of control and privacy over the camera. Because Manual Approve mode provides this balance, participants felt less concerned about privacy violations compared to Auto Approve. Notably, even participants who self-rated as being "highly concerned" with privacy preferred using Friendscope in its Manual Approve mode over Shared Camera Off, the baseline condition representing not having a shared camera at all.

In summary, our main contributions are to enable in-the-moment experience sharing on camera glasses, and to understand the affordances created by different shared camera configurations.

4.2 Related Work

With Friendscope, we explore a new approach to experience sharing which makes in-the-moment experience sharing possible on camera glasses (Figure 4.3). Here we summarize how experience sharing currently works on camera glasses, as well as how it works on larger devices such as smartglasses and head-mounted displays.

4.2.1 Experience Sharing on Camera Glasses

Camera glasses are a new category of wearable device that look, cost, and weigh similarly to sunglasses (See Figure 4.3). Their light weight and similarity to sunglasses is precisely why users like them for outdoor activities, "mundane" activities with friends, and while traveling (Bipat et al., 2019). Consumer product reviews are very positive for glasses with this type of slim form factor (Carman, 2019; Chokkattu, 2019). Nearly all of the top uses for camera glasses involve capturing outdoor activities, where network bandwidth is often poor (Bipat et al., 2019). The success of "action cams" such as GoPro (GoPro Inc., 2019; Chalfen, 2014), even in spite of their bulky form factors, suggests further that consumers want to share experiences in places with less-than-ideal network bandwidth.

A major limitation of current commercial camera glasses is that they do not support any form of real-time communication. They do not allow a group of people to feel like they are experiencing an event together in the moment. Most of today's consumer camera glasses (including zShades (Zetronix Corporation, 2017), Kestrel Pro (Zetronix Corporation, 2019), and Spectacles (Snap, Inc., 2018)) employ asynchronous sharing to compensate for their constrained hardware, meaning that users share their experiences *later* rather than in the moment. This is because asynchronous sharing is "camera glasses-friendly": it works with camera glasses' form factor and does not require high network connectivity to transmit content well. However, researchers who study live performances have shown that experiences that are shared in the moment increase the sense of connection between participants compared to ones shared later (Webb et al., 2016; Couldry, 2004).

Haimson et al. (2017) offer an in-depth analysis of what live events on social media platforms must offer in order to be engaging. They show that, to be engaging, live events must offer immediacy (in-the-moment sharing), immersion (first-person perspective), interaction (bi-directional communication), and sociality (fellowship between friends). Camera glasses currently offer immersion and sociality but are missing immediacy and interaction due to their lack of real-time communication between the wearer and their friends. Friendscope addresses these needs by making experience sharing in the moment rather than later and by adding interactivity via the shared camera.

We do not mean to argue that real-time features such as livestreaming or video chatting are impossible to implement on camera glasses. Such features could be implemented, but their technical requirements already strain the hardware of even larger glasses such as a Google Glass and would thus be highly impractical for camera glasses. LiKamWa et al. (2014) showed that Google Glass can stream video for at most 45 minutes before running out of battery and that doing so will heat the unit by 28° C, risking injury to the wearer. As a result, our work does not explore obvious techniques such as livestreaming to make experience sharing possible on camera glasses. Rather, we explored a new approach — the concept of a shared camera — to make in-the-moment experience sharing possible on camera glasses.

4.2.2 Experience Sharing on Smartglasses and Head-Mounted Displays

In contrast to camera glasses, which are "camera-only" sunglasses with a very limited set of hardware, we use the term smartglasses to refer to more feature-rich and often heavier devices with screens, speakers, and full onboard CPUs. These include Google Glass (Google LLC, 2014), Vuzix Blade (Vuzix Corporation, 2019; Vuzix Corporation, 2020), Nreal Light (Hangzhou Tairuo Technology Co., Ltd., 2020), as well as commercial head-mounted displays such as Microsoft HoloLens (Microsoft, 2021), Oculus Quest (Facebook Technologies, LLC., 2021), and many research prototypes (Chua et al., 2017; Y. Hashimoto et al., 2011; Inkpen et al., 2013; Kasahara and Rekimoto, 2015; Kasahara, Ando, et al., 2016; Matsuda et al., 2018; Neustaedter et al., 2020; Pan et al., 2017; Procyk et al., 2014; Billinghurst et al., 2014; Ishak et al., 2016).

Most of these devices rely on livestreamed video to enable in-the-moment experience sharing. This is true for both commercial devices and recent research prototypes. The research community has explored many new forms of livestreamed video for experience sharing (Billinghurst et al., 2014), including 360 degree video (Kasahara and Rekimoto, 2015), blended views (Y. Hashimoto et al., 2011; Pan et al., 2017), and parallel view sharing (Kasahara, Ando, et al., 2016; Pan et al., 2017; Procyk et al., 2014). But these efforts all employ livestreamed video and require larger devices.

Moreover, researchers have shown that livestreaming approaches do not work well even on high-end devices: they are too hardware-intensive to last long on them. For example, Hashimoto et al. (D. A. Hashimoto et al., 2016) and Paro et al. (Paro et al., 2015) found, in separate studies, that surgeons rated Google Glass's (Google LLC, 2014) streaming video quality as poor and inferior to GoPro (Paro et al., 2015) and iPhone 5 (D. A. Hashimoto et al., 2016), even with their lab environment's high network bandwidth. In addition, LiKamWa et al. (2014) showed that streaming video on Google Glass heats the device by a potentially dangerous 28° C and makes the battery last for at most 45 minutes. Both they and Paro et al. (2015) conclude that Google Glass is only suitable for notifications and quick snapshots, but not for streaming video.

The main distinction between our work and this existing body of work in experience sharing is that we explore how in-the-moment experience sharing might work on camera glasses. As a result, we propose a very different approach from livestreamed video. In our concept of a shared camera, viewers get continuous access to the Wearer's camera rather than a continuous stream. Our approach is consistent with Neustadter et al's recent findings (Neustaedter et al., 2020) that viewers value the mere ability to see someone else's experience – the *access* to the experience – and prefer not to watch the entire thing.

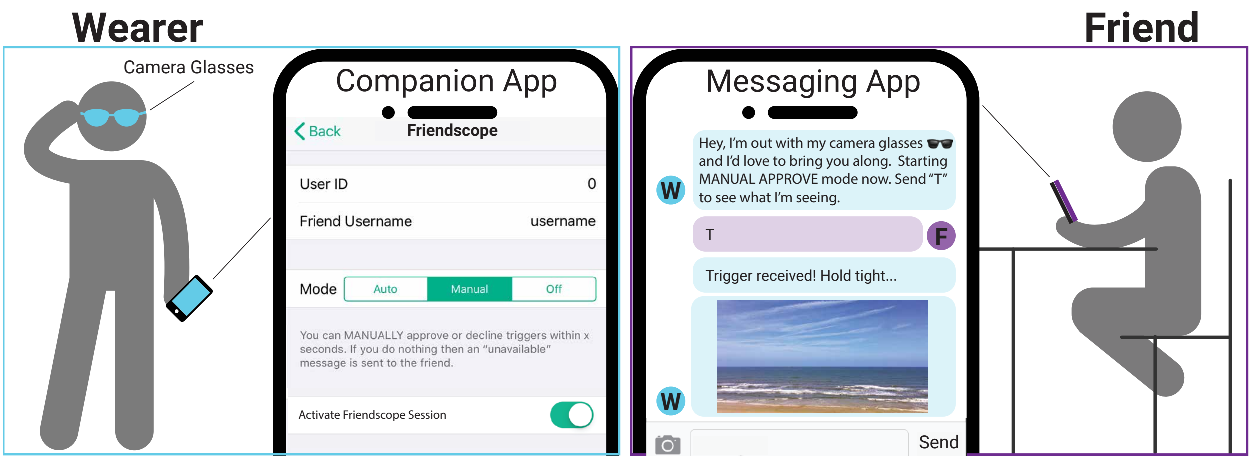


Figure 4.4: Friendscope system overview. (Left) The Wearer wears camera glasses and carries an iPhone running the companion app. The companion app allows the user to choose a friend to share with; switch between Auto Approve, Manual Approve, and Shared Camera Off sharing modes; and start/end a Friendscope session. (Right) The remote Friend uses the messaging app to receive photos/videos and to send trigger requests and "thumbs up/down" messages.

4.2.3 Experience Sharing on Other Devices

Conventional videoconferencing systems such as Skype (Microsoft Corporation, 2020), FaceTime (Apple Inc., 2019), and Zoom (Zoom Video Communications, Inc., 2020) facilitate co-presence through "talking heads"-style (Nardi, Schwarz, et al., 1993) face-to-face communication on mobile, tablet, or laptop devices. Several other systems incorporate wearable cameras and neck- (Matsuda et al., 2018), arm- (Procyk et al., 2014; Neustaedter et al., 2020), shoulder- (Kimber et al., 2014), or bicycle-mounted (Chua et al., 2017; Neustaedter et al., 2020) smartphones to facilitate experience sharing. Experiences2Go (Inkpen et al., 2013) consists of a camcorder and large tablet computer mounted on a tripod. Previous work explores *proxies* or *surrogates* (Ishak et al., 2016; Paulos and Canny, 1998; Misawa et al., 2015; Mitchell et al., 2011), but such surrogate interfaces represent a single-sided approach that provides access to a particular event, compared with our more personalized, bidirectional, experience sharing goals. Our approach is consistent with Neustadter et al.'s recent findings (2020) that viewers value the mere ability to see someone else's experience and prefer not to watch the entire thing.

4.3 Friendscope

Friendscope is an in-the-moment experience sharing system for camera glasses. It employs a novel concept that we call a *shared camera*, which allows the Wearer to share control of their camera with their Friend. With the shared camera, the Wearer can capture *and* send photos/videos to their Friend with a single click, while the Friend can capture *and* receive photos/videos themselves by sending *trigger requests*. Both the Wearer and the Friend can capture photos/videos using the shared camera, and the Friend receives the photos/videos either way. The Friend is able to "join" the Wearer's experience by having continuous access to the shared camera.

When the Friend sends a trigger request, an LED on the inside of the Wearer's camera glasses (which faces the Wearer) flashes green for 10 seconds until it times out. This lets the Wearer know that the Friend would like to receive a photo or video. The Wearer can then approve or decline the trigger request during that period, giving them ultimate control over what is shared. If the Wearer declines a trigger request or the request times out, the Friend receives a message saying the Wearer was unavailable. In both cases, the message is sent at the ten-second timeout moment, affording the Wearer "plausible deniability" (Nardi, Whittaker, et al., 2000) that they did not explicitly decline the request. The trigger requests allow Friends to get a photo or video back and see what the Wearer is up to. The Friend can also send the Wearer "thumbs up" and "thumbs down" feedback messages.

We designed Friendscope around the very basic set of hardware components that camera glasses typically have — a camera, a microphone, a button, and an inward-facing LED — so that it can be applied to a wide range of lightweight, hardware-limited camera glasses and wearable camera interfaces. Our Friendscope implementation has three components: a camera glasses app and a companion smartphone app for the Wearer, and a smartphone messaging app for the Friend. We describe these in detail in the rest of this section.

4.3.1 Wearer Side: Companion Smartphone App

As with most consumer camera glasses (Snap, Inc., 2018; Zetronix Corporation, 2017; Zetronix Corporation, 2019), Friendscope's settings are controlled by a companion app on the Wearer's smartphone, in our case an iOS app. The app is depicted on the left side of Figure 4.4. It allows the Wearer to start and end Friendscope sessions and to switch between sharing modes based on their current scenario or comfort level.

Friendscope sessions

Camera glasses wearers typically use their glasses in *sessions* while they are performing an activity (Bipat et al., 2019), so we designed Friendscope to be session-based. Using the companion app, the Wearer can start and end Friendscope sessions and specify who to include as their Friend. Pre-selecting the Friend before starting the session makes Friendscope nearly hands-free for the Wearer and gives them complete control over who has access to the shared camera.

When the Wearer starts a session, their Friend receives the following invitation message as shown at the top-right of Figure 4.4: *"Hey, I'm out with my camera glasses, and I'd love to bring you along. Send 'T' to trigger a photo or video of what I'm seeing right now."* The

Friend also receives a message when the Wearer ends a session or changes mode. Together, these messages let the Friend know about the Wearer's availability and whether it is a good time for the Friend to send a trigger request. While a session is active, the Wearer can spontaneously initiate and send photos/videos to show the Friend what they are up to. The Wearer can send photos/videos whenever they want and do not need to receive a trigger request first.

Sharing modes

Friendscope's shared camera lets Friends "join" the Wearer's experience, but it can also affect the Wearer's sense of privacy and control over what is captured. As a result, we implemented three *sharing modes* (shared camera configurations) within Friendscope to allow the Wearer to control what happens when the Friend triggers the shared camera. These modes give the Wearer more agency and allow us to study how Wearers manage the tradeoff between having complete control over their camera and giving their Friend easy access to it. The three configurations are:

- `SHARED CAMERA OFF MODE`: This mode disables the shared camera and the Friend's ability to send trigger requests. Shared Camera Off represents our baseline condition where there is no shared camera at all. That is, Friends cannot send trigger requests in this condition, and the Wearer must initiate all photos/videos. Of Friendscope's three sharing modes, this mode gives Wearers the most control but gives the Friend the least amount of access to the Wearer's experience.

- `AUTO APPROVE MODE`: This mode automatically approves trigger requests when they time out, sending the Friend a ten-second video. Since this mode is hands-free, we had to choose either photos or videos to be automatically sent. During our pilot study with 22 participants, we found that Friends preferred videos to be sent as the default in this mode. Before timeout, the Wearer can either decline the trigger request or fulfill the trigger request "early" by capturing a photo/video. This mode allows the Wearer to fulfill trigger requests hands-free but gives them the least amount of control compared to the other modes. The Friend, on the other hand, gets direct access to the Wearer's experience with this mode.

- `MANUAL APPROVE MODE`: This mode declines all trigger requests that time out, requiring the Wearer to manually "approve" requests. This mode strikes a balance between giving Wearers control and giving Friends access to the Wearer's experience.

Auto Approve and Manual Approve modes behave identically while a trigger request is pending; the only difference between them is what happens when the request times out after 10 seconds. The Wearer can decline trigger requests in both of these modes. In that case, for the Friend it will appear as if the trigger requests timed out.

During a session, the Wearer can switch between modes at any time and initiate photos/videos themselves in any mode. Switching modes triggers a message to the Friend, informing them of the new mode, since this may influence the Friend's behavior and expectations.

4.3.2 Wearer Side: Camera Glasses App

The camera glasses app allows the Wearer to capture photos and videos. It also mediates trigger requests from the Friend. Captured videos (with audio) are ten seconds long to match the functionality of Spectacles (Bipat et al., 2019).

Due to lack of a public API for current camera glasses (Snap, Inc., 2018; Zetronix Corporation, 2017; Zetronix Corporation, 2019), we prototyped Friendscope using a Unity (Unity Technologies, 2018) app that runs on Vuzix Blade (Vuzix Corporation, 2019) smartglasses. We chose Vuzix over other Unity-compatible products such as HoloLens (Microsoft, 2021) because the Vuzix are relatively lightweight and are the closest approximation of minimal camera glass interfaces.

Ideally, we would have tested the value of the shared camera by implementing Friendscope on current commercial camera glasses hardware such as Snapchat Spectacles or zShades rather than the Vuzix Blade. However, existing screenless commercial camera glasses lack public APIs. In spite of that, we mimicked these camera glasses' functionality on the Vuzix Blade hardware and to foster realistic scenarios and usage behaviors in our studies: our pilot studies, main study, and field exploration with 82 participants in total. Recall that camera glasses feature only a camera, a microphone, a button, and an inward-facing LED. Vuzix Blade smartglasses, by contrast, have many more hardware features. As a result, we explicitly disregarded much of the Vuzix Blade's hardware to simulate camera glasses. We repurposed its screen to represent a single mock LED (see third column of Figure 4.5), and we repurposed its touchpad to represent a simple button.

Input actions

The Wearer can perform three actions on their camera glasses: send a photo (on their own or while responding to a trigger request), send a ten-second video (on their own or while responding to a trigger request), and decline a trigger request. In general, the camera glasses need only a single button for the Wearer to perform these actions since they can be mapped to different gestures. Our prototype's Vuzix Blade camera glasses feature a touchpad on their right side, so we mapped the actions to the following gestures: a "press" to send photo, a "press and hold" to send video, and a "swipe back" to decline a trigger request (see Figure 4.5). Explicitly declining a trigger request sends an "unavailable" message to the Friend after 10 seconds as if the trigger request had timed out.

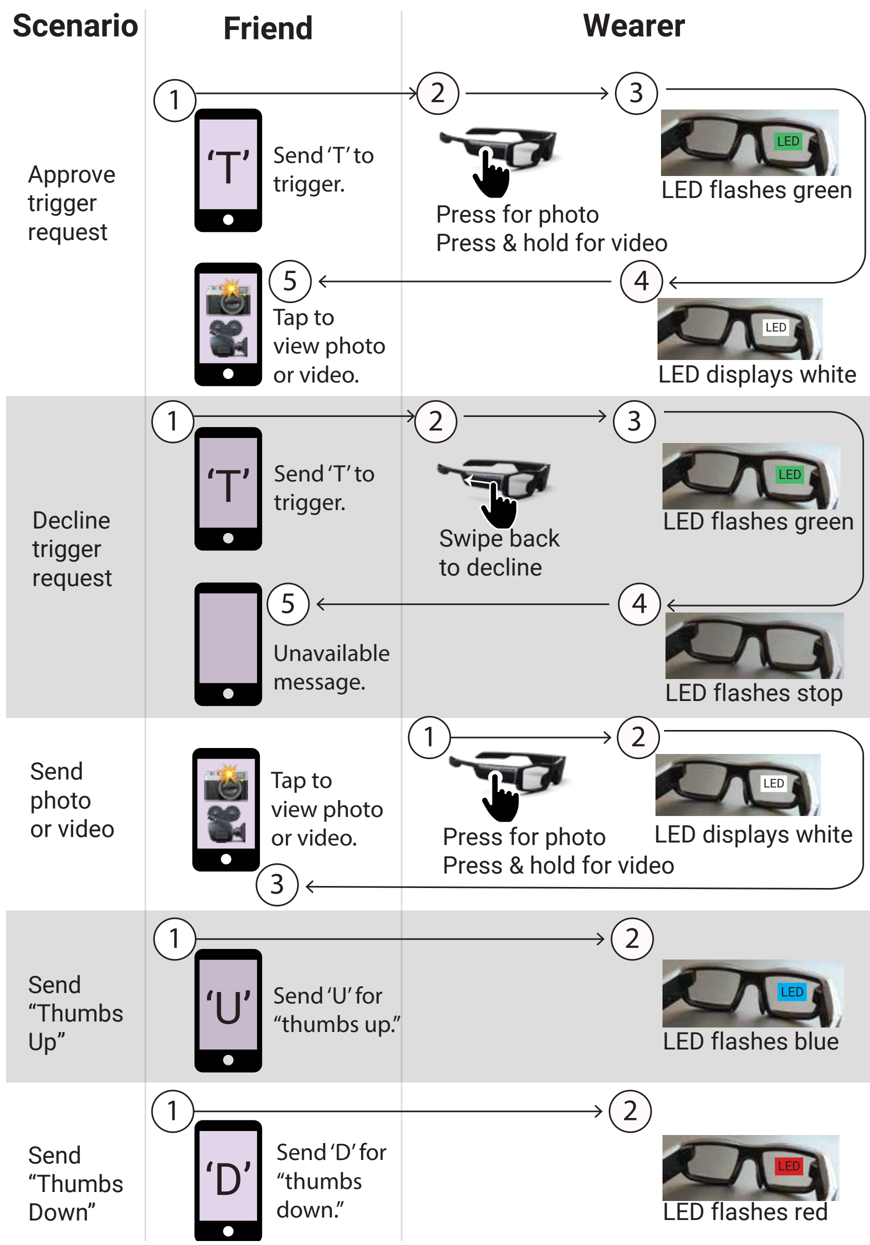


Figure 4.5: Interaction flow between Wearer and Friend. This sequence diagram shows the input gestures, LED signals, and messaging codes that Friendscope uses. The Wearer can approve trigger requests and initiate photos/videos themselves using the same gesture. The Wearer's inward-facing LED flashes green, blue, or red to represent the Friend's trigger requests ('T'), "thumbs up" messages ('U'), and "thumbs down" messages ('D'), respectively.

Fast fulfillment of trigger requests

Since fulfilling the Friend's trigger requests quickly can make Friends feel more tightly connected to the Wearer's experience, Friendscope actively creates opportunities for fulfilling trigger requests immediately. To do this, Friendscope holds all photos/videos initiated by the Wearer for 10 seconds before delivering them to the Friend. If the Friend sends a trigger request during this holding period, Friendscope sends the held photo/video immediately to create an instant response to that trigger request.

Under perfect network conditions, a naively-designed trigger request could take up to 25 seconds for a video to return (= 10 s "trigger request pending" state + 10 s to record + 5 s to transmit) and 12 seconds for a photo to return (= 10 s "trigger request pending" state + 1 s to capture + 1 s to transmit). Using the rapid fulfillment technique described above, Friendscope narrows this gap to only 5 seconds for a video and 1 second for a photo, keeping just the time needed to transmit the video or photo.

Screenless LED interface

To keep power costs low and make Friendscope applicable to as many types of camera glasses as possible, Friendscope's camera glasses app is screenless and uses a single LED as its display to the Wearer. As a result, we opted not to fully utilize the Vuzix Blade's built-in screen for our Friendscope implementation. Instead, as Figure 4.5 shows, we display just a colored area on the Vuzix Blade's screen to represent a "mock" inward-facing LED. This "LED" is usually off but turns on to communicate the following:

- It flashes green for ten seconds when a trigger request is received and is awaiting action.
- It displays white while a photo is taken or a ten-second video is recording.
- It flashes white when a photo or video is successfully sent.
- It flashes blue to show a Friend's "thumbs up" message.
- It flashes red to show a Friend's "thumbs down" message.

4.3.3 Friend Side: Messaging App

We created a basic text messaging app for our Friendscope implementation to demonstrate how Friendscope would work within a standard messaging app. The reason is that evidence suggests that Friendscope will work best for Friends if it is compatible with existing messaging apps and embedded within them rather than being a separate smartphone app. Most in-the-moment photo/video sharing today happens on instant messaging apps such as iMessage, WhatsApp (WhatsApp, Inc., 2021), Facebook Messenger (Facebook, 2021), and Snapchat (Snap, Inc., 2011), where people send and receive photos/videos seamlessly and spontaneously as part of their normal communication with each other (Alhabash et al., 2017). These apps allow users to interact asynchronously and do not require them to coordinate with each other or be online at the same time. They also notify recipients whenever photos/videos are sent so that they can go online and join the conversation if they are not online already.

The Friend can send trigger requests by texting the Wearer a "T" in the messaging app, as shown in the right side of Figures 4.4 and 4.5. After sending the "T," they will get an automatic *"Trigger received!"* confirmation message. If the trigger request is approved, the Friend receives a series of messages to keep them updated about the status of their request, starting with a message saying, *"Trigger approved! Hold tight for a [photo/video]!"*, followed by *"Video/photo is being transmitted!"* then the countdown (*"5. . . "*, *"4. . . "*, etc.), and finally the photo or video.

If the trigger request is declined or times out after 10 seconds, they will get a message saying that the Wearer was unavailable. The message comes after 10 seconds in either situation, in order to afford plausible deniability (Nardi, Whittaker, et al., 2000). Friends also get a notification message when the "sharing mode" is changed by the Wearer. For example, changing the mode to Auto Approve would display the following message to the Friend: *"Starting AUTO APPROVE mode now! Send 'T' to trigger a photo/video of what I'm seeing right now."* Likewise, changing the mode to Shared Camera Off would display: *"Starting SHARED CAMERA OFF mode now. Pausing trigger requests for a bit, but I'll keep sending you photos/videos whenever possible."*

During our pilot study with 22 participants, Friends requested additional ways to interact with Wearers. (Wearers can already communicate to their Friend by simply speaking while capturing a video.) As a result, we made it possible for Friends to send "thumbs up" and "thumbs down" messages to Wearers by texting a "U" or a "D" (respectively) in the messaging app. These will flash the Wearer's LED blue or red, respectively. F. Liu et al. (2019) and Kaye et al. (2005) show that even extremely limited communication channels can be popular and can fulfill users' need for connection with friends.

4.4 Evaluation

Friendscope's key design contribution is its shared camera, which enables in-the-moment experience sharing on camera glasses. With Friendscope, we wanted to understand how different shared camera configurations — Auto Approve, Manual Approve, and Shared Camera Off — lead to different types of experiences for users in terms of *fellowship* between users, *privacy* for the Wearer, and *sense of control* for both Wearer and Friend. We also studied how Friendscope's screenless design impacted users' experience. Shared Camera Off represents our baseline condition, with no shared camera at all (no trigger requests — only the Wearer can initiate photos/videos). This baseline allows us to understand the affordances and behaviors that the shared camera and trigger requests bring.

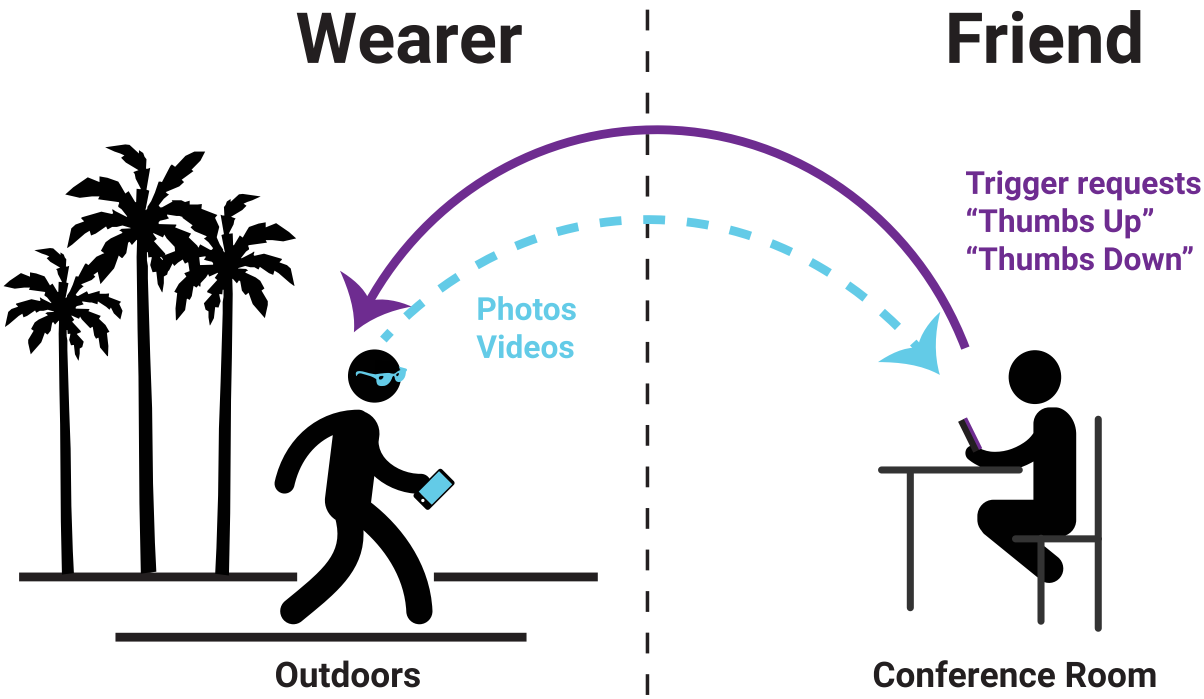


Figure 4.6: User study scenario. The Wearer visited an outdoor area while the Friend stayed behind in a conference room. We ran the study in three tourist locations: Venice Beach in Los Angeles, Pike Place Market in Seattle, and Times Square in New York. Each Wearer/Friend pair went through Friendscope's three sharing modes (Auto Approve, Manual Approve, and Shared Camera Off) and answered surveys about their experiences with them.

4.4.1 Participants

Our main user study had 24 pairs of participants (48 participants total: 22 female and 26 male), but we ran pilot studies with 11 additional pairs of participants (22 participants total) first as part of our iterative design process. We recruited all 70 of our participants from a technology company using their employee mailing list. We recruited from ten diverse teams within the company, representing a wide variety of technical and non-technical roles including HR and sales/marketing. We recruited from three company offices: New York, Los Angeles, and Seattle. We asked people to participate in the study with their closest friend within the company.

In our main study, eight participants self-reported as having extensive experience with wearable camera interfaces such as GoPro (GoPro Inc., 2019), Google Glass (Google LLC, 2014), or Spectacles (Snap, Inc., 2018) [1]. Participants' ages ranged from 18 to 44: 13 aged 18–24, 25 aged 25–34, and 10 aged 35–44.

[1]Cost as of 2022: GoPro Hero10 Black - $499 (Axon, 2021), Google Glass - Price on request only (Google LLC, 2014), Spectacles 3 - $380 (Snap, Inc., 2022)

4.4.2 Study Procedure

Our study used a within-subjects design in which each pair of participants experienced all three modes of Friendscope together. Within each pair, we randomly assigned a Wearer and a Friend unless one of the participants required glasses. Since our Vuzix Blade glasses did not have prescription lenses, we assigned participants who needed prescription lenses to be the Friend.

We were careful to choose a realistic scenario during our main study. We took the Wearer to a popular tourist destination nearby to explore it freely as a tourist would and had the Friend stay behind in a conference room to interact with the Wearer through trigger requests and thumbs up/down messages. The popular destinations were Times Square, Venice Beach, and Pike Place Market for New York, Los Angeles, and Seattle participants, respectively. Participants were given the chance to practice using Friendscope before splitting up. Figure 4.6 illustrates our study design.

Each participant pair tried Friendscope's three shared camera configurations (*Shared Camera Off*, *Auto Approve*, and *Manual Approve*) in a counterbalanced order, where Shared Camera Off represents our baseline condition. They tried each sharing mode for 10 to 15 minutes. After trying each mode, we asked each pair to complete a questionnaire about their experience with that mode (see below for questionnaire details). Once they had tried all sharing modes, we reunited the participants and asked them to complete a final survey comparing the three modes. The sharing mode was our independent variable, and the user responses, including ratings of fellowship, control, and privacy are our dependent variables. We concluded by performing a semi-structured interview with each pair to gather their final thoughts and takeaways. As we describe in Section 4.4.4, questions in the interview probed their prior experience with live-streaming, asked them to compare and contrast the modes, and unearthed details about the screenless experience.

In summary, each main study participant completed five questionnaires during the main study in addition to the semi-structured interview at the very end. The five questionnaires were the pre-study questionnaire, one questionnaire for each of Friendscope's three sharing modes (right after they tried out that mode), and one final questionnaire. Each main study session took 2 hours and 15 minutes in total.

4.4.3 Survey Design

The pre-study questionnaire collected simple demographic information, including age and gender as well as prior experience with camera glasses and smartglasses (including Google Glass (Google LLC, 2014), Spectacles (Constine, 2018), etc.). We also collected self-reports of levels of privacy concern, using relevant questions from the "Global Information Privacy Concern" portion of the IUIPC privacy questionnaire (Malhotra et al., 2004). We used the single-item, pictorial Inclusion of the Other in the Self scale to assess interpersonal closeness in both the pre- and post-study questionnaires (Aron et al., 1992).

We constructed the three sharing mode questionnaires in three primary steps. First, we held a team-wide brainstorming session with all authors of this chapter to discuss the potential costs, benefits, and societal ramifications of shared cameras. This discussion brought forward several topics such as closeness between friends, togetherness, enjoyment, privacy, sense of control, control over access, social concerns, and others.

Second, we drafted a survey and conducted a set of pilot studies, in which we had participants use Friendscope outdoors for a short period of time and then complete a questionnaire asking about their impressions with respect to the positive and negative impacts that we identified. Participants' responses to many of these questions were similar, indicating that our initial set of possible impacts of shared cameras could be merged into a smaller set of broader themes. Based on the findings from our pilot studies, we arrived at three broad themes that would form the structure of our survey — fellowship, sense of control, and privacy.

Third, for each theme, we crafted parallel questions for Wearers and Friends addressing each aspect of using Friendscope. For example, to understand how the camera modes affected fellowship: *"I felt closer to my friend by giving them the ability to trigger my camera"* (for the Wearer) and *"I felt closer to my friend because I had the ability to trigger their camera"* (for the Friend). To probe our system's effect on participants' sense of control, we asked these two questions in addition to others: *"I felt that I always knew when Snaps were being taken"* (Wearer) and *"I felt as if I took the Snaps that I received"* (Friend). To address the theme of privacy, a subset of our questions includes: *"I was never worried about sharing something I didn't want to"* (Wearer) and *"I never felt that I was invading the privacy of my friend"* (Friend).

We asked these type of questions for each sharing mode (Manual, Auto, Off). The surveys featured both open-ended responses and 7-point Likert scale ratings, where '1' indicated Strongly Disagree and '7' indicated Strongly Agree. This enabled us to understand the experience for both sets of users (Wearer and Friend) across all sharing modes in detail. The final questionnaire asked participants to rank each mode in terms of overall preference (see Figure 4.7), fellowship (see Section 4.5.2), privacy (see Section 4.5.4), and feeling of control (see Section 4.5.3). We additionally used the NASA TLX (Hart, 2006; Hart and Staveland, 1988) to ask about cognitive load and mental effort while using the system.

4.4.4 Semi-Structured Interview

At the end of every study session, after each participant had completed their final questionnaire, we engaged each pair of participants in a semi-structured interview to further elicit details about the experience. The topics we discussed in the interviews included concepts related to Fellowship (including social presence, connectedness, interaction, immersion, and closeness), Privacy (intrusiveness, vulnerability), and Control (access, risk). Here we share a subset of our interview guide which included the following questions, following best practices for conducting semi-structured interviews (Weiss, 1995; Suchman and Jordan, 1990; Charmaz, 2006): *"Can you describe the experience of letting your camera be shared?"*, *"What were* *your main concerns when using this system?"*, *"Can you go into detail about how you felt when receiving / sending a trigger?"*, *"Compare and contrast the different modes (why did you choose this ranking?)"*, *"What did receiving/sending a trigger mean to you — how did you interpret that?"*, *"Can you talk about any concerns you had about seeing or sharing something you didn't want to?"*, *"How did the lack of ability to preview affect your experience?"*. We also asked participants to directly compare 1:1 messaging, group sharing, livestreaming, and Friendscope.

Following best practices for Charmaz's grounded theory (Charmaz, 2006), we simultaneously engaged in analysis and data collection, iteratively constructing our analytic frame and updating our question prompts for future interviews as we synthesized and identified emerging themes. We read and analyzed all interview data and discussed all emerging themes (McDonald et al., 2019), which are presented below.

4.5 Study Results

Our study data includes survey responses, usage logs, and qualitative feedback through our open-ended survey questions and semi-structured interviews. We analyzed quantitative survey responses using non-parametric Friedman tests[2] with an alpha level of 0.05. Additionally, our post-hoc tests used Wilcox tests with Holm-Bonferroni method for correcting multiple comparisons (all reported p-values are adjusted).

For our thematic analysis process, we first transcribed each semi-structured interview, then performed open-coding (Strauss et al., 1990) on the transcripts. Following best practices for grounded theory (Charmaz, 2006), we simultaneously engaged in analysis and data collection, iteratively constructing our analytic frame and updating our question prompts for future interviews as we synthesized and identified emerging themes. We iteratively reviewed and refined these into a closed set of codes, which we then re-applied to the transcripts as we performed additional interviews. Since the inception of grounded theory, it has split into three main branches: Strauss and Corbin, Glaser, and Charmaz (Sato, 2019). We embrace Charmaz's constructionist research style that understands knowledge as co-constructed between interviewee and researcher (Charmaz and Belgrave, 2007; Charmaz, 2006). Our analysis is interpretivist, seeking to understand how our informants create meaning in their experiences (Gligor et al., 2016), and is rooted in the social construction of knowledge and polysemic understandings of truth (Kvale, 1995). Since we followed a grounded theory approach, it was not appropriate or necessary to compute inter-rater reliability (McDonald et al., 2019).

Here we report our findings about how different shared camera configurations — Auto Approve, Manual Approve, and Shared Camera Off — lead to different types of experiences

[2]While opinions on the importance of normality vary dramatically, and statisticians continue to debate appropriate techniques (Knief et al., 2021), in this work we follow standard statistical analysis best practices. Specifically, we employ non-parametric statistical tests since the Shapiro-Wilk test showed that our data violated the Assumption of Normality.

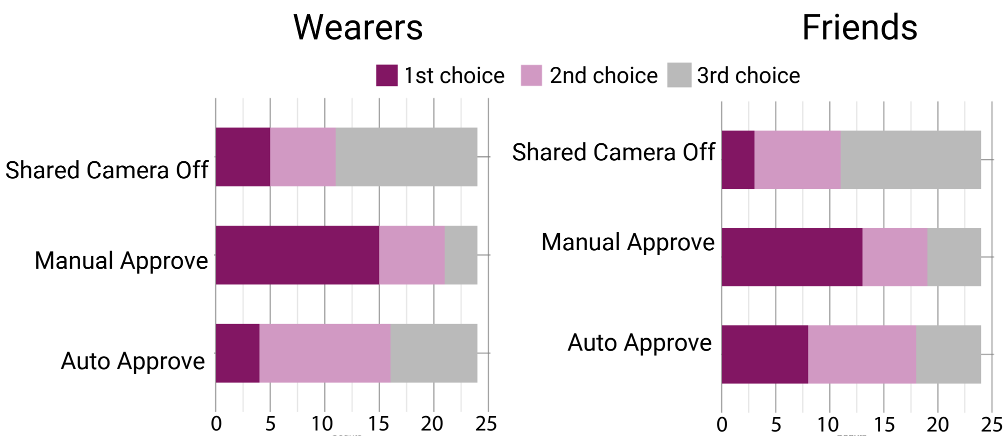


Figure 4.7: Sharing mode preference rankings. Overall, Wearers (Left) and Friends (Right) both preferred Manual Approve mode. This preference was statistically significant for Wearers ($p < 0.01$).

for users in terms of *fellowship* between users, *privacy* for the Wearer, and *sense of control* for both Wearer and Friend. We split our discussion into each of these topics, and further split it between Wearers' and Friends' perspectives.

4.5.1 General Findings

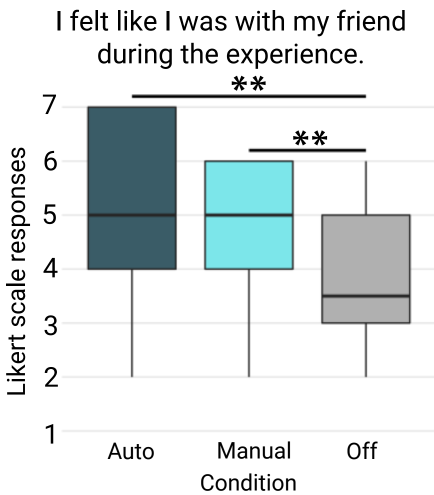
Wearers sent a total of 864 messages during the study: 389 photos and 414 videos. Remote Friends sent 631 messages: 242 trigger requests, 263 thumbs up messages, and 126 thumbs down messages.

Towards the end of the study, we asked participants to share their overall feedback. Both Wearers (*Md=6.5*) and Friends (*Md=6*) rated Friendscope as being fun to use on a 7-point Likert scale. Wearers rated it as requiring low mental effort (*Md=2*). When asked whether they felt Friendscope would add value to existing camera glasses products, both Wearers (*Md=7*) and Friends (*Md=6*) rated the system very highly.

We also asked participants to rank Friendscope's three shared camera configurations by order of preference. As shown in Figure 4.7, Wearers and Friends both preferred Manual Approve mode the most, possibly because this mode strikes a balance between giving Wearers control and giving Friends a feeling of liveness. This preference was statistically significant for Wearers ($\chi^2(2, 24) = 10.75, p < 0.01$).

4.5.2 Findings: Fellowship

Here we report our findings related to fellowship: how different shared camera configurations give users a sense of being together with each other.



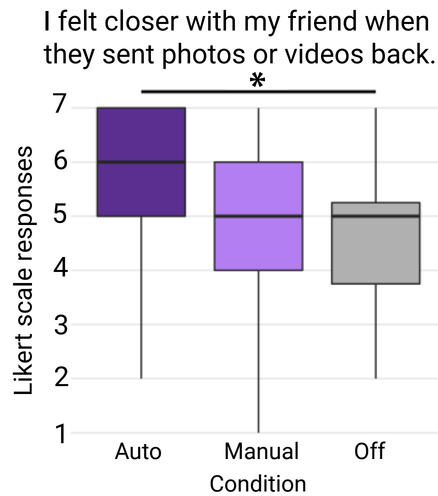


Figure 4.8: Fellowship ratings. (a) Wearers rated both Auto Approve and Manual Approve sharing modes as fostering a significantly higher ($p < 0.001$) feeling of togetherness than Shared Camera Off. (b) Friends rated Auto Approve significantly better than Shared Camera Off at making them feel closer to the Wearer.

Fellowship for Wearers

As shown in Figure 4.5.1, we found a significant main effect of sharing mode on Wearers' feeling of togetherness: $\chi^2(2, 24) = 11.39, p < 0.001$. Post-hoc analyses revealed that Wearers ranked both Auto Approve (*Md=5*) and Manual Approve (*Md=5*) sharing modes as fostering a significantly higher ($p < 0.01$) feeling of togetherness than Shared Camera Off (*Md=3.5*). Both Manual Approve and Auto Approve allowed Friends to send trigger requests, while Shared Camera Off did not. Trigger requests acted as signals to the Wearer that their Friend was watching live, making them feel more together with each other.

In addition, we found a significant main effect on how close the Wearer felt with their Friend after sending photos/videos in response to trigger requests compared to sending photos/videos on their own: $\chi^2(2, 24) = 13.13, p < 0.01$. Post-hoc analyses revealed that Wearers felt closer to their Friends after sending photos/videos in both Auto Approve (*Md=5*) and Manual Approve (*Md=5*) ($p < 0.01$) modes compared to Shared Camera Off (*Md=4*), with $p < 0.01$. Closeness ratings using the IOS scale (Aron et al., 1992) stayed consistently high for both Wearers and Friends after using our system.

During the semi-structured interview, one third of Wearers confirmed that Friendscope felt "more personal" than other forms of image-based communication such as sending photos over an instant messaging platform. In particular, Wearers emphasized the sense of being directly connected, in the moment, to their friend:

W19: It was nice to get that immediate feedback that someone is paying attention

> to what you're doing. The trigger also let you know when someone was engaged. It was cool to have someone watching what you were creating.

Wearers favorably compared Friendscope to a live video call:

> W22: I felt like I was streaming something to him even though that's not actually what's happening.

Throughout the interviews, Wearers were enthusiastic about the idea that their Friend was "jumping into [their] head" (W11) and actively watching their shared images right at that moment. The idea that someone was paying attention seemed to increase the sense of togetherness and closeness for Wearers. In other words, the "liveness" experienced by both Wearers and Friends was associated with the "sharing event" of the photos or videos (as opposed to the original event). Shared attention has been shown to increase "mood infusion" and emotional experiences (Shteynberg, Hirsh, Apfelbaum, et al., 2014; Shteynberg, Hirsh, Galinsky, et al., 2014; Shteynberg, 2015). Our findings resonate with Haimson and Tang, showing that the immediacy of using Friendscope made for an engaging experience (Haimson et al., 2017).

Fellowship for Friends

As shown in Figure 4.5.1, we found a significant main effect of sharing mode on how close Friends felt with Wearers when receiving photos or videos ($\chi^2(2, 24) = 11.39, p < 0.001$). Further analysis revealed that Friends rated Auto Approve (Md=*6*) significantly better than Shared Camera Off (Md=*5*) at making them feel closer to Wearers. Note that Shared Camera Off represents our baseline condition where there is no shared camera at all and the Wearer must initiate all photos/videos. Being able to trigger the Wearer's camera seems to have made Friends feel closer, with the system described as "a step above existing communication" and "way more personal."

In addition, in our interviews, Friends reported feeling a live connection with the Wearer even though Friendscope itself is asynchronous:

> F16: And since it was live – it wasn't taken a while ago – it was happening right there, it felt connected.

This feeling of liveness made the shared experience more intimate, interactive, and personal for Friends:

> F4: I did like the fact that [my friend] would talk to the camera so it felt very close. I was experiencing it much more than just viewing [it].

Many participants directly compared the experience to live-streaming or watching a video, which they had all experienced:

> F3: [I was] more participating than watching a video.

Several Friends described the shared camera as an embodied experience and felt that they were "sharing [the Wearer's] eyes." Friends also described the experience as a more intimate and personal form of livestreaming. Even those who do not normally watch livestreams found the shared camera appealing:

> F3: Livestreaming is more interesting when it's just for you.

This resonates with earlier work on videos filmed from a first-person view (FPV). Footage from this perspective have been shown to increase the sense of 'seeing with the eyes of another' (Pan et al., 2017; Masai et al., 2016). Our work builds on these findings, emphasizing the unique potential for camera glasses to enable closeness, making them uniquely suited to sharing intimate moments with close friends and family. Friendscope's system design also takes advantage of known benefits of photo- and video-based sharing, which afford greater opportunities for self-expression than text-based systems (Waddell, 2016) and enable more frequent communications with close friends and family (Trieu et al., 2019) (see (Alhabash et al., 2017) for a thorough overview).

A lack of immediacy and intimacy can reduce social presence when people communicate through mediated channels (Gunawardena, 1995; Gunawardena and Zittle, 1997). Promoting social presence should promote feelings of connectedness (IJsselsteijn et al., 2003). The shared camera's focus on immediacy and intimacy enhanced feelings of social presence and connectedness.

4.5.3 Findings: Sense of Control

Here we report our findings on how the shared camera affects Wearers' and Friends' sense of control over what is captured. Figure 4.9 shows our survey results.

Sense of Control for Wearers

As Figure 4.5.2 shows, we found a significant main effect of sharing mode on Wearers' feeling of control over what was captured: $\chi^2(2, 24) = 31.75, p < 0.0001$. Post-hoc analysis revealed a higher feeling of control ($p < 0.05$) in Shared Camera Off mode (*Md=7*) compared Auto Approve mode (*Md=5*). Wearers preferred Manual Approve mode the most:

> W28: I liked Manual Approve mode the most. That was the perfect blend of spontaneity and having me in control.

Sense of Control for Friends

As we expected, Friends ranked both Manual Approve and Auto Approve modes as providing them greater control compared w/ Shared Camera Off, the baseline condition where there

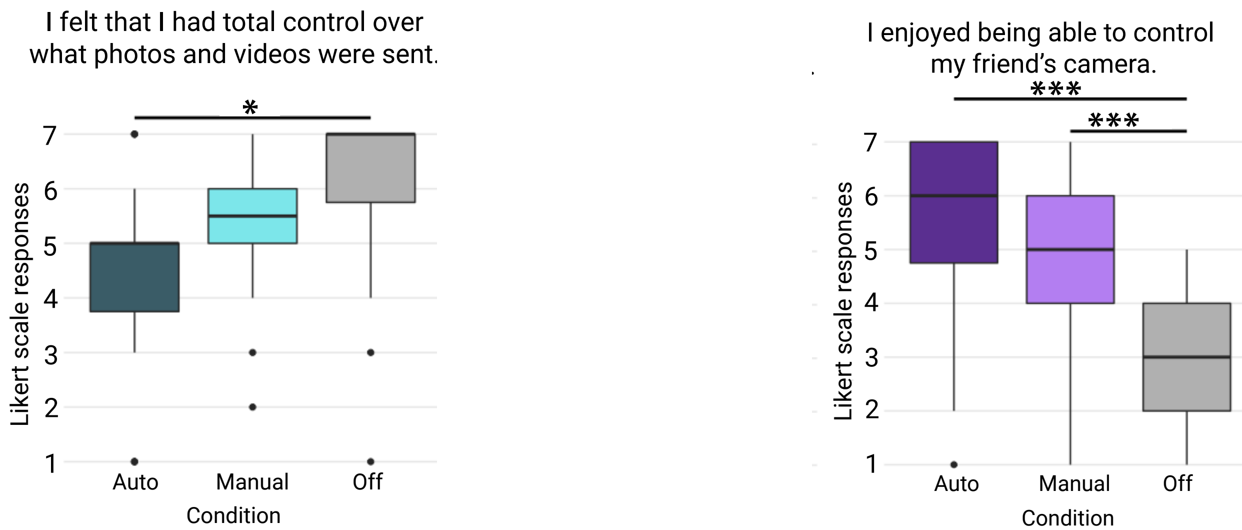


Figure 4.9: Control ratings. (a) For Wearers, post-hoc analysis found a higher feeling of control ($p < 0.05$) in Shared Camera Off mode than in Auto Approve mode. There was no statistically significant difference between Shared Camera Off and Manual Approve modes. (b) Friends felt more able to control the Wearer's camera ($p < 0.01$) in Auto Approve and Manual Approve modes than they did in Shared Camera Off mode.

is no shared camera at all. Friends "felt free to control [the Wearer's] camera" ($p < 0.01$) to a greater extent in Manual Approve (*Md=5*) and Auto Approve (*Md=5*) modes compared with Shared Camera Off mode (*Md=2*). As Figure 4.5.2 shows, Friends enjoyed being able to control the shared camera significantly more ($p < 0.001$) in Manual Approve (*Md=5*) and Auto Approve (*Md=6*) modes as compared with Shared Camera Off mode (*Md=3*). We did not find a significant difference between the extent that friends enjoyed Auto Approve mode and Manual Approve mode.

In addition, the need for a gesture in Manual Approve mode seemed to increase feelings of interactivity, consent, and connection:

> F27: Manual mode felt like it was more interactive. With Shared Camera Off mode she's just shooting things to me. With Manual I felt like it's an actual interaction. The fact that there was a request and an approval element made me feel "Oh! I'm interacting with [my friend]." I'm sending you this, this is what you asked for and I approved: it really creates that connection and interaction.

Friends were sensitive about how frequently they sent trigger requests in Auto Approve mode (*Md=5*), which they described as "spamming" during the interview. They did not want to cause the Wearer to share something they did not want to share. By contrast, Friends felt comfortable triggering the camera as frequently as they wanted to in Manual Approve mode (*Md=6*).

The practice of lifelogging represents an early exploration around the perception of a lack of control and privacy with body-worn cameras. Lifelogging involves a small camera clipped onto clothing or otherwise attached to the body that automatically captures first-person perspective photographs at a predetermined rate throughout the day. Lifelogging is typically automatically triggered, meaning the wearer has even less control than when using Friendscope's shared camera. Researchers found that users prefer to maintain control over what pictures are captured and shared. Kärkkäinen et al. (Kärkkäinen et al., 2010) found that limiting who can see the images and automatically deleting older images both provide this sense of control. The shared camera design that we explore with Friendscope incorporates both of these techniques. Incorporating these has the additional benefits of avoiding known (Koelle, Heuten, et al., 2017) issues with wearable cameras, including self-censoring behaviour by the user.

4.5.4 Findings: Privacy

For the concept of a shared camera to be embraced by users, it must accommodate their privacy preferences. Here we report our findings on what users thought of the different shared camera configurations from a privacy perspective. We report findings from users in general and from those who self-describe as being sensitive to privacy specifically.

As a means of gauging our participants' sensitivity to privacy concerns, we averaged their responses to relevant questions from the "Global Information Privacy Concern" portion of the IUIPC privacy questionnaire (Malhotra et al., 2004) to form a new "privacy awareness metric." We included questions regarding personal beliefs and behaviours around technology, and we omitted questions about unauthorized data usage and other topics not related to shared cameras. By this metric, our participants rated themselves as being moderately concerned with personal privacy on average: 4.7 out of 7.

Privacy for Wearers

We found a significant difference in how Wearers ranked the three sharing modes in terms of respecting privacy: $\chi^2(2, 24) = 24.33, p < 0.00001$. Wearers ranked the modes in the following order from most to least privacy-preserving: Shared Camera Off, Manual Approve, and Auto Approve. We also found that Wearers were significantly less "worried about [accidentally] sharing something they did not want to" ($p < 0.01$) in Shared Camera Off mode (*Md=6*) and Manual Approve mode (*Md=6*) compared to Auto Approve mode (*Md=4.5*). Additionally, Wearers felt equally "in control of [their] privacy" and privacy settings in each mode (Same scores for both questions: Shared Camera Off mode *Md=7*, Manual Approve mode *Md=6*, Auto Approve mode, *Md=5*).

Next, we examine a subset of our users who self-described as being particularly sensitive to personal privacy concerns. We define this subset to be users whose personal privacy awareness metric value (described above) was at least 6 out of 7. Five Wearers and five Friends matched this criteria.

Six of these ten participants ranked Manual Approve mode as their most-preferred mode, which means that even these privacy-sensitive participants preferred to use Friendscope's shared camera instead of turning it off (Shared Camera Off). Only two of these ten participants (one Wearer, and one Friend) preferred Shared Camera Off, and two preferred Auto Approve. Participants' comfort with the shared camera stemmed from them getting to choose who to include in their Friendscope session:

> W8: In general I don't like to share much so all my [social media] is private. But with this I felt more comfortable because it was just an experience I was having with my friend.

Privacy for Friends

By and large, Friends agreed that they "never felt that [they were] invading the [Wearers'] privacy," ranking all three sharing modes relatively highly for protecting Wearers' privacy. The ratings were $Md{=}6$ for Shared Camera Off, $Md{=}5.5$ for Manual Approve, and $Md{=}5$ for Auto Approve modes. These differences were not statistically significant.

4.5.5 Findings: Screenless Experience

Friendscope's screenless design makes it compatible with consumer camera glasses which generally lack screens and speakers. This limits the types of interactions that are possible, including the ability to preview photos/videos before sending, and the ability to see Friends' messages. During our interviews, participants consistently reported their experience with Friendscope's screenless design.We summarize their remarks here.

Screenless Experience for Wearers

The lack of a screen meant that Wearers were not able to see text message responses from their Friends. While Wearers could take the phone out of their pocket to see messages from their Friends, Wearers specifically shared that they preferred to not be "connected to [their] phone the entire time". The lack of a screen also meant that Wearers were not able to preview their photos or videos before sharing them. 18 out of 24 Wearers were comfortable with not being able to preview photos/videos before sending, with six actually preferring not being able to preview. For the 18 Wearers, the lack of a preview helped them stay immersed in their activity and enhanced their feelings of sharing it live:

> W16: No I don't want preview. That spoils my experience of the ongoing activity.

> W4: I really liked not being able to curate [the images]. I really felt like I was sharing them in the moment.

The remaining six Wearers would have preferred having a way to preview and/or edit their photos/videos before sending, the main reason being to annotate them with personal context.

Screenless Experience for Friends

Since Friendscope is screenless, the only way for Wearers to converse with their Friend was to speak while recording videos. Wearers quickly figured this out, and Friends valued these types of videos very highly. During the semi-structured interview, one Friend described watching these videos as “experiencing more than just viewing.” The narrations seemed to increase Friends’ sense of being with the Wearer:

> F4: The way [the Wearer] was using it felt very intimate. I felt like I got to know [her] better.

When Wearers did not narrate their videos, Friends described the videos as “generic,” “random,” or “impersonal.” Friends also found photos less appealing than videos for this reason.

In general, throughout the interviews Friends expressed a strong desire to communicate with Wearers in more ways than what Friendscope provided. Even though Friendscope supported limited feedback via “thumbs up/down” messages, the majority of Friends (18/24) felt that the communication was one-sided. Since Friendscope was designed around a small number of hardware components, Friends could not ask Wearers questions or respond to Wearers as they would be able to if they used a smartphone:

> F25: It felt like she was trying to have a conversation and I was ignoring her.

14 Friends expressed a desire to send emojis or other simple yet expressive messages beyond “thumbs up/down” messages. Several Wearer/Friend pairs reported that they had repurposed the “thumbs up/down” messages to mean other agreed-upon things. For example, one pair reported that the "thumbs up/down" messages were “practically an inside joke already” (F10). This resonates with earlier work by F. Liu et al. (2019) and Kaye et al. (2005), who show that even extremely limited communication channels can be popular and can fulfill users’ need for connection with friends.

4.6 Field Exploration

We conducted a small field exploration in addition to our main study to get a short glimpse of how people would use shared cameras “in the wild.” We report our findings here as basic observations only and not as a complete field study. We loaned camera glasses to six interested users for longer periods of time (from one day up to one week) and allowed them to use Friendscope as they saw fit. These users were from the same technology company as our previous study. They acted as Wearers and chose a Friend, resulting in six pairs of users (12 field exploration participants total).

Five of these users were female, 3 were male, and 2 preferred not to respond. Seven were aged 25–34, one was aged 35–44, and four preferred not to respond. As with the main study, these users represented a wide variety of roles within the company, including many non-technical roles. We gave these participants the same onboarding procedure as in the main study, but we encouraged them to use Friendscope whenever and however they wanted, including changing the sharing mode (shared camera configuration) as they saw fit. We performed a semi-structured interview with each pair collectively after they finished trying out Friendscope.

Wearers used Friendscope in many contexts: both indoors and outdoors, for both daily life and special events, and both in and out of coordination with their respective Friends. We describe some of the use cases and users' resulting experiences here.

One pair of participants borrowed the glasses for a day. The Wearer wore the glasses during a children's baseball game while his Friend stayed at his office. The Friend enjoyed the immediate sharing, saying that it greatly increased his sense of being with the Wearer:

> F1: I loved using the trigger function to feel like I was live participating...It made me feel like I was living the experience with him.

This pair had such a positive experience that they asked to borrow the glasses every week afterward. Their experiences echo that of our main study participants, who also found that Friendscope makes them feel together with each other in the moment.

Another Wearer used the glasses to share a personal celebration at home with her Friend. She emphasized that the immediacy of the connection increased her sense of being with her Friend:

> W3: It was really cool because when I was sharing that with her, she immediately responded...I really felt like she was there even though she wasn't.

The Friend emphasized the special experience of having a trigger request approved:

> F3: It was like I was being allowed into her world. Her saying yes to [my trigger] request is like opening a treasure box.

Another pair typically works together in the same office, but the Friend was working remotely when the Wearer borrowed the glasses. Both Wearer and Friend spent several hours going about their normal activities while using Friendscope. They always used Auto Approve mode. The Wearer interpreted trigger requests as confirmations that her Friend saw her message at that moment, finding that feedback helpful and not requiring "thumbs up/down" messages from the Friend.

Table 4.1: Summary of our study findings and design recommendations for experience sharing systems.

Theme	Study Findings	Recommendations
Fellowship	Users emphasized the sense of being directly connected — live — to each other when using Friendscope and described it as a more intimate form of livestreaming.	While *continuous streaming* is a popular approach for sharing live experiences, consider supporting *continuous access* instead or in addition. The mere feeling of having access can promote the feeling of closeness.
	Lightweight signals such as "trigger requests" signaled to both Wearers and Friends that their partners were connected "live."	Even very minimal interaction techniques can provide feelings of immediacy and intimacy in experience sharing systems. Consider incorporating "trigger requests" and other forms of lightweight signals in addition to standard message types such as text and voice notes.
Privacy	1:1 sharing enhanced participants' comfort with the shared camera.	To mitigate privacy concerns, consider allowing users to choose small, private groups to share content with.
	Manually approving trigger requests assuaged Wearers' concerns about sending content accidentally.	Designing interactivity into a system can help communicate users' intent. Consider enabling explicit actions to signal explicit consent.
Control	Both Friends and Wearers preferred Wearers to have complete control over what was shared.	Consider using multiple, complementary techniques to give Wearers control — from allowing them to invite selected friends only, to switch sharing modes anytime, and to reject or approve each trigger request.
Screenlessness	Many participants preferred the spontaneity of having no screen.	Consider embracing screenlessness. Not having a preview can support spontaneous, low-stakes communication by preventing users from polishing their output.
	Friends who wished the system had a screen wanted to use it for mostly low-fidelity responses.	Bidirectional interaction between friends is important, but consider keeping things simple even if the form factor allows higher fidelity. For instance, emojis or icons may be sufficient or preferred over text or photo responses for many.

4.7 Discussion and Limitations

Our results show how different shared camera configurations — Auto Approve, Manual Approve, and Shared Camera Off — lead to different experiences and affordances for users in terms of fellowship, privacy, and sense of control. We summarize our results and present our design recommendations for future experience sharing systems in Table 4.1. In this section, we discuss these recommendations, Friendscope's privacy implications, and our study's limitations.

4.7.1 Continuous access supports in-the-moment experience sharing

Experience sharing systems have traditionally relied on continuous streaming to create a feeling of liveness for remote viewers, but with some major trade-offs. Continuous streaming is too hardware-intensive to last long on consumer camera glasses, and it requires a consistently high network bandwidth for acceptable video quality.

Our findings suggest that the concept of a shared camera makes it possible to avoid these limitations. By providing continuous *access* rather than continuous streaming, the concept of a shared camera enables users to share experiences in the moment using camera glasses. Users emphasized the sense of being directly connected — live — to each other when using Friendscope and described it as a more intimate form of livestreaming. Trigger requests signaled to both Wearers and Friends that their partners were connected "live." Even users who do not normally watch livestreams found Friendscope appealing.

In traditional livestreaming, the streamer initiates the session and streams their experiences continuously, involving them and their viewers throughout the session. Friendscope's shared camera design, by comparison, gives both parties more agency and flexibility. It allows the Wearer to share their highlights whenever they want rather than continuously, and it allows the Friend to learn about the Wearers' state and send trigger requests whenever they want to see what the Wearer is up to.

Building on this, future livestreaming systems can also incorporate the concept of continuous access in addition to (or instead of) continuous viewing. They might, for example, allow the streamer to "mark" or "highlight" interesting moments as they are happening, then notify friends who are not yet watching about those opportunities to tune in. Those friends, in turn, could send trigger requests to catch up on those interesting moments — in the moment — without having to follow the entire livestreaming session. Future continuous access-based systems can also allow the Wearer to add their status with the session invite to indicate what they are up to, i.e., their state, or prompt the Wearer to capture photos/videos at regular intervals to keep the Friend abreast of what they are doing throughout the session.

These findings reinforce Neustaedter et al.'s recent finding (Neustaedter et al., 2020) that it is "the *ability* to see [a friend's video] rather than the *act* of seeing [the video constantly] that ma[kes] video a powerful connector." The concept of continuous access is generalizable and can be applied to existing or new systems regardless of hardware or software limitations. We hope that Table 4.1 acts as a catalyst for researchers and designers to explore the design space enabled by the concept of shared cameras further.

4.7.2 Shared cameras do not feel privacy-invasive for users when the owner has control

The idea of sharing control of one's personal camera may seem invasive to privacy. Friendscope helps Wearers maintain their privacy in multiple ways: by allowing them to choose who to include in their session, by supporting ephemeral messaging, and by giving them control to approve or decline each trigger request regardless of sharing mode. Our findings suggest that these strategies work.

Of Friendscope's three shared camera configurations, including Shared Camera Off (our baseline condition), both Wearers and Friends preferred Manual Approve mode the most in our forced ranking (Figure 4.7). To them, Manual Approve struck the right balance between providing access to the shared camera and maintaining the Wearer's control over what is shared. When we designed Friendscope, we hypothesized that Friends would have a clear preference for Auto Approve mode since that gives them the most access to the Wearer's camera, but that was not the case. Friends enjoyed the interactivity of the Wearer manually approving their trigger requests, and they also enjoyed knowing that with Manual Approve mode they would not cause the Wearer to inadvertently send something they do not want to.

Even privacy-sensitive users preferred to use the shared camera in Manual Approve mode vs. not having a shared camera at all (Shared Camera Off), primarily because they got to choose who to include in their Friendscope session. Hence, we believe that it is crucial for any future shared camera system to include a Manual Approve mode.

Manual Approve mode was not only the most preferred mode in our studies but it is also the mode that can prevent misuses of Friendscope-like systems such as remote "spying" and invading bystanders' privacy. Manual Approve mode's design grants full control to the wearer and maintains existing norms around camera glasses, specifically: (1) an externally visible LED to inform bystanders when recording is occurring, and (2) a visible hand gesture when capturing or approving a video/photo. The ephemeral nature of all photos and videos captured by Friendscope goes beyond these existing privacy-protecting expectations to help additionally protect the privacy of people around the Wearer. Note that social norms around technology do evolve, and researchers continue to track expectations around data glasses in particular (Koelle, El Ali, et al., 2017). In the future, features like auto-expiration of sessions can make such systems even more privacy-protecting.

4.7.3 Camera glasses do not need screens to enable interaction between friends

Screens might seem necessary to allow the Wearer and Friend to interact with each other, but our findings show that even simple indicators such as LEDs can serve that purpose. Additionally, screenless designs make experience sharing systems such as Friendscope more glasses-friendly. Many camera glasses do not have screens, and screens are power-intensive.

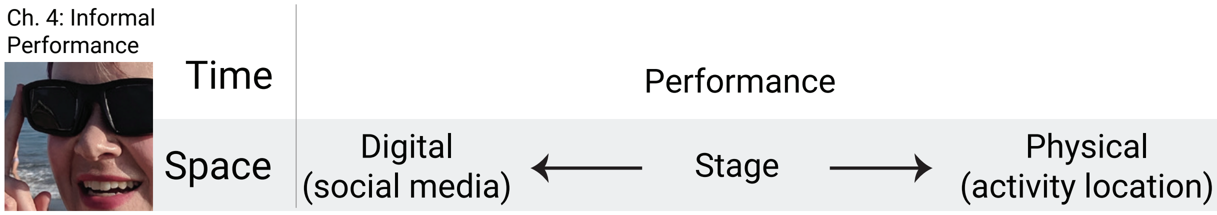


Figure 4.10: This chapter identified design opportunities for expanding the notions of time and space in the context of informal performances that happen on social media.

During our study, many participants preferred the spontaneity of having no screen, and those who wanted a screen only wanted to show simple messages such as text or emojis.

We believe that future experience sharing systems can leverage more sophisticated LEDs, dot matrix displays, or even audio to allow the Wearer and Friend to interact with each other and still be glasses-friendly. Future systems can even incorporate physiological data such as biosignals since they have been shown to be powerful for building social connection (Webb et al., 2016; F. Liu et al., 2019).

4.7.4 The concept of a shared camera is designed for camera glasses, but can be generalized to a wide variety of smart glasses and wearable camera interfaces

We designed Friendscope to make in-the-moment, interactive experience sharing possible on camera glasses, which have a very limited set of hardware (not even a screen!) and support only a delayed form of sharing. We believe, however, that Friendscope's design concepts can benefit larger devices such as smartglasses and other wearable camera interfaces as well, even if it is implemented exactly as we have done in this chapter.

For example, if the Wearer and Friend want to participate in an experience together but do not want to be online the entire time, they could use Friendscope to have a "lighter" form of interactive connection compared to a continuous livestream or video call. Neustadter et al. found that users prefer *not* to have to attend a friend's or family member's live video call during their entire experience (Neustaedter et al., 2020). In addition, a user could use a Friendscope feature instead of a livestream or video call to save on battery life or counter poor network connectivity. Note that the current implementation of Friendscope does not rely on hardware such as speakers or screens, but using them on smart glasses can enable a richer experience. A similar "shared camera" experience is supported by the Clos application (*CLOS App* 2020), which allows photographers to take pictures remotely (PetaPixel, 2021).

4.8 Summary

To address how this work supports my framework, I briefly discuss the project across the three main elements of **roles**, **space**, and **time**. In this chapter I presented Friendscope, an experience sharing system for camera glasses that enables in-the-moment, interactive experience sharing on lightweight consumer camera glasses. Friendscope supports two **roles**: the Wearer and the Friend. Both have access to and varying amounts of control over the shared camera. Through our pilot study, main user study, and field exploration with 82 total participants, we investigated how different shared camera configurations — Auto Approve, Manual Approve, and Shared Camera Off — lead to different types of experiences for users in terms of *fellowship* between users, *privacy* for the Wearer, and *sense of control* for both Wearer and Friend.

Our studies showed the benefits of allowing Wearers to share their experience with a remote Friend in the myriad **spaces** that shape our daily lives. Camera glasses are lightweight wearable interfaces that allow Wearers to share experiences across these spaces with each other.

With regards to **time**, Friendscope seeks to keep both Wearer and Friend connected 'live' by transmitting photos and videos as instantaneously as possible. We found that both Wearers and Friends emphasized the sense of being directly connected to each other — in the moment — when using the shared camera, and described it as a more intimate form of livestreaming. We also found that shared camera systems should employ a Manual Approve mode as Friendscope does; even privacy-sensitive users preferred Manual Approve over not having a shared camera at all and were comfortable using Friendscope in its Manual Approve mode. For most participants, Manual Approve mode struck the right balance between giving Wearers control and giving Friends "live" in-the-moment access to their experience.

Many researchers have explored the impact of technology on 'liveness' as experienced in the theatre, including Webb et al. (2016), who introduced the term *distributed liveness* as part of their exploration of the role that networked technologies can play in traditional forms of performance. Our findings align with earlier work (Couldry, 2004; Webb et al., 2016), showing that experiences that are shared in the moment — live, rather than later — can increase the sense of connection. This highlights the impact of designing systems for 'audiences' where those systems acknowledge and support the active role that audiences play. This chapter additionally explored an expanded definition of 'liveness', showing that true liveness is not always necessary to create the *feeling* of liveness.

Our concept of a shared camera is generalizable to other platforms, and we believe that it can make in-the-moment experience sharing possible on any form of wearable camera interfaces.

Chapter 5

Pre-Production

Before a production makes it to the rehearsal stage, many creative practitioners have already been dedicating many hours to the creative process. The playwright has been creating the script, the director has been developing the overall concept together with the production team, in the context of an animated film the character designers have been iterating on character look and feel, often for months or even years before the final production is even cast. This creative work happening "behind the scenes" takes up the majority of the professional performer's creative life, but remains undersupported by designers of creativity support tools (CSTs). In addition to rehearsal support, performance-related creative practitioners have specific needs and challenges within their creative process, and have developed their own techniques and strategies for managing these needs. Understanding how expert practitioners currently use technology can help designers identify opportunities for designing CSTs.

While Chapter 3 looks at expanding the notions of both **space** and **time** for the *audience*, in this chapter I seek to support the extended performance-related creativity for another **role**: the performers. In this chapter, I describe the needs and approaches of performance-related practitioners as they navigate their creative experience, looking at how they manage versions of different creative outputs, and the creative process in general.

5.1 Creative and Motivational Strategies

Creative practitioners deliberately structure their process, environment, and mentality to navigate the ambiguous and complex space of creative work. Techniques for structuring work are essential to "being creative," but from the outside can often seem unstructured, counterproductive, or unrelated to creative output. Practitioners use these *strategies* to manage and structure their creative experience, shaping creative output as well as motivation and emotional affect. Creative strategies can be tool- and domain-agnostic, allowing learning and sharing techniques across practices and between tools. Practitioners experiment with their individual creative processes, deepening their understanding of their own personal

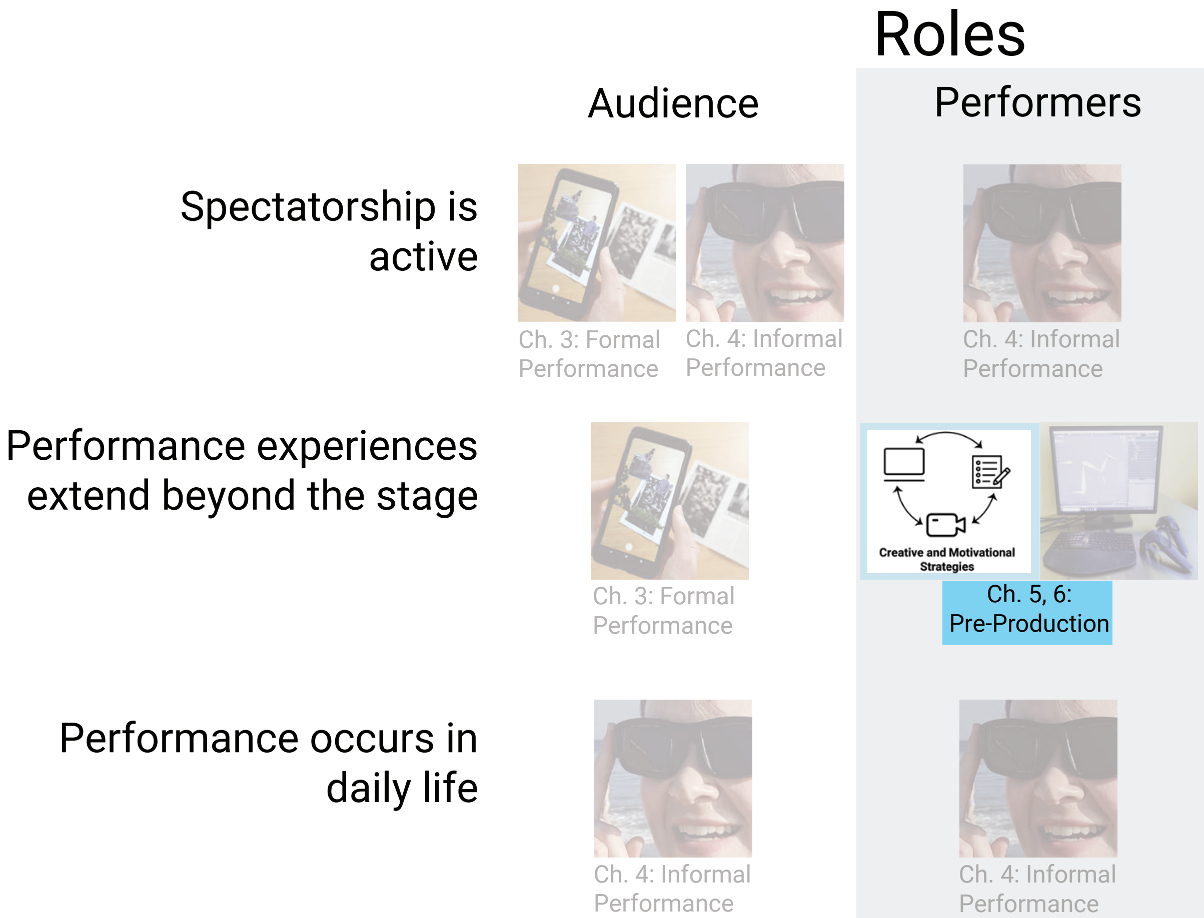


Figure 5.1: In this chapter, I describe opportunities related to designing for a performer during the pre-production process, beyond the performance itself.

process by applying new strategies, or embracing different mindsets. Designers can support creative practitioners by incorporating understandings of such techniques and strategies into tools and systems to support these essential yet undersupported aspects of the creative process.

Creativity support tools can help expert creative practitioners maintain sustainable daily practice and scaffold newcomers into lifelong engagement by considering metacognition, emotional affect, task motivation, and working style. Such tools would go beyond skill- and task-oriented support, to address the overall experience of "being creative." We suggest that increased attention to the process-oriented aspects of sustained creative practice will improve the overall design of Creativity Support Tools (CSTs). In service of this goal, this chapter presents a selection of techniques that expert practitioners use to structure their personal creative experience as both a description of existing practices and a foundation for CST designers to draw from when considering process-oriented CSTs.

This work builds on studies which focus on supporting the personal experience and emo-

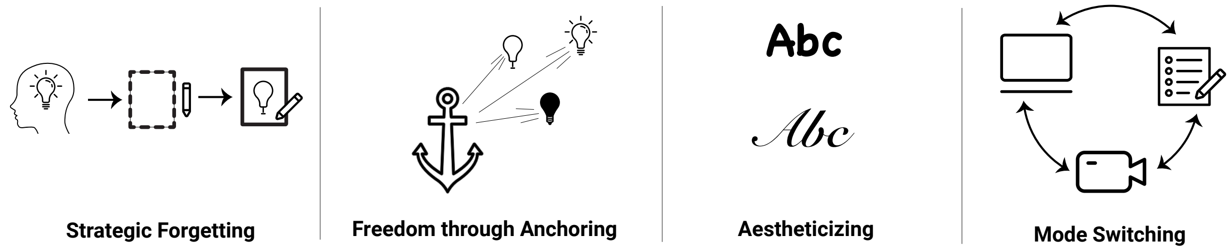


Figure 5.2: Through interviews with 13 expert creative practitioners in diverse domains, we identified four strategies for managing motivation and structuring process in creative work: *Strategic Forgetting*, specifically avoiding capture of creative output (Section 5.7.1); *Freedom through Anchoring*, low-fidelity capture to support cognitive and emotional needs while brainstorming (Section 5.7.2; *Mode Switching*, consciously selecting a tool to shift into a particular creative mindset (Section 5.7.3); *Aestheticizing*, making deliberate aesthetic choices to manage intrinsic motivation (Section 5.7.4).

tional well-being of the artist as they engage in the creative process. For example, Treadaway (2009) articulated the importance of a tool supporting feelings of satisfaction, rather than focusing only on the tool's effect on creative output. Recent work has explored the benefits of supporting process by developing healthy relationships with failure (Torres, Sterman, et al., 2018), supporting productive procrastination (Belakova et al., 2021), and enabling positive self-conception (Dow et al., 2010; Kim et al., 2017) during creative work. Each of these contributions focuses on the subjective experience of doing creative work, an important yet undersupported aspect of the creative process.

5.2 Version-control Strategies

The need to manage prior versions of artifacts and ideas exists across many domains: Writers create multiple drafts; programmers track incremental changes in large projects as they add features and fix bugs; instrument makers evolve violin designs over time. How might a performer, whose creative output is often ephemeral, manage the iterative development of a project over time? What tools might performer practitioners use to assist in managing the history of a performance-related project?

Despite the unique needs of practitioners in the context of performing, the structures of existing digital history management tools remain remarkably limited. Version control systems (VCS) — one category of tools to support history management — have a long history within software development. The core goals of VCS, as designed for the world of software, include supporting collaboration, recording changes, and reverting mistakes, in order to improve programmer effectiveness, efficiency, and collaboration (Koç et al., 2011; Zolkifli et al., 2018; Ruparelia, 2010). It's clear these values benefit software engineering, but they do not necessarily meet the needs for practitioners in other domains. A playwright typically works alone, and a performer may not be overly concerned with efficiency.

However, these values recur within the design of creativity support tools more broadly: Shneiderman identifies "history-keeping" as a central design principle for creativity support tools and identifies its primary goals as recording and comparing alternatives, reverting to and modifying earlier alternatives, and communicating with colleagues (Shneiderman, 2007). These goals closely parallel those of VCS. Digital history management interfaces embedded in consumer applications – such as the timestamped lists of revert-able versions that have become ubiquitous in collaborative online tools like text editors, spreadsheets, file sharing, and design tools – commonly support these goals as well, emphasizing collaboration, precise records, reversion, and efficiency. Such history management tools are used by a wide variety of people across many disciplines, including creative practitioners. Yet creative practices may also have different values from those embedded in the design of software VCS. Might a performing artist prioritize a different set of values over efficiency, fidelity, or the ability to revert a 'mistake'? Additionally, programming also requires creative behaviors, especially in exploratory domains such as data science, machine learning, or creative coding, and these behaviors often do not mesh well with existing VCS (Kery et al., 2017). How might tools designed to support these new strategies, values, and techniques benefit programmers?

5.3 Summary

Taking a process-oriented perspective, in this chapter I identify techniques used by experts across performance practices that 1) embody intra-personal aspects of creativity such as metacognitive skills, emotional support needs, working style, and intrinsic motivation, and 2) identify needs and opportunities relating to idea and history management.

Tools do not just support specific goals of a user, they also in turn shape those goals and working styles (Dalsgaard, P., 2017; Latour, 1994). In software development, version control has become integral to the programming process, where capabilities like 'branching' and 'diffing' fundamentally shape how programmers structure collaboration and solve problems. Far from being immutable personality characteristics, creative and motivational strategies can be shaped and enhanced intentionally, often through the use of specific tools. Understanding how experts currently manage and perceive their own creative strategies can inform the design of future tools that amplify the benefits of successful strategies and scaffold new techniques. This chapter addresses the questions: *What characterizes creative strategies amongst professionals in the performing arts?*

As creative practitioners embrace digital tools as part of their creative practice, we must consider how such tools shape and support the creative process. Are existing capabilities of digital CSTs equally well-matched to the working styles of practitioners in the performing arts? What are the values that best support creative practitioners, and might those considerations benefit programmers as well?

5.4 Motivation

Because the study of creativity necessarily spans disciplines (H. Gardner, 1988), it is crucial to work with experts across a wide range of domains, fields, and communities of practice as we seek to identify how experts manage meta-cognitive and emotional needs. Looking at a diversity of creative processes provides both a lens onto broader commonalities of practice, as well as insights into specific details of unique creative processes, both of which can enrich approaches across domains. In this chapter I focus on performers, an underexplored domain.

Frich et al. observed that current HCI research only sparsely draws from skillful creative practitioners' tool-use and behaviours (Frich, MacDonald Vermeulen, et al., 2019); by drawing on experiences in diverse disciplines we expand existing bodies of knowledge about expert tool-use. Qualitative methods are uniquely appropriate for identifying and curating descriptions of creative strategies, which can provide a source of long-lasting and technology-agnostic knowledge. This type of knowledge complements that gained from novel CSTs, which instantiate new ideas but are often ephemeral and hard to maintain (Frich, Biskjaer, MacDonald Vermeulen, et al., 2019). Strong foundational understanding of creative processes can develop our perspective on how creativity works, and help construct new design directions. For example, Terry and Mynatt described three creative strategies from a series of case studies of expert practitioners across diverse fields (Terry et al., 2002); these rich descriptions remain relevant to the design of creativity support tools (CSTs) even many years later.

In this chapter, I first situate our work within related literature in creativity theory and CST design. Then, I introduce our methodology and analysis. Through analysis of our interviews, we identified strategies and techniques for overcoming ambiguity, staying inspired, and tracking evolving ideas as well as managing the creative process used by expert practitioners across the domain of performance. Each theme is grounded in descriptions of the behaviors of specific practitioners.

I synthesize our observations into four strategies: *Strategic Forgetting*, *Freedom through Anchoring*, *Mode Switching*, *Aestheticizing*. Some of these are different from or even contrary to common design recommendations, expanding our understanding of the range of creative process behaviors: for example, the strategy of Strategic Forgetting recommends *against* capturing output for future reference. Each strategy and technique is placed into our categorization of CSTs, to clarify relationships to prior work. We then ground these strategies in existing research about cognition, design practice, and creativity.

5.5 Related Work

5.5.1 Creativity Research

This work is part of ongoing efforts to connect creativity research more deeply with HCI (Frich, Biskjaer, and Dalsgaard, 2018; N. Davis et al., 2017), as well as to leverage practitioner ex-

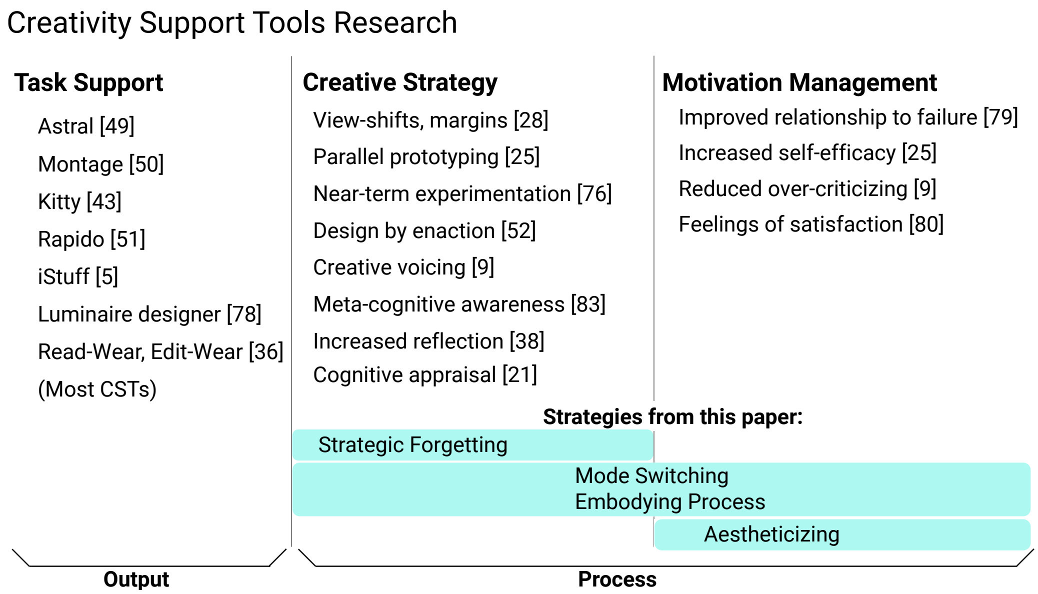


Figure 5.3: To contextualize the field of creativity support tools research, we consider three categories of research: Research that focuses on *task support* creates specialized systems and tools to enable specific types of *outputs* to be created. Research that identifies *creative strategy* provides insight into how creative practitioners work, such as how they generate ideas, gain new perspective, or reflect. *Motivation management* research focuses on how practitioners create and maintain motivation. The techniques described in this chapter fall under *creative strategy* and *motivation management*, aspects of creative process.

pertise in our understanding of tool-use and creativity (Kaufman and Beghetto, 2009; Frich, Biskjaer, MacDonald Vermeulen, et al., 2019). We first establish a shared definition of creativity and a summary of current creativity research. The study of creativity spans disciplines, from neuroscience, cognitive science, psychology, and human computer interaction, to history, anthropology, and beyond, requiring a "synthesis of different disciplinary perspectives" (H. Gardner, 1988). As designers of CSTs, we draw on these myriad creativity theories to inform our approach. Rather than attempt a complete summary of all theories of creativity, here we discuss those most relevant to our work.

While the definition of 'creativity' has evolved over time, the widely accepted (Barron, 1955; Stein, 1953; Plucker et al., 2004; Amabile, 2018; Kaufman and Beghetto, 2009; Frich, Biskjaer, MacDonald Vermeulen, et al., 2019) "standard definition" as articulated by Runco et al. (2012) requires both originality and effectiveness. Embracing this core definition, this chapter additionally takes a social constructivist (Von Glasersfeld, 2012) perspective, which embraces a broad understanding of the ways in which people, environments, and tools combine to shape both process and outcome (Dalsgaard, 2014; Hollan et al., 2000; Latour, 1996; Suchman and Jordan, 1990; Von Glasersfeld, 2012; Plucker et al., 2004; Dalsgaard, P., 2017). Plucker et al. (2004) articulate such a vision of creativity research, focusing on the interaction between "aptitude, process, and environment", a definition that is particularly relevant to HCI researchers. Fundamentally, we understand creative work as being done in a particular social and environmental context.

An example of a particularly influential framing that takes into account both aptitude and process is Amabile's Componential Model of creativity. Amabile emphasizes three core aspects of creativity: domain-relevant skills, creativity-relevant processes, and task motivation (especially intrinsic motivation) (Amabile and Pillemer, 2012). This chapter focuses on the latter two components, creativity-relevant processes, which include cognitive style, working style, and knowledge of heuristics, and task motivation (Amabile, 2018). While some of these 'processes' may be immutable personality characteristics, many (e.g., "tolerance for ambiguity" and "suspending judgment") can be shaped by intentional tool use. Creativity researchers emphasize the value of focusing on dynamic, mutable aptitudes rather than on the study of static, immutable traits (Amabile, 2018; Plucker et al., 2004; Glăveanu et al., 2021; Diakidoy et al., 2001). Recent work has emphasized the importance of understanding the creative *experience* in addition to creative outputs (Glăveanu et al., 2021). This represents an opportunity for CST research: tools that take into account the overall creative experience can facilitate growth and sustainable practice by mediating mutable intrapersonal aspects of creativity. Understanding how experts engage with and manage creativity-relevant processes provides a particularly rich foundation of knowledge for the CST community.

Kaufman and Beghetto identify different levels of creative practice (Kaufman and Beghetto, 2009): our interviews focus on professionals, the "Pro-c" level, with significant experience and established success in their fields. Professional practice is a rich source for understanding creative behaviour (Kaufman and Beghetto, 2009; Frich, Biskjaer, MacDonald Vermeulen, et al., 2019). We seek to contribute to deeper understandings of the way experts, operating at a high level of professional skill, manage and shape their own personal creative experiences, and how tools and systems could support that.

5.5.2 Process-Oriented Creativity Support Tools

HCI research related to creative strategies often focuses on designing tools whose primary purpose is to facilitate high quality output by supporting specific tasks (Ledo, Vermeulen, Carpendale, Greenberg, L. A. Oehlberg, et al., 2018; Leiva and Beaudouin-Lafon, 2018; Kazi, Chevalier, et al., 2014; Leiva, Grønbæk, et al., 2021; Ballagas et al., 2003; Torres, O'Leary, et al., 2017; Belakova et al., 2021; Hill et al., 1992) (Figure 5.3). In contrast, our work focuses on identifying tool-agnostic creative strategies (Frich, Biskjaer, MacDonald Vermeulen, et al., 2019; Terry et al., 2002; Myers, Lai, T. Le, et al., 2015; Jalal et al., 2015a; Dow et al., 2010; Leiva, Maudet, et al., 2019; Belakova et al., 2021), that can inform the designs and uses of many types of tools. For example, Frich, Biskjaer, MacDonald Vermeulen, et al. (2019) identified two strategies in creative practitoners' use of digital tools for iterating on ideas: 'margins', and 'view-shifts'. Both are tool-agnostic strategies used by expert practitioners as they iterate through a design process. In addition to identifying strategies related to idea management and version control, we additionally focus on supporting mindsets that enable creativity. By supporting intrapersonal aspects of the creative process, we seek to improve and enrich day-to-day work and satisfaction (Figure 5.3).

Version Control and Creative Process

Many domains and practices are creative, even if they are not colloquially considered creative the way that art and performance are. For example, software development is creative, as it requires open-ended problem solving and the creation of contextually novel solutions (Mahoney, 2017b). There is no single "correct" process among programmers, and programming process has parallels in other creative disciplines (Turkle et al., 1992).

Li et al. (2021) interview visual artists to understand how they use and create software tools in their artistic practice. We use a similar method of in-depth interviews to understand creative practice, with a focus on versioning behaviors across domains. Li et al. discuss how mismatched values between the practices of visual artists and software developers reduce the adoption and usefulness of existing software tools to visual artists; similarly, we find that a mismatch in values between existing version control systems and versioning behaviors in creative process limit the adoption and usefulness of VCS for performance practitioners.

Large-scale VCSs are not the only way to think about process interactions with history data. "Undo," for example, is a ubiquitous feature in computational tools, allowing the reversion of mistakes on a small scale. The ability to undo is important to creative process to make temporally proximal changes, for example as explored in painting by Myers, Lai, T. M. Le, et al. (2015) and image manipulation by Terry et al. (2002). Myers et al. additionally investigate how to support a "natural" approach to exploratory coding, integrating more complex backtracking in a code editor without requiring explicit version control (Myers, Oney, et al., 2013). Terry et al. discuss the importance of *variation* and *experimentation* to creative practitioners, exposing how creative practitioners appropriate the capabilities of existing software to store proximal history alternatives, such as using layers in photo editing software to store versions within a single file. They focus on near-term history behaviors to support reflection-in-action (D. A. Schön, 1979). Jalal et al. (2015b) explore the importance of version histories for choosing color palettes, and integrate versioning into color pickers, which are usually a component of a larger system.

Affect and Creativity

The relationship between affect and creativity is complex, with some evidence showing the positive impact of positive moods on creativity (Isen et al., 1985; Phillips et al., 2002; Amabile, Barsade, et al., 2005) and other findings that add nuance to this perspective (Bartolic et al., 1999; Clapham, 2001; Bledow et al., 2013). Bartolic et al. (1999) found that brain activity associated with negative moods improves figural fluency compared with verbal fluency, while brain activity associated with positive moods had the opposite effect. Sowden et al. (2011) similarly found that a negative mood helped participants assess the usefulness of a given evaluation, while a positive mood enhances performance on ideation tasks. Bledow et al. (2013) described the impact of an *affective shift* on creativity, taking a dynamic view in which "the emergence of new ideas [and positive affect] is often preceded by and depends on a phase of negative affect".

Creativity support tools can be designed to take emotional affect into account. For example, De Rooij et al. (2015) designed a system to enhance positive emotions which they argued would increase creativity. Increasing positive emotions is not the only way to affect creativity, however: Torres, Sterman, et al. (2018) articulated strategies that expert practitioners use to manage experiences and feelings related to failure, including embracing failure, mitigation of the effects, and reframing failure entirely. Belakova et al. (2021) reframed a 'negative' behaviour in their design of SonAmi: this tool addresses *over-criticizing* – a common barrier to creativity among writers – by providing creative distance from the authors' own writing by replaying written snippets with a computer-generated voice. The computer-generated voice enhanced the authors' ability to both appreciate and constructively critique their own work. Kim et al. (2017) designed Mosaic to celebrate incremental process, a way of reframing the value of unfinished work. Mosaic displays works-in-progress as a way to both promote healthy communities and positive self-conception. Complementary to Kim et al.'s findings, in this work we focus on how practitioners manage their individual creative process, rather than community interactions. Dow et al. (2010)'s research on parallel prototyping articulates not only a specific brainstorming strategy, but also the impact of such a strategy on a novice designer's sense of self-efficacy, which has been shown to influence a variety of outcomes (Bandura et al., 1999), including one's ability to learn (Dweck, 2008), find enjoyment in (Csikszentmihalyi, 1990) and persist through (Mele, 2003) challenges, and engage in activities (Bandura et al., 1999).

Directly influencing emotional affect is only one way to support creativity. Other researchers have discovered ways to support creativity by making the creative process itself more visible and legible. Increased awareness of one's own process can improve metacognitive understanding and learning outcomes (Yan et al., 2019). Creating artifacts can be understood as a way to capture and view 'fleeting moments' of progress for visual artists (Hook et al., 2015), or a way to maintain focus (C. C. Marshall et al., 2004). While these strategies do ultimately improve the final creative output, the immediate benefit is to improve the emotional well-being of the creator by engendering a sense of progress. Our work similarly seeks to scaffold healthy mindsets by designing systems that take into account the emotional well-being of creative practitioners by reframing negative experiences, increasing positive affect, and supporting healthy awareness of process. Building on these earlier findings, we expand the conversation beyond students, designers, and engineers to include the rich practice across other domains, including performance, craft, science, and art.

5.5.3 History Management Tools

History management tools capture, organize, and support interaction with the information and artifacts that form a project history, such as documentation, commentary, specific artifacts, or versions of artifacts. Such a tool might focus on saving content, recording decisions and revisiting reasoning, or enabling group collaboration (Fuller et al., 1993), while also overlapping with other purposes: a design notebook supports active ideation; a website for documenting process shapes community norms (Kim et al., 2017); a tool for visualizing version history enhances grading and instructor feedback (Yan et al., 2019). Digital history management tools include software version control systems such as *git*[1] or *Subversion*[2], as well as tools like file sharing platforms or email, which store the history of documents or conversations. Physical examples might include design notebooks, or a filing cabinet of old drafts.

Version control systems (VCS) are a specific subset of history management tools that organize iterative changes to specific digital artifacts (Chacon et al., 2014). While history management tools encompass information created after the fact to explain or contextualize an artifact, version control tools focus on the artifacts themselves, with metadata created at the same time as the artifact. While the most familiar artifact type is software source code, VCS have been created for and applied to digital artifacts beyond code, such as a custom tool for tangible information design (Klemmer, Thomsen, et al., 2002), or using GitHub to write books (Univalent Foundations Program, 2013; Pe-Than et al., 2018). In this chapter, I discuss history management behaviors through the lens of version control. Version control systems are particularly common and powerful tools, which are tightly bound to the creation of the artifacts themselves, and therefore integral to workflows and process. VCS are also key tools in software practices, providing a foundation to consider adaptations of existing tools to support creative process. In this chapter, I broaden the common conception of VCS as applying only to digital artifacts: certain physical artifacts or tools can be fruitfully considered as versions or version control systems.

Version Control Systems for Software

Version control systems for software development have transformed software development practices, providing essential infrastructure for collaboration on shared artifacts. Yet the conceptual models behind current software VCS have resulted in designs that do not always match the needs of practitioners. Version control, also referred to as revision control or source control, has been evolving for decades, tracing its roots back to the 1970s (Rochkind, 1975). As version control systems grow increasingly more capable, the fundamental goals and concerns have remained relatively stable. In early systems, the focus was on identifying what changed and when, propagating fixes across versions, knowing what version a customer has, and reducing storage requirements (Rochkind, 1975). More recent work identifies key goals as tracking reasons for changes, supporting collaboration, and allowing reversion (Koç et al., 2011), as well as coordination and organization (Zolkifli et al., 2018). These goals are supported by features such as merging, sandboxing, tracking history, reversion, and synchronization for collaboration (Ruparelia, 2010). These features and goals are essential

[1]https://git-scm.com
[2]https://subversion.apache.org

to modern software development practices, and have radically improved both individual and collaborative workflows since their adoption.

Yet software version control is not always successful even among people who write code. Kery et al. show how data scientists who work with code in an exploratory manner eschew version control systems for manual strategies, like copying snippets of code (Kery et al., 2017). These data scientists required speed, flexibility, and visibility of options for their exploratory processes, outweighing needs for collaboration features or reversion. Similar mismatches in the values of VCS and the processes of creative practitioners are present in our findings across creative domains, emphasizing the need for alternative paradigms for version control. *git*, created in 2005, is now one of the most common VCS tools, with GitHub, a graphical, collaborative tool for working with git, reporting over 73 million developers in 2021.[3] Yet Perez De Rosso et al. note that the difficulty of learning git turns away many new users (Perez De Rosso et al., 2013), and that its complex underlying conceptual model does not match how many people approach writing code. Aligning domain values with system capabilities is essential for a successful partnership between user and tool; in this chapter, I explore how versioning behaviors in a broad range of creative domains both share and challenge existing values in software VCS. By understanding the ways version history is used in creative domains, we can understand how the design principles of software VCS might be adopted and adapted to better serve the needs of creative practitioners, both when working with code and with other materials.

Version Control in Non-Software Domains

Code is not the only material for which version control tools have been developed. For example, version control tools are common for office software, CAD, and journal articles (Koç et al., 2011). When considering how to design VCS for CAD, Chou et al. (1986) note the importance of considering the uniqueness of the application domain, as different contexts require different capabilities . We align with this philosophy as we investigate creative processes to understand the capabilities and models of version control needed in creative domains.

Despite the variation across domains, existing VCS systems often share conceptual models and values with traditional software VCS. Khudyakov et al. identify increasing safety and stability, and reducing conflicts or usage of incorrect versions as specific goals for VCS for CAD (Khudyakov et al., 2018). In text editing and office documents, supporting collaboration is again essential, with tracking history, merging, and diffing as key capabilities (Rönnau et al., 2005; Coakley et al., 2014; Filho et al., 2017). Version control is important to feedback and annotations in collaborative writing contexts, keeping comments in sync with content (Weng et al., 2004). Zünd et al. develop VCS for collaborative story authoring in various media, including images and video, again focusing on the collaboration benefits of features like merging changes from multiple authors (Zünd et al., 2017).

[3]https://github.com/about; retrieved Nov 1 2021

Klemmer et al. developed a versioning system for early-stage information design, using digital media to capture the history of a tangible interface, focusing on the capabilities of reversion, collaboration, and reflection (Klemmer, Thomsen, et al., 2002). Such designs mirror the capabilities and goals of software version control. This similarity can be both a benefit and a drawback: leveraging existing capabilities makes VCS systems powerful, yet can constrain the role they play in the creative process. Of 4101 respondents to a 2020 survey about UX tools, 892 or 22% indicated that they were dissatisfied with their main version-tracking tool (Palmer et al., n.d.). Shneiderman includes rich history-keeping as a key feature for creativity support tools (Shneiderman, 2007), yet as we consider the role VCS plays in creative practices, we must go beyond existing models and values for VCS. To create or adapt VCS effectively for creative domains, we must understand how practitioners use version information to shape their own process, engaging how different materials and workflows affect history behaviors.

5.5.4 Summary

In this chapter, I take a process-focused approach to investigate creative strategies for managing the creative process. I identify high-level themes that cross domain and tool boundaries in the context of creative, motivational, and idea management strategies.

To understand the value of this framing, take an existing example: Knotation is a documentation CST for choreographers that incorporates basic versioning (Ciolfi Felice et al., 2018). This tool draws from particular needs of choreographic practice in its design of information representation and exploratory features. Knotation recreates a common design element in version control: the ability to revert to previous states. A dramaturgical design lens might enrich the possibilities created by Knotation by considering other ways version histories might be valuable to choreographers' process: How might choreographers using a digital tool like Knotation benefit from *strategic forgetting*? Would *mode switching* enhance the choreographers' reported desire for "informality" and "imprecision"?

5.6 Methodology

5.6.1 Interview Methods

To understand practice "in the wild" we carried out semi-structured interviews with 12 expert creative practitioners and 3 early career practitioners. Interview questions were guided by grounding themes of artifact use and personal creative practice, and shaped by the individuals' background and reflections. Each interview lasted 1-2.5 hours, during which we asked semi-structured interview questions, focusing on personal creative practice and background. Most interviews took place in participants' primary workspaces to understand their tool use in context (Beyer et al., 1999; Suchman, Blomberg, et al., 1999) [4]. To ground our discussion in concrete examples of daily work, we followed principles of contextual inquiry (Beyer et al., 1999): topics centered on how each practitioner engages in their creative practice, how they use artifacts in their process, the tools and materials they use, and the techniques and strategies of their creative process. Participants were asked to walk us through concrete examples of their work-flows as a starting point for surfacing details about their personal working style. Using a recent project of the participant as a grounding example, each participant was asked questions such as *How do you make progress when you feel stuck? How do you explore alternatives? How do you assess your growth as an artist over time?* and *What tools do you use during different stages of your process?*

Our interviews are interactional events (Suchman and Jordan, 1990), in which the questions evolve in response to participant background, shaped by earlier interviews. We examined the use and creation of artifacts – rather than their functional properties – embracing Suchman's idea that a tool can only be understood in relation to its social environment and use (Suchman, Blomberg, et al., 1999; Inie et al., 2020). Focusing on artifact use additionally allowed us to foreground custom-made tools, such as paper templates for weaving and violin making, or objects not typically understood as "creativity support tools," such as a pile of handwritten notes, or an old project hung up on the wall. These artefacts could be understood as elements of an 'Annotated Portfolio' (B. Gaver et al., 2012; Bowers, 2012), generated as part of a creative practitioner's independent practice, helping to convey the decisions and the philosophy of each practitioner.

We followed a cognitive ethnography approach (Hollan et al., 2000), focusing on how expert practitioners understand and reflect on their own practice. We are specifically interested in the reflective and meta-cognitive activities that creative individuals carry out, as well as their cognitive style (H. Gardner, 1988). Reflective self-report allowed us to investigate the ways that people interpret and manage their own behaviors in their creative process, and what meaning they ascribe to their own actions (Hollan et al., 2000; Kaufman and Beghetto, 2009). As Glăveanu and Beghetto put it, "processes cannot be easily inferred from outcomes" (Glăveanu et al., 2021), so we asked practitioners to engage in reflection about their own techniques and strategies.

5.6.2 Practitioners

Our informants represent domains that require novelty and open-ended problem solving, where practitioners must use creativity skills in daily work (Kaufman and Beghetto, 2009). Many domains and practices are creative, even if they are not colloquially considered creative the way that art and performance are. We take a broad view of what domains are creative, as an area in which the practitioner utilizes creativity. For example, software development

[4] In the case of five participants, video conferencing was used to remotely connect to the subjects at their workspaces due to travel limitations, one because of the COVID-19 pandemic. One participant travels frequently, renting workspaces in different cities, so agreed to meet in a public space and share pictures from her rehearsal spaces.

Interview Participant (Main Creative Domain)	Years of Experience
Animal Behaviour Researcher	11
AR/VR Artist	19
Ceramicist	21
Creative Coder	13
Director	47
Industrial Designer	23
Museum Curator	19
Physical Performer	22
Software Engineer 1	10
Software Engineer 2	12
Stylist	25
Tapestry Weaver	43
Violin Maker	18
Academic	9
Design Lead	6
Software Engineer 3	5

Table 5.1: We interviewed 13 expert creative practitioners and 3 early career practitioners across diverse creative domains. While all interviews shaped our final analysis, in this chapter I focus on the experience of the performers, and especially how it contrasts with the other practitioners.

is creative, as it requires open-ended problem solving and the creation of contextually novel solutions (Mahoney, 2017a). Recruitment began by selecting sites and interviewees according to an *a priori* set of distinctions that seemed most likely to be relevant (e.g. collaborative vs independent work). We chose subsequent creative practices and experience levels to maximize the range and diversity of experiences as our understanding evolved, in concert with our research questions. Following Charmaz's Grounded Theory approach, we chose additional practices and experience levels within this frame that would support theory construction, rather than seeking population representativeness across "all" creative practices (Charmaz and Belgrave, 2007). Each expert participant self-identified as an expert in their field, with a mean of 21 years of experience (range 10-47 years; Table 5.1). Participants were asked to walk through concrete examples of their workflows as a starting point for surfacing details about their personal working styles.

5.6.3 Analysis

Since the inception of Grounded Theory, it has split into three main branches: Strauss and Corbin; Glaser; and Charmaz (Sato, 2019). We embrace Charmaz's constructionist research style that understands knowledge as co-constructed between interviewee and researcher (Charmaz and Belgrave, 2007; Charmaz, 2006). Our analysis is interpretivist, seeking to understand how our informants create meaning in their work (Gligor et al., 2016), and is rooted in the social construction of knowledge and polysemic understandings of truth (Kvale, 1995).

Our goals are to "provide a rich, contextualized understanding of human experience through the intensive study of particular cases" (Polit et al., 2010), and to perform analysis that identifies the transferability of findings (Polit et al., 2010). We contrast quantitative understanding of generalizability, or statistical generalizability (generalizing from subjects drawn at random from a representative sample), with both analytical generalizability (generalizing to a construct or a theory), and transferability (a collaboration between readers and authors, where authors provide rich, thick description and readers do work to apply the findings to other fields) (Polit et al., 2010; Carminati, 2018; Kvale, 1995).

Following best practices for Charmaz's branch of Grounded Theory, we simultaneously engaged in analysis and data collection, iteratively constructing our analytic frame and updating our question prompts for future interviews as we identified and synthesized emerging themes (Charmaz, 2006). For thematic analysis, we first transcribed each semi-structured interview, then performed open-coding (Strauss et al., 1990) on the transcripts. We iteratively reviewed and analyzed all interview data and discussed all emerging themes (McDonald et al., 2019). Themes are presented below, addressing strategies practitioners use to structure their creative process to feed inspiration, break out of creative ruts, stay motivated, and tap into different aspects of the creative process when faced with ambiguity.

5.7 Findings

Throughout the interviews, we identified themes relating to the creative process, creative cognition, motivation, and emotional affect (discussed below in this chapter). We additionally uncovered tensions around version control systems, and identified values embedded in CSTs which are at odds with some aspects of the creative process. Because each interview evolved organically, following discussion topics relevant to the creator at hand and our evolving analytic frame, we did not address each topic with each practitioner in depth. As such, we focus the below discussion on the creative and motivational techniques emphasized by our performing informants. We identified four themes across our interviews as dominant strategies used by creative practitioners: Strategic Forgetting, Freedom through Anchoring, Mode Switching, and Aestheticizing. We highlight each with a description and grounded observations.

It is useful to define three additional terms as they are used in this chapter:

Artifacts are physical or digital objects created by people. The final output of a creative process might typically be understood as an artifact, such as a violin created by a luthier, or it may be an ephemeral work, such as a performance. An ephemeral work might generate artifacts, such as an audio recording of a concert. Artifacts are also generated during the process, such as notes, tools, documentation, or drafts.

Figure 5.4: The Performance Director keeps and displays many artifacts from his career, including notebooks with extensive rehearsal content. He is dedicated to building a collection of artifacts to track and manage his creative process. Despite his dedication to capturing, his creative practice also involves Strategic Forgetting (described in Section 5.7.1). These images represent selected artifacts from his creative space, the tangible history of what has not been “strategically forgotten”. From left to right: 1., 2. The Performance Director’s working space, filled with props, costumes, set pieces, and memorabilia from his long career as a working artist. 3. A notebook containing notes on acrobatic tricks. 4. Hand-drawn stick figures showing acrobatic tricks, from the notebook. 5. A cut-out from a magazine, used to recall technique.

A *version* is an artifact captured at a particular point in time that is conceptually linked to prior or subsequent iterations. This is easy to imagine with digital artifacts, as they can be directly copied and modified. It also applies to physical artifacts: for example, we can understand two physical sketches as *versions* if one is an iterative change to the first. A paper sketch and a subsequent prototype might also be considered versions, despite the change in materials.

Documentation is an artifact or collection of artifacts specifically designed for communication about the project. This may be targeted at people other than the creators, or intended for the creators themselves in the future. In this chapter, we focus on versions rather than documentation; while the two are often related, the ways they are created and used differ significantly.

5.7.1 Strategic Forgetting

Inverting the common practice of capturing ideas at the moment of creation, we observed several practitioners purposefully leverage the natural forgetfulness of their mind as part of their creative process. We observed this technique of *Strategic Forgetting* in the Performance Director and Physical Performer. The Performance Director has been performing professionally for 47 years, and teaching performance for 30 (Table 5.1). He has performed as an acrobat, juggler, and clown, and worked as a teaching artist, producer, director, and playwright for both theatre and circus shows. His primary domain is physical performance; recently he has expanded into writing and consulting. As a playwright, his process draws from his background as a performer, acting out scenes as he writes them.

When developing material for a show, the Performance Director relies on his imperfect human memory as a filtering mechanism that results in only "memorable" work getting saved. Even while engaged in a writing process, the Performance Director first generates many ideas through physical improvisation – a familiar and comfortable practice for him. The nature of these improvisational sessions is fleeting; yet rather than taking notes or recording the sessions, he purposefully prevents himself from capturing them:

> **Performance Director** [My mentor] would say "Here's the scene, try it," and then I would do it... he would not let me write it down in rehearsal. [He would] say "write the scene up tonight," on the theory that whatever I remembered was worth keeping from the scene. Which I found incredibly frustrating. But it works!

In other words, the Performance Director relies on the inherently ephemeral nature of his craft to allow himself to forget ideas. After some time has passed, he will finally write down notes on the rehearsal from earlier, capturing the ideas "worth" remembering.

The Physical Performer engages in a similar process. The Physical Performer has been working in performance for 22 years. She designs, directs, and performs one-woman physical comedy shows, drawing on her years of training in mime, acrobatics, and physical comedy. Her primary creative domain is physical performance; recently she has expanded into music and spoken comedy. Her creative process involves improvisation, or "playing": trying out new ideas and cycling back to old ideas. This improvisation is inherently physical, acting out the details of a scene to feel it in her body. She often deliberately avoids referencing her notes while improvising, and does not write a script:

> **Physical Performer** I'd spend the week journaling, [then] I would flip through whatever I had written that week... And then I'd get on stage, put the notebook down, and I would just improvise for 10-15 minutes... Things that were not important didn't get put in and things that were important got said.

Like the Director, the Physical Performer found this to be a very successful method. She trusts her subconscious processing to foreground the parts of the story that were important to tell. She specifically structures her working style to enable her subconscious mind to play an active role in the creative process.

Through this process, the Physical Performer maintains freedom, flexibility, and liveness in her individual process and her collaborations by deliberately omitting certain information. For example, the Physical Performer would audio record instead of video record her performances, because she didn't want to constrain herself by repeating the gestures she had done in that earlier performance. This practice supports her own expectations and values of what a performance should be, and how it should feel from her perspective:

> **Physical Performer** I need to keep something unscripted, otherwise I feel like it dies.

We can also see the effects of using video to capture an ephemeral art form through the experience of the Performance Director. When watching a juggler in person, one cannot catch all the details of a trick. These errors can be productive, enabling the trick to evolve:

> **Director** Those little errors [are] like a little genetic mutation, generation to generation.

These mutations contribute to each juggler's unique style, and to the evolution of juggling as a field. These days, videos of juggling techniques are easily accessible on the Internet, and able to be replayed over and over to tease out the details:

> **Director** I don't think we lose [the mutations], I think that still happens with video. [But] it doesn't spread as fast.

Video slows the process of evolution by reducing the space for serendipitous variation. In this example we see a case where the amount of detail and accuracy of the past version, captured in memory or in video, changes how an individual's style develops.

These two performers found value in purposefully embracing the ephemerality of their medium in the generative phases of their work. Strategic Forgetting supports liveness and curation of ideas.

5.7.2 Freedom through Anchoring

Reversion, going back to an earlier state of the project and continuing forward from that point, is a highly valued capability of version control systems. The ability to quickly and completely revert to an earlier state, which is possible with many digital anchors such as code commits or duplicating a document with a new name before making a big change (as the Animal Researcher often does), is one useful benefit of anchors. However anchors have broader applications, as we found in many physical and ephemeral practices, where the main benefits centered on emotional and mental freedom rather than the ability to completely revert. In these cases, practitioners rarely captured a high fidelity snapshot, even when the technology to do so was available to them. Instead, low-fidelity anchors served to free the creator to take more risks and move forward more fluidly.

Software Engineer 3, who has been working as an engineer for 5 years in Research and Development for a wireless technology company, described the benefit of reversion to his process:

> **Software Engineer 3** [Committing] is kind of an insurance policy. Because a lot of times I'll make a change and I'll break something, and then I won't remember how I got there. So any time something kind of works, or I feel like I hit a milestone or a checkpoint, I'll make a commit so that I know I can at least get back to that point.

Using history as an insurance policy to enable experimentation also showed up in history management behaviors in the performer's practice. The Physical Performer sought such freedom to take chances when developing a physical comedy show. As the Physical Performer and her collaborator improvised together to design their show, they captured their evolving ideas in a scribbled "script" on butcher paper:

> **Performer** [On] a huge poster-size paper... we would write down "[A] grabs napkin, [B] double-takes, [A] this," every little minute movement.

Recording the "choreography" was essential to supporting free improvisation and exploration. This low-fidelity anchor allowed safe experimentation and mitigated risk:

> **Physical Performer** Often times we did go off on tangents, and then we came back to the script...It helped me feel more comfortable to just go really far out because I knew that we weren't going to forget what worked in the beginning.

Capturing even an extremely simplified form let them play, and freely negotiate about the show:

> **Performer** [The butcher paper] was the space where we agreed on what was going to happen, and so if we were ever playing and someone did something else, [and] then the other person was like "wait I don't know", we could refer back to [the poster] and be like "is this the best way, or should we do how we just improvised and change this thing". And then often times we *would* change it, but it helped us continue to anchor back to something.

The Physical Performer understood the butcher paper as an "anchor" to their initial creative idea. Capturing concepts allowed the collaborators to experiment freely without fear of losing access to their original creative intuition, or of forgetting something that had worked better. In this way, the butcher paper script is a tangible version history, providing the same feeling of safety while exploring that Software Engineer 3 gains from his version control software.

5.7.3 Mode Switching

In Actor-Network Theory, Latour articulates what happens when a person (actor) works with a tool: a new actor entity comes into existence that represents the unique combination of them both (Latour, 1994; Latour, 1996). Creative practitioners similarly change which tool is in use in a conscious effort to bring a new, combined, person-tool entity into existence. We see Software Engineer 3 and the Physical Performer both leveraging this relationship with tools to enter and support particular *modes* of creative behavior by deliberately changing *tools*.

Software Engineer 3 has been working professionally as an engineer for 5 years. He works in the Research and Development arm of a wireless technology company. He has a habit of printing out new code he's learning, taping the pages together, and adding hand-written annotations to track his thinking. He keeps three different whiteboards in his office, one on his desk for quick notes, one on his wall for brainstorming, and one behind his computer for longer-term reference. The affordances of the different whiteboards initiate certain creative modes:

Software Engineer 3 I like the size of [the wall whiteboard]: it's a nice big whiteboard, you can draw big things. It's also easier to reference – to look at [up on the wall]. Because sometimes I'll sit here, [puts legs up on desk], and I'm just staring at my whiteboard, like "what am I going to do with this..." It's harder to do that with a small, 8x11 piece of paper.

The large whiteboard prompted a creative *mode* that supported engagement with "big ideas". Participants such as Software Engineer 3 are attuned to the ways in which different tools shape and define their creative process, and they consciously select a tool to shift into a particular creative mode. This behavior is distinct from choosing a tool in order to generate a specific output; instead, the tool is chosen to shape the practitioner's behavior or mindset, driven by changing creative, cognitive, and emotional needs.

The Performer also described consciously leveraging different tools to generate a particular mode of engagement with her work. For example, when she creates a new show, she sometimes improvises in front of a video-camera. The video-camera acts as a pseudo-audience, allowing her to access her performing mindset "without a lot of pressure, and with a lot of freedom and a lot of joy." Next, she re-watches these recordings, and writes down her favorite parts. Switching to writing is a deliberate choice; writing is a more difficult medium for her, which has "different vibes" from videotaping. Switching mediums allows her to switch mindsets, from "the improv, physical, playful channel" to the "gleaner of info channel". This switch is driven by her physical and emotional needs, rather than a need for a particular type of recording:

Physical Performer There's a time when it's right for me to get up and move and then there's a time when that window closes and it's a time to reflect and it doesn't feel right to get up and move – it would be forceful to do that. It's almost like a switch: different channels are open. There's a point where it's "off". The door on that [mode] is closed.

Writing in a journal was a relatively new introduction to the Physical Performer's creative process. Her previous techniques involved meditating on mental images, and sketching high-level 'texture maps' of her shows. She discovered journal writing in a class designed to help performers create a new show. The instructions from the course involved writing a script that would later be performed, but instead she found it more beneficial to integrate this new journaling technique with her "home domain" of improvisation, and uses each medium at different parts of the process.

Physical Performer Many times I've videotaped 15-25 minutes [of improv] and that's like 3 minutes of something I like. So the writing would be grabbing the 3 minutes. And then the next video I would look at [the writing] and start with that, or I'd just put that to the side and [see] what wants to come through today. And then take the 2 minutes from that one, and then put the 2 minutes and

Figure 5.5: The Physical Performer finds benefits in consciously leveraging different capabilities of tools in her practice to manage and respond to her evolving creative needs (*Mode Switching,* described in Section 5.7.3). Left: Components of a show, physically rearrangeable on notecards. Right: A rehearsal room the performer used while on tour.

> 3 minutes together. And then do another video session that's 1 minute. ...It feels like a distilling process. One modality to the other modality would distill it.

Here, the Physical Performer is deliberately leveraging different forms of reflective conversations by using different tools and mediums through the strategy of mode switching.

5.7.4 Aestheticizing

Brainstorming literature shows that encouraging quantity (over quality) produce both higher quantity *and* higher quality ideas in the end (Paulus et al., 2011; Diehl et al., 1987; Reinig et al., 2008; Osborn, 1953). In the context of brainstorming there is no trade-off between quality and quantity: by focusing on quantity, you get quality too. But for prototypes, which involve more time and effort to construct, this trade-off is an important concern. Design practitioners often sacrifice aesthetic refinement in favor of quickly generating many low-fidelity prototypes, which while individually less accurate or refined, lead to better end results (Dow et al., 2010; Wulff et al., 1990; Muller, 1991). However the aesthetics of an artifact do not only affect the output: deliberate choices around aesthetics are key factors in intrinsic motivation and overall creative experience. Motivation is an essential component of the process of creative work, with intrinsic motivation supporting creativity, and extrinsic motivation often suppressing it (Amabile, 2018). Among some of our participants, aesthetic refinement in their work was a source of intrinsic motivation.

Attention to beauty suffused all aspects of the AR/VR Artist's workflow, not just in his artistic outputs but also in even basic documentation. The AR/VR Artist is an expert in creating digital art in augmented and virtual reality. His creative process involves building reusable digital assets and creating documentation that he or others can use in the future to learn skills and process. The AR/VR Artist invests considerable time and effort into saving information, resources, and research if he feels that they might be useful for himself or others later. Yet even if a document will never be shared publicly, he takes time to make the visuals feel "finished". For example, as he collected examples for how to write campaign emails, he structured them into a beautiful slide deck because it satisfied his own sense of progress:

AR/VR Artist I like to at some point take my ideas from a notepad document to...something that is a little bit more nice to look at. ...It helps me visualize it as being more done, or presentable.

While he begins with less aesthetically refined collections of screenshots and notes, the act of creating a beautiful presentation helps him distill his thoughts. After creation, the aesthetic artifact is one he desires to return to and continue working with, which keeps his task motivation high. He emphasized how much this process benefited not only others, but upheld his own satisfaction with his work:

AR/VR Artist It helps me feel like it's officially out there... it motivates me, more, than – if it were just in a notebook, I might feel like I were just scrawling out ideas.

The AR/VR Artist is highly intrinsically motivated by creating visually appealing content, and by designing for an audience, whether that audience is real or imagined (he described creating a 60-page document in InDesign that "no one asked for").

While the AR/VR Artist increases intrinsic motivation through highly aesthetic artifacts, some participants felt an opposite effect. The Academic, early in his career, found freedom and motivation in "lowering the bar" of quality, both for aesthetics and content. The Academic is an advanced graduate student at a university in the United States. He specializes in studying how humans understand systems from an interdisciplinary lens and cares deeply about the craft of research. The Academic specifically described being "scared" by his "proper art notebook":

Academic Because I want every piece of art that goes in there to be beautiful ...so whenever I go to draw in it, I'm like: "Once I draw in here, that page is in here forever, I can't remove it."

For him, the permanence and high quality of the art notebook was intimidating, stymieing creation. In this case, the art notebook placed external expectations of aesthetic refinement on his work, decreasing motivation. Instead, he prefers to hand-bind his own notebooks, using the cheapest possible printer paper.

Academic If I put a real clunker of a poem in [the handbound notebook], it's like, eh, who cares, I'm probably not even going to come back and read these, no one is going to read them, it's ok. It gives me more latitude to just try something.

Theme	Recommendations
Strategic Forgetting	Design tools to flexibly support capture and omission, including no capture at all. A system that captures early brainstorming could also explicitly allow 'hiding' of early iterations to let the creative mind process.
Freedom Through Anchoring	Deprioritize rapid reversion in favor of supporting confidence and freedom to explore. If capturing a complete, recoverable state is not necessary or possible, a lower-fidelity approach can act as a useful anchor while providing cognitive and emotional benefits.
Mode Switching	Support different creative modes through distinctive interfaces that take advantage of different mediums and modalities. Simplify transitions in and out of an application to help creators make a personalized 'pipeline' that works for their own process.
Aestheticizing	Provide tools that help creators become aware of and focus on the aesthetics of their creations. Highlight synergistic extrinsic and intrinsic motivations.

Table 5.2: Summary of our study findings and design recommendations for process-focused creativity support tools.

By deliberately de-emphasizing aesthetics, the Academic increases his motivation. While their approaches to aesthetics differed, the AR/VR Artist, Industrial Designer, and Academic all found deliberate choices around aesthetics to be key factors in intrinsic motivation and overall creative process.

5.8 Discussion

Here we situate our findings in current creativity support research, and identify future directions. While our findings primarily represent strategies used by expert creative practitioners, we speculate on ways in which these techniques may apply across domains, or be used to scaffold newcomers into sustainable creative practice.

5.8.1 The Value of Forgetting

Recent thinking in psychology has resulted in a major reframing of memory "failures", uncovering the ways in which errors can be beneficial to mental processes, including evidence that memory failures can facilitate novel thinking (Ditta et al., 2018). These recent findings have not yet been incorporated into the design of creativity support tools, but offer a structured way to consider how tools might leverage creative strategies like *Strategic Forgetting*. For example, memory errors that involve incomplete encoding, which the Director and Performer embrace, can be categorized as one of three types of 'omission' error (Ditta et al., 2018), two of which are relevant here: *transience* and *absentmindedness*. Transient memories, or those that gradually fade over time, may help break creative "fixation" by letting irrelevant information fade, resulting in more focus on the problem at hand. Deliberately not capturing ideas may allow the subconscious mind to distill out the valuable content, only retaining the ideas that resonate. Absentmindedness describes the tendency of the mind to drift to new topics, which may result in creative combinations of seemingly unrelated information. Not writing down notes about an idea may increase the chances of encountering new ideas together with the topic at top of mind.

Because the mind automatically has a tendency to drift to new topics, Strategic Forgetting may increase opportunities for new and creative connections. This technique is related to, but distinct from, a well-known strategy of *incubation*, framed by early discussions of mathematical creativity: "incubation generally precedes illumination. In this period of incubation, no work of the mind is consciously perceived" (Hadamard, 1945). Incubation continues to be important to conceptions of creativity; Shneiderman refers to those who embrace incubation and illumination as "Inspirationalists" (Shneiderman, 2002; Shneiderman, 2007). Strategic Forgetting is a more extreme strategy: rather than only taking time away from a project to allow the mind to incubate and free-associate, Strategic Forgetting prevents the capture of any information during the generative phase or prior to incubation. Identifying potential benefits of such a strategy is an area ripe for future exploration. CSTs could be designed to support hiding or obfuscation of data (e.g., by sub-sampling images, dithering, dropping frames, applying filters, etc).

While this strategy has recently begun to be explored within the field of creativity research, few designers[5] have attempted to incorporate this technique into a CST. Might a programmer think differently about the range of solution options if they prohibit themselves from writing down the details of an early solution draft? Would the architecture of an application simplify if an engineer had to remember it instead of writing it down? If we design digital tools that selectively blur notes and sketches to aid in "forgetting", should this forgetting be stochastic or predictable? Which details should be hidden, and when (if ever) should they reappear? At what point in a practitioner's development is it helpful to introduce these techniques - would a novice benefit from them as much as an established expert? Strategic forgetting may provide benefits through not creating artifacts at all. However, some practitioners must create artifacts in order to think-through-doing, such as a writer who develops their thoughts by drafting. To gain some of the benefits of strategic forgetting, a system could support the behavior of destroying that first draft. These represent themes that are currently underexplored in the world of software in particular, and creativity support tools

[5] One example is "another day", a tool that allows the capture of only 4 days' worth of writing at a time: `https://github.com/thmsbfft/another-day`

in general.

5.8.2 Anchors Provide Liveness, Flexibility, Safety

The Performer and Director, who both work in physical performance, both value change and flexibility in their work, and choose lower-fidelity representations of version histories. Confidence and freedom to explore are essential across practices. However, VCS may place a lower priority on rapid reversion in order to gain these benefits. As seen with the Industrial Designer, Violin Maker, and Performer, easy reversion may not be a necessary capability: version histories provide these benefits even when additional labor is required to return to an earlier state. Similarities between different mediums and differences within the same medium reveal aspects of creative process that are separated from any specific creative medium.

Software engineers and creative coders, though working in the same material, have radically different paradigms of creative process and the role of version histories. Though code and physical performance are different materials, VJ'ing, or live-coding visuals to accompany music, requires spontaneity and liveness in much the same way as a physical comedy show. The Physical Performer gains liveness by excluding the visuals of her performances from her version history; the Creative Coder uses rapid creation of parallel versions to allow him to pursue many different directions during a single performance, but only reuses a small selection of key modules between performances. Despite the different materials – bodily performance and code – the values are similar.

5.8.3 Constructing Creative Modes via Tool Use

The Physical Performer's description of her relationship with her process, environment and tools closely parallels Dalsgaard's notion of *instruments of inquiry*, an understanding of the way the creative process "intertwines" and "co-evolves with" the environment and tools. This Deweyan pragmatist perspective, which underlies Dalsgaard's philosophy, elucidates the way the Performer leverages tools to augment her own cognition and creative process (Dalsgaard, 2014).

For example, we can frame her use of Mode Switching as 'knowing-through-action': combining her expertise as a professional performer with the tools of video-recording and writing together produces output – in this case, a scene – that is meaningful and that moves her design process forward. This 'knowing-through-action' arises as she leverages different tools throughout her process. She explicitly describes the different 'modes of work' she taps into by using the video-camera, or the journal, and how these tools then shape the mindset she has and the way she interacts with her own output. Distributed cognition (Hollan et al., 2000) presents a similar lens for understanding this concept, which also embraces the larger context of her working environment as part of her cognition. In other words, her creative process is an emergent property of the interaction between her own skills and the camera or the journal.

A similar method, reported by Frich et al. (2019), is the 'view-shift' strategy, described as: "deliberately shifting the perspective or view of the workspace in order to move between a view of the whole composition and a component that is part of it." View-shifting is primarily about switching between two perspectives to gain additional perspective on a particular subpart of a project. In contrast, Mode Switching is about deliberately using different tools to manage creative, cognitive, and emotional needs across a project's lifetime. However, both represent emergent properties of the interaction between the practitioner and their tools.

Seen through the lens of *instruments of inquiry* (Dalsgaard, P., 2017) or distributed cognition (Hollan et al., 2000), we can see the importance of understanding how closely enmeshed the creative behavior is with the tools at hand. In the example described above, switching modalities (from video-taping to writing) was nearly synonymous with switching creative modes (from generating to editing). It is difficult to separate the thinking and doing aspects of her working style, and difficult to separate the goal of the task from the tools used in that task. In what ways can tools support this process? Is the switch from paper-based to a video-based medium important? Our findings resonate with earlier work on tangible tools that tap into muscle memory and tacit, embodied forms of knowledge (Klemmer, Hartmann, et al., 2006). Finding ways to switch modes by switching tools can help practitioners transition across different stages of their creative process. Our work further motivates the design of tools that span modalities and mediums, or that have distinctive digital interfaces. More extreme switching of mediums may help more extreme switching of creative modes. Additionally, tools that make it easy to transition in and out of an application can help creators make a personalized 'pipeline' to support stages of a personal creative process.

5.8.4 The role of aesthetics in task motivation

Some of our expert participants have found that embracing aesthetic refinement keeps them engaged in their creative practice. This engagement relates to the nature of motivation, intrinsic and extrinsic: the AR/VR Artist's and Industrial Designer's approaches are "synergistic extrinsic motivators", part of the task motivation component of Amabile's Componential Model of creativity (Amabile, 2018). Synergistic extrinsic motivators both 1) support a "sense of competence" and 2) enable a deeper involvement with the task, without undermining their sense of self-determination (a known problem with extrinsic motivators such as gamification). For these creative practitioners, aesthetics is such a synergistic motivator. Aesthetic satisfaction also has echoes of the values of craftsmanship: "an enduring, basic human impulse, the desire to do a job well for its own sake" (Sennett, 2008). Craftsmanship fosters a sense of pride and satisfaction in one's work, and ownership over process; for these creators, valuing aesthetics contributes to their sense of a job well done. Aesthetic enjoyment might also increase the length of time someone spends engaging with their creations, or make the creations themselves more memorable.

For some creators the pressure to create something beautiful can disrupt their creative process and cause writer's block. We note with interest that the early career Academic reported this, while the experts did not. For our expert informants, the joy they got from creating high quality artifacts kept them engaged in the process, and motivated them to continue creating. Our view is that nearly any behavior that keeps a creative practitioner joyfully engaged with their practice is valuable, as long as it does not become a fixation that prevents forward motion. Even if "best practices" recommend low fidelity creations, experts often find value in taking the time to enhance aesthetics when it works for them. Low-fidelity is often conflated with low-aesthetics, but even low-fi prototypes can maintain a level of craftsmanship and care. The Industrial Designer describes the extensive effort he put in to avoiding ragged edges when cutting foamcore, investing significant effort into creating clean cuts even during lo-fi prototyping. There is a certain level of craftsmanship that can be embraced even when other details are excluded. Because aesthetic taste is so personal, and tools cannot be designed to satisfy everyone, tools might instead help practitioners *identify* and *reflect on* their aesthetic preferences, and how these might be influencing their creative process.

5.9 Limitations and Future Work

In this chapter, we have engaged with a broad array of creative practices. We have identified tool- and domain-agnostic strategies that have great potential to provide insights that are relevant across domains, mediums, and approaches. Our primary interest is in what Kvale might describe as the “what could be” target of generalization (Kvale, 1995); seeking insight from the true experiences of individuals. We have found that learning about others’ successful creative strategies is often beneficial; though creative process is highly personal, heuristics and work styles can be learned, shared, and adapted between individuals (Amabile, 2018). Indeed, people often informally share their creative strategies in online settings as part of their creative process.

Foregrounding creative strategies may help individual practitioners experiment with their own process by applying new heuristics. Designers of creativity support tools can engage with process-focused aspects of creativity, incorporating support for heuristics to assist users in developing satisfying, lifelong practice. In the future, we hope to present these strategies and techniques to practitioners across disciplines. For instance, what would the AR/VR Artist or the Weaver think about the concept of ‘strategic forgetting’? How might the Animal Behavior Researcher incorporate ‘Aestheticizing’ into her process? In addition to expanding our understanding of these practices, this could help identify the extent to which such techniques are actually ‘practice-agnostic’.

Our methodology engages primarily with techniques that a practitioner is consciously aware of and can actively reflect on. Complementary methodologies may surface techniques that practitioners are not aware of or are hesitant to share with an interviewer. In future work, observations and formal contextual inquiry, paired with further interviews and micro-genetic techniques are a particularly promising area for generating deeper understanding of unconscious behaviors (Kaufman and Beghetto, 2009; Torres, Jörke, et al., 2019). We also note that the two practitioners who shared feelings of dissatisfaction with their process (the

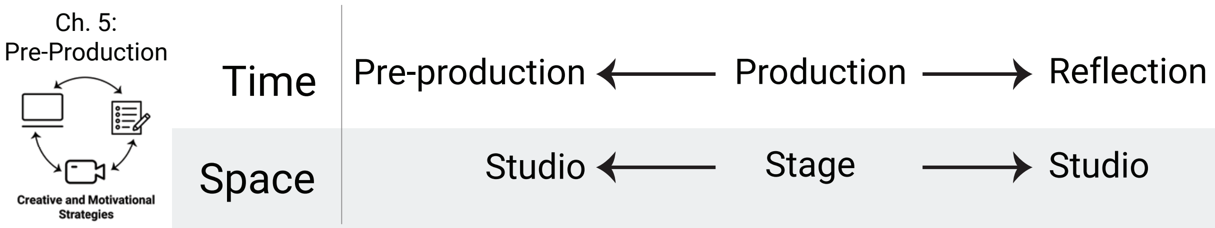


Figure 5.6: This chapter identified design opportunities for expanding the notions of time and space in the context of pre-production creative work.

Academic and the Software Engineer 3) are both early career practitioners. Further work may explore how creative satisfaction evolves over time. An additional area of interest is how and when to scaffold newcomers into behaviours that experts identify as supporting successful, sustainable careers. The strategies reported here are a selection of examples; many more creativity heuristics exist, and could be identified and shared through further research with other practitioners and domains.

5.10 Summary

In this chapter I have explored the way two other performance-related **roles**, the production team and performers need support across **time** that extends beyond the moment of a performance, and in **spaces** separate from a formal stage. In this chapter I have described strategies and techniques that expert performer practitioners leverage throughout their practice to manage their cognitive state, working style, motivation, and creative output. I identified four strategies from semi-structured interviews: Strategic Forgetting, Freedom through Anchoring, Mode Switching, and Aestheticizing. I then connected these to existing creativity research literature, and synthesized our findings into recommendations that I hope will inform the future design of Creativity Support Tools that increase generation of creative work in a way that also enhances creativity itself.

While these strategies may be tool- and domain-agnostic, I identify them here as reported by expert performers.

Chapter 6

Pre-Production: Movement Sketching with Embodied Interfaces

In Chapter 5 I identified creative strategies and techniques that may be important to performers as they engage in their creative process, namely: aesthetics, strategic forgetting, freedom through anchoring, and embodied exploration. In this chapter, I encode those strategies into the design of a tool for supporting motion sketching for novice animators.

Specifically, I designed a tool that allows for embodied exploration, supports creative freedom through quick anchoring of a movement sketch, but strategically avoids overly detailed capturing. While the visual aesthetics are somewhat limited, but aesthetic quality of the movement — the core material under development — is quite high, allowing the novice animator to develop their eye for lifelike movement. In this chapter, I describe the motivation behind the system development, how the system relates to animation and puppetry techniques, and how it is designed to scaffold novice animators.

6.1 Introduction

In animation, movement is key for conveying a character's personality, emotions, story, and meaning. However, current animation tools for designing character movement remain challenging to learn, requiring extensive investment in time and effort (Dontcheva et al., 2003) limiting both their adoption by novice animators, and their usefulness in early ideation sketching even for experts. Additionally, the use of techniques such as creating keyframes and interpolating between them keeps designers focused on low-level mechanisms rather than allowing them to quickly engage in sketching behaviors – early ideation that is quick, exploratory, ambiguous, gestural (Buxton, 1999; Buxton, 2010) – a key step in the creative process (Buxton, 2010; Kaufman, 2016). Sketching can be understood as a low-cost design strategy that allows experienced sketchers to engage in a reflection-in-action constructionist process (Goldschmidt, 2014), or as early externalizations of an idea, or as filters and man-

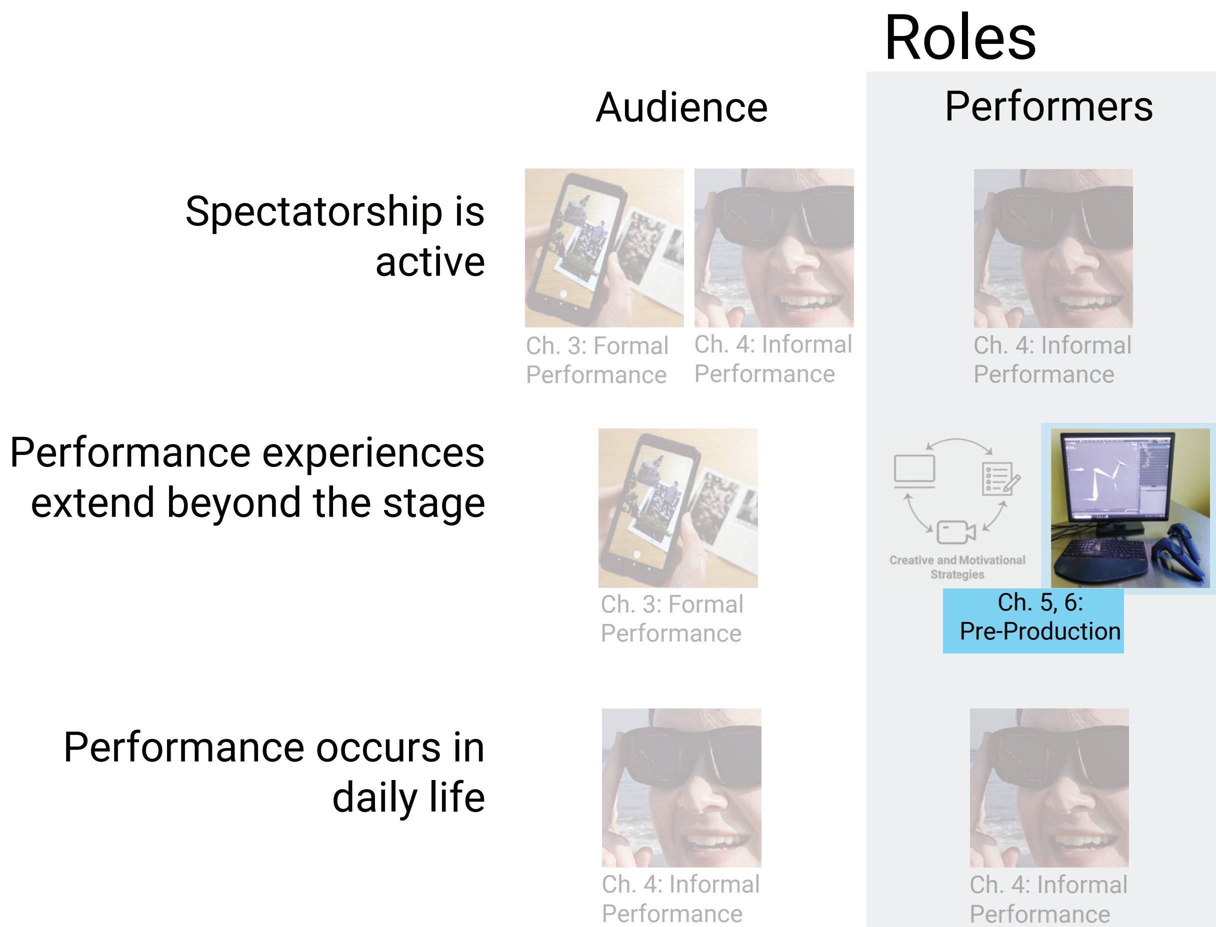


Figure 6.1: In this chapter, I describe a specific tool for performers to use during the pre-production process.

ifestations of design ideas (Lim et al., 2008). As such, the early ideation sketching process benefits from tools that provide a low *threshold* (Myers, Hudson, et al., 2000) and *paths of least resistance* (Myers, Hudson, et al., 2000) to expressive behaviours. In this work, we ask the question: *How can animation tools scaffold animators towards beneficial movement sketching techniques?*

Rapid embodied movement sketching is the domain of another creative field: puppeteering. Puppeteers have been bringing inanimate objects to life to the delight of many for hundreds of years. In Found Object puppetry, everyday materials directly shape the design of compelling characters. For example, a napkin may be crumpled in a particular way and combined with a ceramic cup and a stick to create a fighting character (see Figure 6.3). Also called "live 3D animation", this puppeteering technique is a *bricolage* practice (Vallgårda et al., 2015) that relies on a "knowing-through-action" (Dalsgaard, 2014; Dalsgaard, P., 2017), reflective conversation with materials (D. A. Schön, 1979). Because it relies on physically manipulating "objects at hand" (rather than requiring a constructed puppet, as in

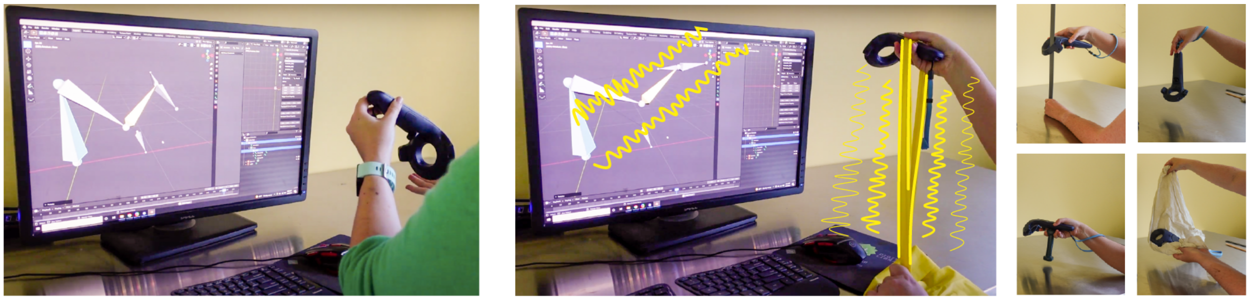


Figure 6.2: Incorporating physical materials – such as a stretchy band, weights, fabric – into the movement sketching process has the potential to enable novice animators to deeply engage with movement qualities. Left: Tangible controllers allow for embodied manipulation of 3D digital models. Center: "Found objects" such as a stretchy band act as material jigs. Recording the movement of a digital character while pulling the band adds an ineffable quality of tension to the movement. More importantly, playing with physical materials enhances the ideation process for novice animators. Right: Novice animators using the tool for the first time experimented with using material jigs in diverse ways. Clockwise from upper left: Using a stick to constrain movement along a path; dangling the controller to allow gravity to generate novel movements; dropping the controller into a piece of fabric; and holding a set of weights to embody the experience of a 'heavy' or 'sad' character.

Marionette, Hand and Rod, Costume, or Shadow Puppetry (see Figure 6.4), this technique is particularly well-suited to supporting quick engagement in embodied movement exploration.

Specifically, we suggest that the materials typically used by Found Object puppeteers could helpfully influence animation techniques, if they could be incorporated into the animator's workflow. In this chapter, I introduce a system for novice digital animators which incorporates aspects of analog, tangible, Found Object puppeteering. The expert Puppeteer I interviewed described the materials that he uses in his practice as helpfully constraining his movements, much like the way that jigs and fixtures support woodworkers by providing selective constraints to motion. While jigs in woodworking are typically solid and hold cutting materials securely in place, and the Puppeteer used soft or flexible materials such as a napkin or a jacket, the core idea of an external tool that helpfully limits movement remains the same. We therefore also refer to the materials we incorporate into the animation process as *jigs*. We show that by conceptualizing these "found objects" as *material jigs* and incorporating them into the animator workflow, novices use the materials to engage in embodied exploration to generate movement sketches: using a stretchy band between both arms to create tense, vibratory movement or hanging a controller by a piece of fabric to capture naturalistic pendular effects. Together, tangible animation controllers and material jigs enhance the novice animator's character design practice and ability to engage in a reflective, embodied conversation with both the digital sketching output and the physical sketching materials themselves (D. Schön, 1992; Klemmer, Hartmann, et al., 2006).

Figure 6.3: Found Object puppeteering, also known as "live 3D animation" involves puppeteers manipulating everyday materials with their hands. In this image, puppeteers wearing all black manipulate napkins, a tea cup, and chopsticks to create two sword-fighting characters.

In this chapter, I draw on techniques from expert puppeteer practitioners to inform the design of a system that allows novice animators to engage in embodied movement sketching practices. We identify Found Object-style puppeteering as uniquely positioned to contribute character design strategies to the world of animation. We first describe strategies and techniques used by expert practitioners in two distinct but related fields – animation and puppeteering – and describe how the Found Object puppeteering strategy of material "jigs" can be fruitfully imported into the core animation workflow. Next, we describe our authoring tool, PuppetJig, which allows designers to define, layer, edit, and replay motion-tracked character animations via the manipulation of tangible controllers and material jigs. We then share the results of an exploratory evaluation with participants experiencing the tool for the first time. Finally, we discuss how this concept of jigs applies to the world of digital animation, and suggest future directions for exploration.

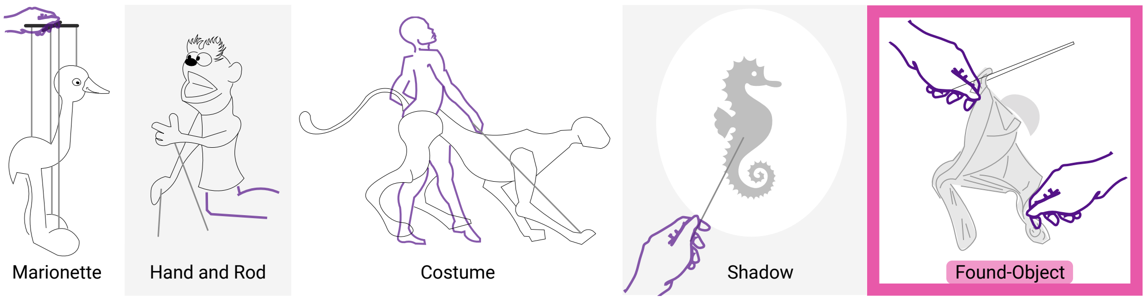


Figure 6.4: There are many different forms of puppeteering, of which the majority are not as potentially beneficial to incorporate into the animator's workflow. From left to right, Marionettes like Pinocchio are suspended from strings attached to a hand-held control mechanism. Hand and Rod puppets (e.g. "the Muppets") are controlled with a hand inside the head opening and closing the mouth, and rods attached to both hands. Costume puppets like Big Bird, or many of the creatures in Julie Taymor's The Lion King on Broadway, incorporate the puppeteer's body into the character. Shadow puppets rely on light and can either be made of cut-outs (as in traditional Indonesian Wayang Kulit (Escobar Varela et al., 2017)), or with hand shapes. Found Object puppetry involves the manipulation of materials such as napkins, paper bags, plastic forks, etc. Nearly any object can become a puppet in this style of puppetry. Such a bricolage practice (Vallgårda et al., 2015) is uniquely positioned to contribute character design strategies to the world of animation via material jigs that can define, shape, and influence movement qualities of digital puppets.

6.2 Related Work

6.2.1 Tangible Tools and Systems

Tangible interfaces have long been recognized for providing benefits in contexts that require experimentation, muscle memory, tacit learning, and the ambiguity and complexity of the physical world (Klemmer, Hartmann, et al., 2006). Analog tangible interfaces – such as clay – are known for enabling a rich "conversation with materials" (D. A. Schön, 1979) which designers frequently seek to recreate with digital materials (Moradi et al., 2022; Torres, 2019; Torres, M. J. Nicholas, et al., 2019). For example, Jones et al. created a system that enables designers to fabricate clay sculptures (Jones et al., 2016), arguing that an interactive, physical prototype affords a more accurate, iterative, and responsive design process. Raffles et al. introduced Topobo, a tangible interface designed to support children learning about how "balance, leverage and gravity affect moving structures" (Raffle et al., 2004). Tangible systems also enable the capture of physical performances for archive purposes (Escobar Varela et al., 2017). ChronoFab is a 3D modeling tool for crafting motion sculptures (Kazi, Grossman, et al., 2016). Such tangible systems are frequently celebrated for being easy to learn, yet also having a high expressive ceiling (Myers, Hudson, et al., 2000), which we hope to incorporate into our system.

Tangible systems have been particularly valuable in the context of animation. An early example of a tangible system for animation comes from the artists who worked on the classic film Jurassic Park. Their whimsically-named "Dinosaur Input Device" is described in a 1995 CHI paper (Knep et al., 1995). The authors embedded sensors into an armature to control an on-screen puppet. The animators preferred the movement quality of the physically manipulated puppet as compared with computer interpolation-generated movement (and audiences did too - Jurassic Park is frequently cited as one of the best early examples of an animated character). Such tangible interfaces – called "maquettes" – are relatively common in the film industry; a recent example is the Baby Yoda character from Disney's The Mandalorian, controlled by four puppeteers with remote controls and one manipulating sticks connected to the arms. Glauser et al. (2016) created a system that allows animators to create tangible and modular rigs for controlling digital characters, demonstrating improvements in accuracy and time with a posing task. Tangible puppets also enable capture for digital archive purposes (Escobar Varela et al., 2017). Dontcheva et al. (2003) introduced a motion capture system that allows designers to use a variety of input methods as they rapidly prototype non-humanoid character motion. Gupta et al. (2014) enable animators to collage together multiple takes of an animation performance. Building on the benefits of tangible motion design systems, we draw from the field of puppetry to further augment tangible systems for animation design. Specifically, we seek to create a tool that focuses on scaffolding novice animators into rich, embodied explorations of movement, especially early in the design stage.

6.2.2 Sketching as a Design Practice

Sketching – whether with pen and paper or digital tools – is a design practice that enables a creative practitioner to develop and refine ideas through an iterative process. Sketching – especially early in the design process – should support "rapid, active and contextualized" (Leiva, Maudet, et al., 2019) exploration and creation of a given design space. Creativity Support Tools (CSTs) that support early exploration can provide new *paths of least resistance* for navigating a design space (Myers, Hudson, et al., 2000). Fundamentally, the purpose of a CST is to support and extend the creative practitioner's relationship with her process, environment and tools. We embrace Dalsgaard's articulation of Deweyan philosophy, specifically the notion of *instruments of inquiry*, an understanding of the way the creative process "intertwines" and "co-evolves with" the environment and tools. This elucidates the way a practitioner might leverage tools to augment her own cognition and creative process (Dalsgaard, 2014; Dalsgaard, P., 2017; Hollan et al., 2000). These overarching concepts align with Schön's notion of reflection-in-action (D. A. Schön, 1979). Specifically, our tool creates a *path of least resistance* towards leveraging the physical world, and allows character designers to include diverse physical objects in their iterative brainstorming process.

(Hagbi et al., 2015) identify three 'sketching' patterns: *Sketching then playing* (where the sketch is a playing area for future gameplay), *sketching as playing* (where the purpose of the activity is sketching - it is the main activity), and *sketching while playing* (where participants alternate between sketching content and manipulating it). Our system embodies the ethos of 'sketching while playing', but interprets the notion of 'sketching' more broadly, supporting 3D motion capture rather than on-paper drawing.

6.2.3 3D Animation Tools and Techniques

Most animation is carried out by following one of two classic animation techniques: keyframing (also called pose-to-pose) where the animator first defines specific poses along the animation trajectory, and then fills in the poses "in-between" these key poses using a process called "in-betweening" or "tweening". When animation is done digitally, this tweening may be done automatically by the computer, using a technique called *interpolation* where the computer calculates the path between each pose and moves the relevant component along their respective paths. Interpolation has known issues with producing natural motion: namely the generated movements tend to be uncannily smooth (Knep et al., 1995).

Another classic animation technique is known as "straight-ahead". This is the type of animation typically used in claymation or stop motion because it involves proceeding along the animation sequence linearly (rather than skipping ahead to future poses as happens in pose-to-pose). Some animators consider this more intuitive, especially for novice animators. A third technique is referred to as "layered" animation, and involves defining motion for collections of body parts separately, and then collaging the motion together in a final step. For example, K-Sketch allows the animator to create an animation of a wheel spinning while also moving forward along a path by allowing the animator to record both motions separately, and then automatically suggesting various combinations (R. C. Davis et al., 2008). Dontcheva et al. specifically designed a system around layered animation for motion capture (2003). Their system allows animators to perform different aspects of a moving character and layer these movements on top of each other to create the final animation. Our system similarly supports recording separate aspects of a digital character then combining them in a separate step. These techniques are complementary and are employed differently based on the animator's preference and the situation at hand.

As these traditional animation techniques were brought into computer graphics, designers began to create new systems, techniques, and tools for generating and capturing motion. One of the earliest examples of playing back an animation coupled to the motion of an input source was demonstrated in Baecker's Genesys system (1969). A later computationally mediated motion capture tool includes Calvert et al.'s Life Forms, the front-end of a more general-purpose 3D animation system that allows choreographers to use keyframes and inverse kinematics to create movement sequences (Calvert et al., 1993). Multi-touch has been shown to lower the barrier to manipulate complex characters (Kipp et al., 2010). Meador et al. (2004) used live motion capture to explore the role of mixed reality in a live dance production . Procedural animation and physic simulation systems, including those built-in to Blender [1] enable automatic generation of rigid-body, particle, and soft-body simulations.

[1] https://www.blender.org/

While the generated outcomes are often extremely compelling, there is less of a role for a human to design the movement in these procedurally generated animations. Most animation tools tend to support either key-framing (Glauser et al., 2016; Calvert et al., 1993), straight-ahead (Knep et al., 1995), or layered (R. C. Davis et al., 2008; Dontcheva et al., 2003; Ciccone et al., 2017) animation techniques. While the final result created with any technique should be identical, the tools vary in how they support the ideation process. In this work, we seek to support an embodied, iterative, rapid prototyping process for animators creating character movement.

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6.3 Design Motivation: Drawing from Expert Creative Practice

As part of the design process, we engaged with professional creative practitioners in two related fields – animation and puppeteering – about their existing movement design process. We interviewed experts in both fields to develop an understanding of common approaches, techniques, and strategies for engaging in movement design. We identified both commonalities and differences, which allow us to identify fruitful opportunities for cross-pollinating the two fields.

6.3.1 Interview Procedure and Analysis

To gain an understanding of puppeteering and animation practice, we carried out semi-structured interviews with 2 expert creative practitioners. Interviewees were paid at the rate of $40 an hour. The interview questions were guided by grounding themes of tool use, artifact generation, and personal creative practice, and shaped by the individuals' background and reflections. Each interview lasted between 2 and 2.5 hours, during which we asked a semi-structured set of interview questions, focusing on their personal creative practice and background. Questions included probes about the creative process such as *"Can you walk me through your design process for a particular project?"* or *"What role does this technique/strategy/approach play in your creative exploration?"* or *"What are the benefits of technique A in comparison with technique B?"* We then performed thematic analysis on the interview transcripts, iteratively reviewed and analyzed all interview data and discussed all emerging themes (McDonald et al., 2019). Themes are presented below, categorized into strategies these practitioners use to structure their respective creative processes.

6.3.2 Participants

Both participants were recruited via professional contacts, and invited to speak with the lead researcher while remotely connected over a video-conferencing system.

Animator – The animator has been working professionally as an animator for over 11 years. She now works for a large animation studio, and has worked with many different companies throughout her career. She works primarily in 3D, and has also explored 2D, stop-motion, and VR animation.

Puppeteer – The puppeteer is an Emmy award-winning performer who has been performing professionally for over 25 years. His work could be categorized as physical comedy, clowning, mime - he excels at physical performance. His primary puppeteering technique is Found Object puppeteering, where everyday materials are manipulated with the hands to create compelling characters. For example, a plastic bag may fold and slightly inflate to become the body of a chicken, with plastic forks for feet.

6.3.3 Findings

Experts in their respective fields, both our informants have rich practices of movement design. We identified both similarities and differences in their techniques, and identify opportunities for importing expertise from puppeteering into animation, which could shape the design of tools to help scaffold newcomers.

The importance of texture and rhythm

Both the Animator and the Puppeteer are highly attuned to movement qualities such as rhythm and texture as they design characters, develop scenes, and tell stories through their respective mediums.

> **Animator** I don't make everything smooth in the scene. I try to include staccato movement to give more rhythm... I use some motions more straight and then some motions more like round shapes.

The Animator was highly attuned to movement qualities like rhythm (e.g., staccatto, smooth) and texture (e.g., sharp, round) and how these would shape the final outcome. Similarly, the puppeteer heavily emphasized Laban movement concepts, specifically the four categories *sustained*, *pendular*, *abrupt*, and *vibratory*. As he's developing a character or a scene, he keeps these terms top of mind, using them to shape his rehearsal process, and iterate on the design of a character.

> **Puppeteer** The real kicker is the transition between multiple states. So you create a low vibration going into a high pendulum movement. It's surprising to see that shift of the two different energy levels and that's what people respond to.

Both experts emphasized the importance of texture and rhythm throughout their design process, highlighting attention to detailed aspects of movement quality as a shared value.

While both experts highly valued nuanced movement qualities, they had different relationships to the process of generating such movement. The puppeteer's Found Object puppetry technique emphasizes the use of physical materials to create characters. A paper bag can be expanded with the hands, then crumpled, then re-inflated to convey breath. A piece of foam or a scrap of fabric might be stretched out to communicate gravity and weight. The puppeteer articulated the ways in which these materials shape his exploration of characters:

> **Puppeteer** [The character design] all depends on the material that you're using...you start playing with it and then that's where you make the discoveries.

The materiality inherent in his puppeteering practice guides him throughout his design process and helps him generate new movement qualities. In contrast, the Animator's digital process has a more limited relationship to materiality. She discussed the particular challenge she would face if asked to design an abstract, non-humanoid, non-animal character:

> **Animator** If I had a character that was the shape of water I would just try to [create] motion in general, I guess, rather than looking for a reference...thank God I have never had to do that – I probably would have a hard time.

In contrast, the puppeteer was able to rely on exploration with tangible materials to aid his ideation as he generates motion ideas for such abstract characters. In general, the physical objects played a major role in the Puppeteer's design process, the materials directly influencing movement:

> **Puppeteer** [The way we move] becomes unconscious, becomes habit, becomes muscle memory, becomes us. [Using a puppet provides] a sense of allowing your body a chance – and your mind a chance – to shift its perspective. You add new limitations onto yourself and create new avenues for yourself.

He articulated the value of a physical object: it provides additional movement constraints, suggests new movement qualities because of those constraints, and provides some "separation from oneself" throughout the creative process. While tangible "puppets" – called maquettes – were frequently used in the early days of animation (Knep et al., 1995), they are less frequently used now, and the Animator had not used them in her 3D animation projects. Her design process centers around digital characters, which have no analogous qualities.

Observation and attention to detail

The Animator also described the "misconception" that animators often feel early in their career, when they incorrectly believe they can simply generate natural movement without first engaging in focused observation:

> **Animator** Even right now, you talking to me – you think you know what you're doing, but your shoulder is moving and your head is nodding and you don't notice the frequency at which it's nodding. We think we do, but we don't. You need help to go to the source of the movement and seek the truth of the animation, which is recreating life.

Both practitioners articulated strong attention to the way subtle and nuanced movement design influences the final character.

Summary

– In summary, movement qualities are very important to character design in both contexts, and the Puppeteer finds that incorporating physical materials into his character design process is an extremely effective method for positively influencing the movements and characters he generates, especially for abstract characters. As we reflected on these interviews, we generated the following questions, which this chapter seeks to address: *Would an animator get similar benefits from incorporating materials into their design process? In what ways might the Found Object puppeteering technique positively influence an animator's style, or exploration process? How might we design a computational system that allows such material explorations? Would a new or augmented animation tool fit into an animator's existing workflow?* In this work, we seek to answer how we might design a computational system which incorporates the material exploration that the Puppeteer found so essential.

We also discussed the role of computational tools in animation with the Animator, who repeatedly emphasized the importance of developing skills in the "art form of animation", and of not getting hung up on the specific animation software in use. She discussed the way novice animators are sometimes undermined as they begin their journey to learn animation:

> **Animator** We all say "animation is recreating life" but then the first thing that new animators do is get in front of a computer and try to learn software – they forget that life aspect.

We interpret this as a call to the importance of observation of the physical world in animation. The combination of the Puppeteer's physical materials – or jigs, because they helpfully constrain movement – and the Animator's desire for novice animators to develop an eye for movement suggests the potential value in incorporating physical objects into the animation process.

6.4 PuppetJig

Throughout the formative interviews, we were struck by the role that materials played in the Puppeteer's process. While both experts discussed the importance of varied movement qualities, we wondered how much the digital "material" of 3D animation influenced the final outcome for those using 3D animation tools. The core idea behind PuppetJig is finding a way to incorporate the same types of physical materials used by the Puppeteer into digital animation workflows in order to enhance sensitivity and attention to the physical movement qualities valued by the Animator.

The Puppeteer described his materials as helpfully constraining his movements, much like the way that jigs and fixtures support woodworkers by providing selective constraints to motion. While jigs in woodworking are typically solid and hold cutting materials securely in place, and the Puppeteer used soft or flexible materials such as a napkin or a jacket, the core idea of an external tool that helpfully limits movement remains the same. We therefore also refer to the materials we incorporate into the animation process as *jigs*.

In order to incorporate physical jigs into the animation process, we needed to develop an animation system that 1) provides extremely precise controls for manipulating digital characters, and 2) allows for the incorporation of physical materials that may occlude the hands into the animator design workflow. To fit into existing animation workflows and maintain ecological validity, our tool should utilize familiar rigging, modeling, and animating software. To satisfy this last requirement, we use the open-source 3D CAD application Blender for the rigging and modeling of our digital characters. The second requirement eliminates many otherwise promising solutions: even state of the art hand-tracking libraries are not designed to work when the hands are occluded, for example. Instead, we use HTC Vive controllers, which are accurate even when partially or mostly occluded, and provide a more robust connection between the digital and physical worlds. The HTC Vive is a fully immersive headset for virtual reality. In addition to a headset, it provides hand-held controllers, and various wireless tracking devices. The HTC Vive controllers provide centimetre-level accurate tracking, thereby satisfying the first requirement especially for an early sketching tool (Buxton, 2010). By displaying the model on a desktop monitor we eliminate any need to repeatedly remove and replace the headset (a frustrating barrier to creation in the world of VR (Thoravi Kumaravel et al., 2019)) which would violate our original goal of creating a rapid sketching tool. Below we describe the technical architecture of PuppetJig, and the evaluation we carried out to assess the system.

6.4.1 PuppetJig Technical Architecture

PuppetJig is a system that enables animators to manipulate a digital character while also interacting with physical material jigs, or otherwise taking advantage of features in the physical world (e.g., gravity, momentum). It shares important features with other motion capture systems: both our system and other motion capture systems allow animators to capture performed body movement. However, there are important distinctions: our system does not require a full-body tracking outfit, instead the only tracked components are the controllers. This makes tracked movement simpler to generate and allows for quicker transitions between performing and editing, key to any creative process (Simon, 1969). Our system is designed to support rapid, early ideation in the pre-production character design process where designs are meant to stimulate conversation; any generated character movement is not meant become part of the final production. In this way, the generated movement can be understood as an early sketch, and is not meant to be highly polished or complete.

The system consists of three components (see Figure 6.5):

- The Animation Tool – this provides access to the rig and 3D model. The Animation Tool is Blender, an open source 2D/3D content creation tool [2], running on a desktop

[2]Version 2.93, `https://www.blender.org/`

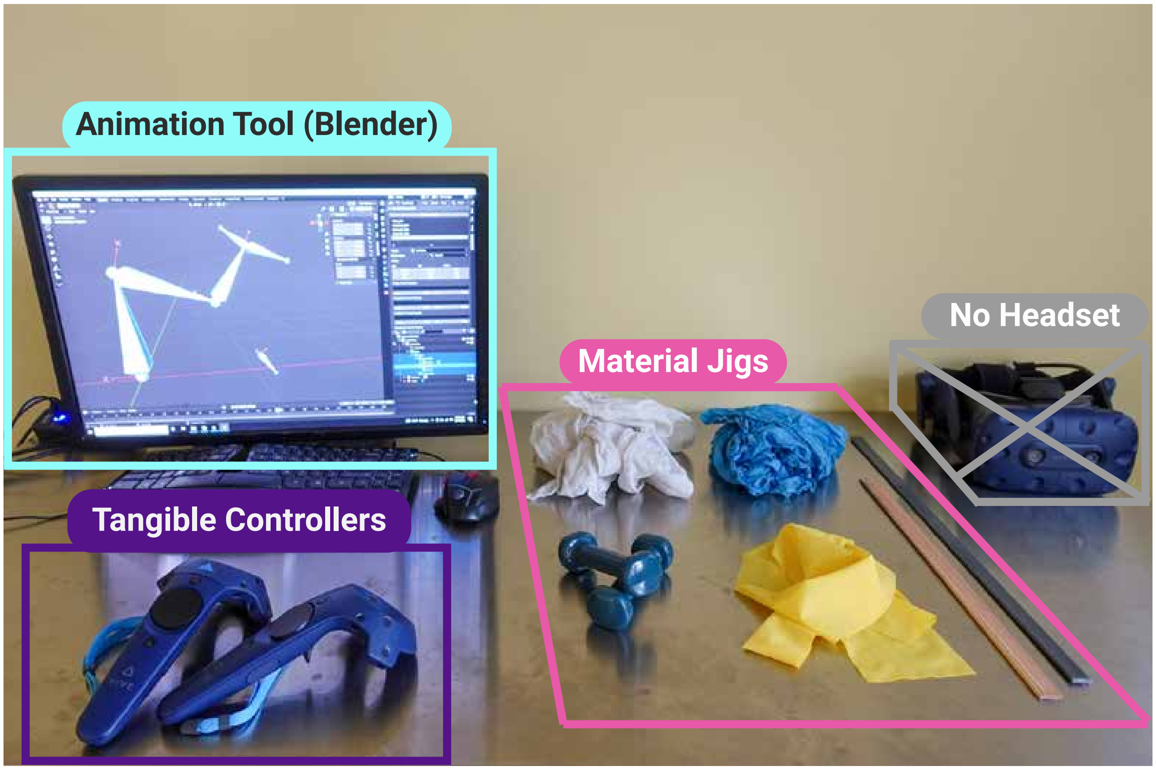

Figure 6.5: PuppetJig consists of 1) the animation tool Blender running on a desktop computer, 2) HTC Vive controllers, allowing tangible manipulation of the digital model, and 3) material "jigs" for the designer to manipulate during ideation. Note that no headset is required: the digital puppet is viewable through the desktop computer monitor.

computer. The model can be adjusted with either the keyboard and mouse, or the tangible controllers. Blender also provides basic animation functionality such as keyframe recording, rigging controls, inverse kinematics, etc.

- The Tangible Controllers – Two HTC Vive controllers provide centimetre-level accurate position tracking, and act as a translator between the physical world and the digital one. Using a custom script[3] and the opensource library PyOpenVR[4], we stream location data from the controllers into Blender, where they change the location and orientation of a selected character.

- Material Jigs – based on the Puppeteer's described technique, we collected a variety of physical objects for animators to use as jigs during their animation process, including weights, a stretchy band, different kinds of fabric, and a plastic bar (see Figure 6.5).

[3]The open-source software is available here: https://github.com/molecule/puppet-script
[4]https://github.com/cmbruns/pyopenvr

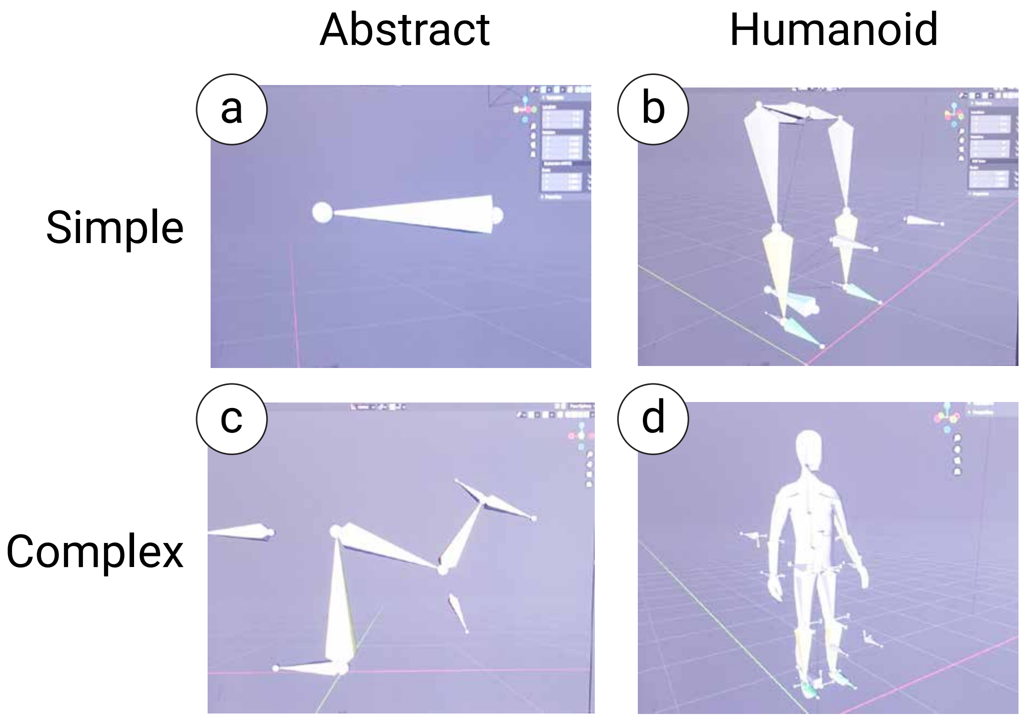

Figure 6.6: Four 3D models provided to participants during the user study. a) the simple abstract model provides almost a direct mapping to the controller, providing a good baseline for understanding the system. As expected, participants immediately ascribed personality and a story to even this simple geometric shape (Heider et al., 1944). b) Two ankle bones and a pole target located at the knee control these humanoid legs. c) the complex abstract character uses inverse kinematics to move two bones by controlling a bone connected to the head bone. d) The full humanoid includes more than 5 control bones, and multiple pole targets providing motion constraints.

To use the system, an animator first creates or downloads a 3D rig (a standard first step in all animation). Next, the animator opens the custom UI , and connects any single bone in the armature to each controller. Now the controller movement is bound to the 3D rig, which allows the animator to control the digital character with physical movements in the real world. Optionally, the animator can use the material jigs to influence, perturb, inspire, and shape their movements, similar to the way the Puppeteer used materials in his design process (see Section 6.3).

6.5 PuppetJig Evaluation

Evaluating novel toolkits is notoriously difficult (Olsen Jr, 2007), sometimes – as in the case of usability assessments – even considered harmful (Greenberg et al., 2008). Beyond usability evaluations, there are a variety of strategies that can be used to assess toolkit effectiveness (Ledo, Houben, et al., 2018). Like many novel toolkits, PuppetJig requires time and effort to build familiarity and incorporate into a workflow, meaning such a tool would not typically be considered a good candidate for lab usability studies (Ledo, Vermeulen, Carpendale, Greenberg, L. Oehlberg, et al., 2019; Greenberg et al., 2008). Instead, the focus of our user study was not on usability, but rather on understanding how incorporating physical elements as a first-class design material alters the design decisions taken by practitioners even during a first encounter. We therefore invited two novice animators in to experience the tool.

6.5.1 Procedure

Both participants visited our lab for a 1.5 hour workshop and was compensated $40. Each session consisted of 1) interview on background and personal design practice, 2) a warm-up tutorial 3) a series of exploratory design tasks following a think-out-loud protocol and 4) a post-study interview. Participants were introduced to the tangible controllers first, while learning to control a single bone (see the simple abstract model in Figure 6.6a), and learning how to move the controller in physical space to control the digital character. Next, they were introduced to the notion of the physical jigs: *"When puppeteers design a new character, they often play with different materials as they're exploring. We've provided these different materials for you to use as you think about the character you are designing. Interacting with a physical material might influence how the final movement looks"*. After participants had experienced the simple abstract character and the jigs, participants proceeded to the exploratory design task. Participants were instructed to iterate on a new character design, and to create two 5-10 second scenes (one with low energy and one with high energy) where an audience would learn about that character through the way that they move. Both participants chose to design their movement using the complex abstract character (see Figure 6.6c). During the study, participants chose which found object material jig(s) to use while holding the controllers and manipulating the on-screen digital character.

We recorded and transcribed what each participant said while thinking-aloud as they experimented with the tool for the first time. We then performed a thematic analysis on their transcribed quotes, and synthesized our findings into themes. This study design allowed us to observe the way the tool affects the design process on a first encounter, with designers who are new to the system.

Participants

The study was conducted with two [5] novice designers (avg. 29 years of age, 2 female). Participants were recruited from university mailing lists in Art, Architecture, Design, and Computer Science. Prior experience with 3D modeling was self-reported in a preliminary

[5]Due to a spike in COVID-19 cases in our area, we unfortunately had to cancel the vast majority of scheduled participants.

survey; we purposefully recruited participants with varying levels of expertise in animation: one participant reported intermediate experience with animation, and the other participant had no prior experience. Since we have a small number of participants, we describe them in more detail to further contextualize their responses:

P1 - P1 is learning Blender, and has intermediate experience - she has used it for several ongoing animation projects. Her background is in product design, and while she has primarily worked on websites up until now, she is very interested in tangible experience design.

P2 - P2 has a background in psychology, and has zero prior experience with animation, or animation tools. She is a film buff, and considers herself well-versed in animated movies as an artform, but has never created animation of her own.

6.5.2 PuppetJig Study Results

Even in a brief workshop-style experience with limited exposure to the tool and this method of working with digital animation, users readily engaged in unique movement-generating behaviour. See Figure 6.2, right for examples of jig exploration our participants engaged in.

Access to Jigs Influenced Design Process and Outcome

P1, who has some prior experience designing animation in Blender, compared her experience using PuppetJig with Blender. In particular, when designing a "low energy" experience for her character, she experimented with weights as jigs. P1 connected the feeling of heaviness with the increased weight of the emotional message she was hoping to convey:

> **P1** Low energy means I have a lot buried in my shoulder and in my mind. That's how it feels - your body is very heavy. I just want to see what that would do to my hand and my character if there's actually weight on it.

While she was familiar with Blender's built-in parameter to increase the weight of a character's body part, the experience of physically manipulating weights as she performed the digital puppet's movements impacted her design experience. She described the way she might update the "weight" of an object in Blender, and compared that with the experience of holding varying amounts of weights while animating with PuppetJig, which she described as "the real version" of such a design choice. The tool created an embodied experience with weight:

> **P1** [This tool] is a way to embody when I change the metrics or parameters in the software. Without this tool, it was just a click from the mouse and it doesn't feel that real. I thought it was real before, but now, with this, I feel like this is great – way more real!

P2 also engaged in extremely physical exploration of the tool, moving around the room, waving her arms in the air, bouncing the controller on the fabric, and swinging the controllers around. She felt that the material jigs anthropomorphized the movement that the tool helped her create:

P2 Using this free-flowing and bouncy material almost personifies this figure in a way. If I use it just with my hand it's more controlled but this makes [the movement] more unpredictable

P2 found this controlled unpredictability an appealing and compelling addition to her character during the creation process.

Tangible Control System Enabled Physical Explorations

In addition to using the jigs to modify her character's movement qualities, P1 experimented with using the tangible controllers to incorporate gravity and momentum into the digital character movement. She tied the controller to a piece of stretchy fabric, and let it drop as an expression of despair:

P1 I like how it just hangs here. Because when you drop everything you're like "I don't have any hope - I'm so sad, no, no."

Similarly, P2 described a compelling sense of less control when using the material jigs, which she felt improved the movement:

P2 I really like using these [materials] because you have more range and it comes to life more. It's just less structured.

Both participants felt the material jigs positively affected their overall design experience.

6.6 Discussion

By incorporating the material jigs into the design process, our participants developed their sense awareness (Ghefaili, 2003) of the physical world. That is, in addition to choosing jigs to influence, shape, refine, or limit their movement, participants also began to experiment with the way other physical elements such as gravity and momentum could influence their character's motion design. This increased sensitivity to physical effects and the way such effects could influence their design resonates with the Animator's goal of encouraging novice animators to "recreate life". In addition to material jigs, future tools could explore the use of software jigs as have been introduced in woodworking (Tian et al., 2021). Additionally, digital jigs such as a gyroscope, a buzzer, or an electromagnet could further shape the motion design experience, and may influence the puppeteer's analog methods.

While novice animators wouldn't be expected to generate polished animations during a first encounter with any novel animation tool, participants did deeply engage with the design process, and articulated perspectives on movement design that align with the goals of both the Animator and the Puppeteer. Even with the simple abstract model (see Figure 6.6), participants immediately jumped up from the table, and used the provided materials to investigate different movement qualities. Participants did tend to anthropomorphize this

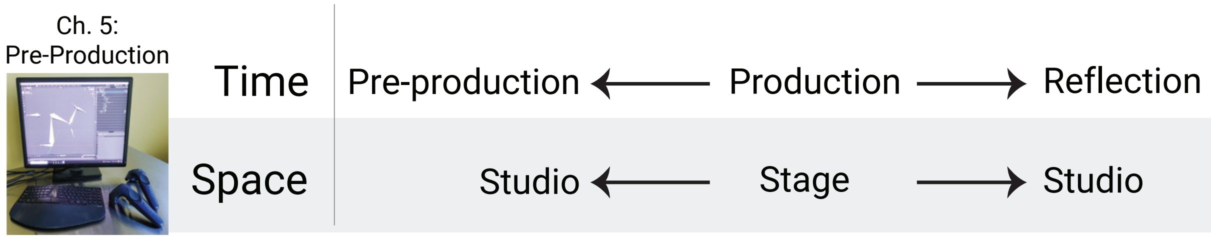

Figure 6.7: This chapter described a specific tool to support some elements of pre-production creative work in the context of animation.

simple geometric shape, probably a demonstration of the classic Heider and Simmel Illusion, where observers ascribe personality to moving geometric shapes (Heider et al., 1944). As a next step, we hope to invite in participants who are more familiar with Blender, as well as expert animators to try the techniques and assess how such infleunces might fit into the professional's workflow.

Our findings position our tool as a low-fidelity, early prototype "sketching" style interface ideal for quickly generating a multiple options for movement, or for exploring a character's movement style. We imagine such tools used for exploratory animation work in tandem with established animation pipelines, which are already highly effective for precise control.

6.7 Limitations and Future Work

While this system requires the fairly extensive HTC Vive setup to use, we hope to inspire future designers to think about smaller, even more accessible tools that support the capturing, saving, collecting, or collaging of motion. Similar to the way many music artists keep collections of "found" audio clips (such as a dentists' drill, or the beep of a traffic light notification), we envision a broader engagement with movement as a design material. For example, imagine being able to quickly design the wave your Bitmoji does in a conversation with a friend. We imagine tools that support increased engagement with movement across many contexts: animation, application design, social media.

6.8 Conclusion

In this chapter, I have taken the first steps towards investigating the benefits of incorporating material objects as jigs into the animator's workflow. Our initial user study is an exploratory probe into the impact Found Object puppeteering techniques can have on novice animators as they engage in movement sketching. I end by celebrating the benefits of drawing on expertise from two separate but related fields, each with complimentary approaches.

I have also shown one example of a tool designed with the strategies identified in Chapter 5. These strategies align with the sensitizing concepts, especially embodiment and aesthetics.

Chapter 7

Conclusion

This final chapter reviews the contributions of this work, describes limitations and their impact on our findings, and concludes with a future envisionments of the Dramaturgical Framework for Interactive Performance.

7.1 Dramaturgical Framework for Interactive Performance

In this dissertation I have introduced the Dramaturgical Framework for Interactive Performance, which consists of expanded definitions of **roles**, **time**, and **space**. I expanded the notions of time and space in the context of three performance environments: formal productions, informal performances, and pre-production creative efforts. In each context, I identify opportunities for design that emerge from these expanded definitions of time and space.

In terms of roles, each chapter focuses on a different role (see Figure 7.2). I identified three core guiding principles that shape the ultimate design outcomes for each role: 1) Spectatorship is active, 2) Performance experiences extend beyond the stage, and 3) Performance occurs in daily life. Note the design space identifies opportunities for design to support the role of the production team.

I have also introduced five core sensitizing concepts for any dramaturg seeking to design technologically-mediated theatre experiences: *liveness, aesthetics, agency, immersion,* and *embodiment*. I argue that work at the intersection of performance and technology may benefit from drawing on the extensive literature in the field of Performance, Theatre, and Audience Studies (as described in detail in sections 1.3.1 and 1.3.2). By cross-pollinating perspectives from these existing fields, I identify roles, space, and time as the most important elements to consider when designing technology in, around, and for performance. I identified these through my collaborations with expert theatre practitioners.

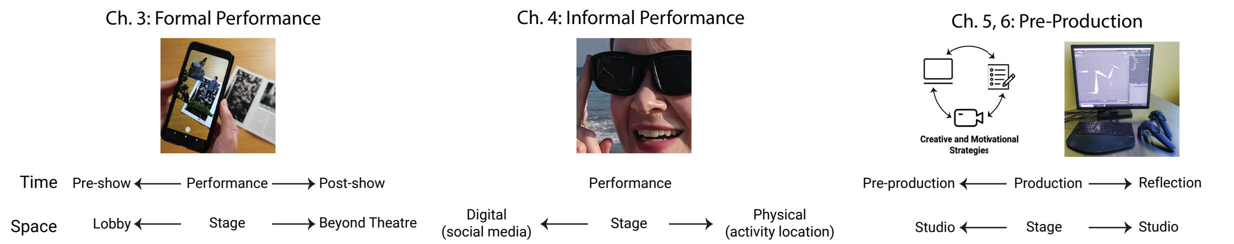

Figure 7.1: A summary of how each chapter expands the notions of space and time, in their respective contexts.

7.2 Restatement of Contributions

When designing technology that can be incorporated into the expanded context of a performance, designers must consider many different aspects of the world of performance: where and when technology can be incorporated into the production pipeline, what kind of experience the audience and performers will have, and what new interaction techniques are needed to support the core needs of all participants. Designing technology in these contexts also has the potential to suggest new interaction techniques which may shape the design of technology in other contexts beyond performance.

My thesis has shown the importance of taking into account **roles**, **time**, and **space**, and especially the benefits of embracing an expanded definition for each. In particular, throughout this thesis I've shown how current framing around audience engagement has shaped current trends in technology design and I've shown how developing an understanding of the history of technology in performance and drawing on the extensive body of literature from Audience Studies (Sedgman, 2016; Sedgman, 2018; Freshwater, 2009; Freshwater, 2011; Bennett, 1997; Brook, 1996; Carlson, 1989; Jackson et al., 2007; Keidan et al., 2015; Frieze, 2016; R. Goldberg, 2001; Abercrombie et al., 1998; Brecht, 2014; De Kosnik et al., 2019; Keidan et al., 2015; Heim, 2015; Butsch, 2000; Butsch, 2008; Blackadder, 2003; Murray et al., 2016; Carlson, 2013) constructively supports the design of new systems.

In this dissertation, I motivated and argued for an expanded design space for incorporating technology into performances. I defined the Dramaturgical Framework for Interactive Performance as a collection of sensitizing concepts to help frame and support work at the intersection of performance and technology and addressed two research questions:

RQ1: What tools, strategies, techniques, insights, and systems from the world of performance can — and should — inform the design and analysis of both new and existing technology?

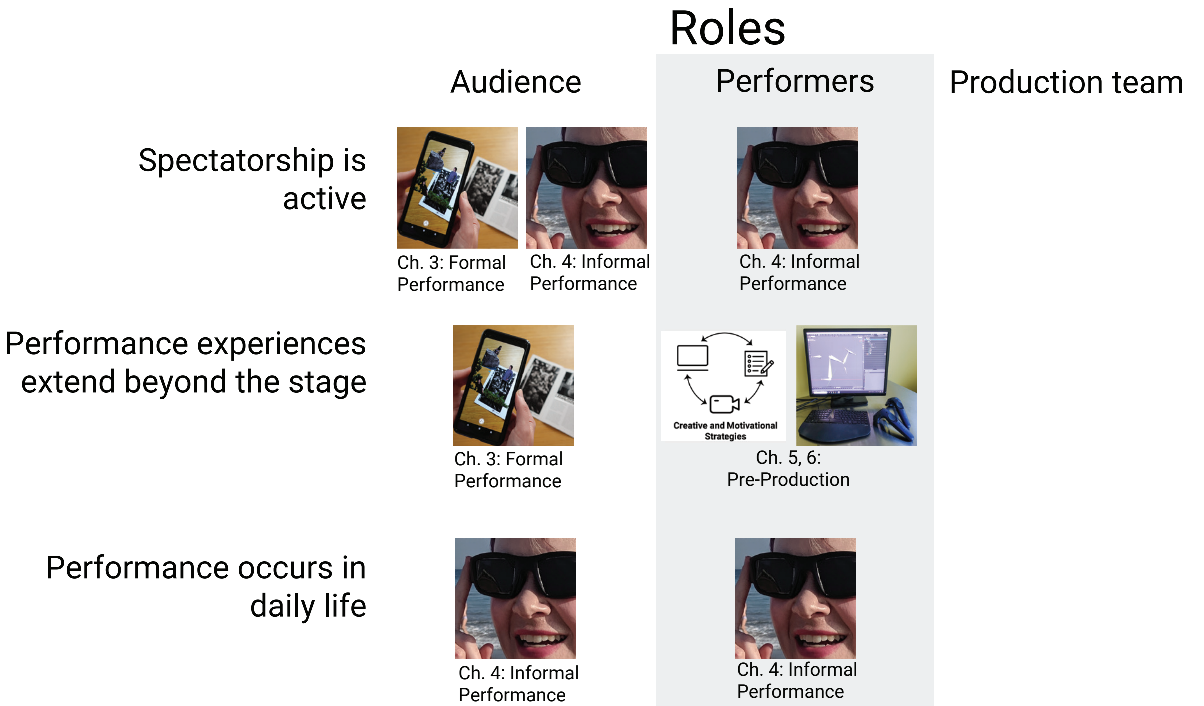

Figure 7.2: A summary of how each chapter addresses roles. I also introduce the role of the "production team". Throughout these projects, I played the role of the production team, creating the technology and incorporating it into rehearsal where appropriate. The production team represents another role that might benefit from designing technology, either for creativity support or for logistical support.

RQ2: What new interaction techniques are suggested by the needs, goals, opportunities, and constraints of performance, and how can technology be used to expand existing notions of space, time, roles, and the creative process in the context of performance?

First, in Chapter 3, I articulated the results of embracing the Audience Studies perspective on agentic audiences (see Sections 1.3.2 and 1.3.1). Through the 4-month co-design process, I iteratively developed a set of guidelines for designing technology-mediated theatre, and presented three functional prototypes that embody these guidelines. This perspective lead directly to our expanded notion of the design space of a live performance, including the *time* and *space* used before and after the performance.

Then, in Chapter 4, I expanded the notions of *time* and *space* yet again, viewing social media as a site for digitally-mediated performances. I described how the field of Audience Studies can shape the design of an informal performance for both *roles* of audience and performer. I introduced the Audience Studies understanding of audiences as 'active' and 'engaged' and used this as a lens through which to analyze the design of an in-the-moment experience sharing application that runs on camera glasses. I articulated how the *shared camera* — an interaction technique that embodies the notion of spectator as engaged participant — supports enhanced feelings of togetherness, intimacy, and closeness, while not disrupting concerns about control and privacy.

Next, in Chapters 5 and 6, I took this expanded notion of *time* in relation to performance and identified *pre-production* as another *time-space* in which to introduce technology. In Chapter 5 I identified four strategies that performance practitioners use in their daily life to manage and structure their creative work. In Chapter 6 I constructed a tool that scaffolds novice animators into these strategies, and supports an *embodied* relationship with a low-cost movement sketching tool. I combined creative techniques and strategies from everyday real life into the world of a hybrid real-digital animation context.

Collectively, these four projects represent three perspectives on incorporating technology into performance. Each project demonstrates the benefits associated with incorporating the Dramaturgical Framework for Interactive Performance, and especially how the expanded notions of time, space, and role result in novel, compelling, and dramaturgically-appropriate interaction designs.

7.3 Limitations

The approaches presented in these projects represent new techniques and strategies for engaging with the intersection of performance and technology. A major limitation of this work is the focus on Western and especially culturally white performing contexts. As one counter-example, Black performing spaces (e.g., a Black church) have rich traditions of audience interactions (e.g., call-and-response), and may have an entirely different understanding of 'audience' and 'interactivity' than any described here. Audiences in Japan and other areas of Eastern Asia are known among professional performers for distinct and unique audience responses (e.g., minimal clapping, no laughter or verbal responses). While researchers have explore ways to relate to the *performance* aspect across cultures (e.g., see (Escobar Varela et al., 2017) for a system built around traditional Indonesian Wayang Kulit), future work would benefit from an increased engagement with *audience* behaviour in different cultural contexts.

The way that performance spaces even in modern times are often segregated comes out of persisting racist policies and Western (often: white) cultural expectations seen across domains (Knopper, 2021; Lopez, 2020; Doherty, 2020). This additionally relates to a shift in cultural norms, and especially a focus on controlling other audience members, which Kirsty Sedgman discusses in her book, *The Reasonable Audience* (2018). I briefly described the history of 'audience behaviour policing' in Chapter 1, but understanding the social norms that shape our theatrical experience is important to not only enriching everyone's experiences, but also to identifying and deconstructing racist ideologies that underpin some of our public behaviour. It is crucial that future study of technology and performance focus on expanded cultural engagement. While this work tried to engage with diverse *forms* of performance (formal theatre show on-stage, social media as a site for informal performances, and the animation production pipeline), there are many culturally diverse performance spaces and contexts that remain to be explored.

7.4 Future work

Future researchers, designers, and practitioners working at the intersection of technology and performance may find it beneficial to apply, extend, or modify this framework (using them more as sensitizing concepts, as described in Chapter 1). Researchers could continue to explore and expand 'modes of attention' as technology continues to evolve and provide access to novel perceptual input Freshwater, 2011, p. 19.

7.4.1 Extended Theatrical Experiences

Expanding the design space of a 'performance' to include the time leading up to and extending a performances introduces opportunities to create experiences that evolve over time. For example, a future version of the Augmented Playbill described in Chapter 3 could display updated content over time. The Playbill could continually update, remaining fresh for weeks, months, or even years. This could allow old playbills stored as a keepsake to prompt memories as it is revisited over time. The design of such a system raises questions about how and when to change: should the characters in the Playbill have a life of their own that continues whether or not anyone is looking?, or do they evolve in response to interaction by the audience member? If so, who should be considered the author of the final piece? How personalized to the audience member should this evolution be? In either case, how does the audience member get notified about such changes? Would there be benefits to designing geo-located content changes, so the same playbill keeps track of in-person theatre attendance long-term? Another opportunity for computational systems incorporated into a theatre production is increased personalization of the experiences, based on the audience members' preferences and interests. For example, if an audience members is particularly drawn to a certain character, could the evolving content highlight that character, adding additional details about the story outside the existing narrative? What would theatre practitioners do with the opportunity to expand their characters and storylines, and how might such an opportunity result in directors witholding such character information as an interesting contrast? How might such a system impact our understanding of authorship? How might future designers resolve the tension between artists wanting additional space for story content and audiences desiring behind-the-scenes information? Could such long-term engagement be a useful way for theatremakers to elicit feedback from their audiences? By expanding the design space around how and when to incorporate technology into theatrical shows, designers can begin to answer such questions.

In addition to the contexts explored in this dissertation, the Dramaturgical Framework for Interactive Performance may be relevant to other contexts as well, from teaching, to

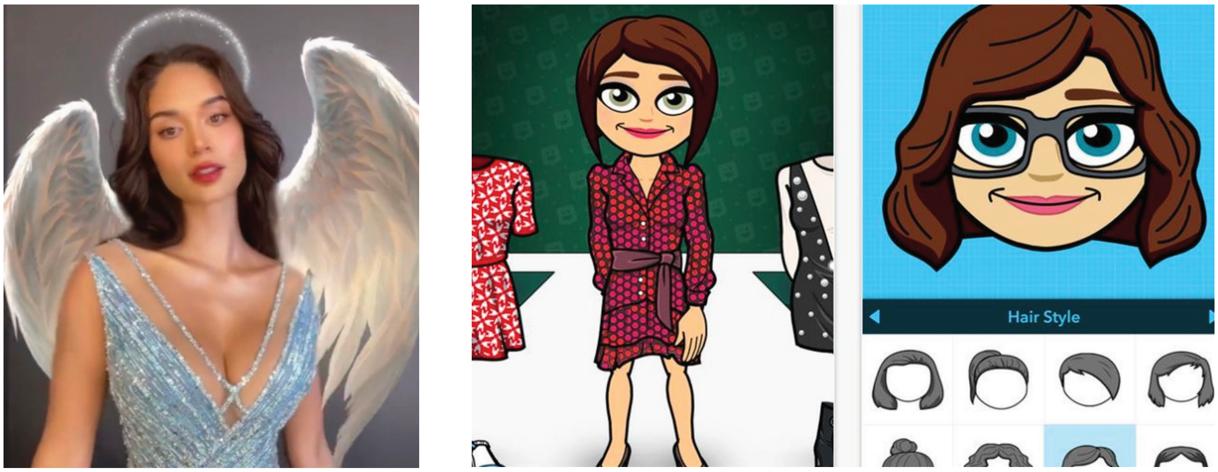

Figure 7.3: Left: An example of an animated filter on Tiktok, which adds flapping angel wins and a glowing halo to a video. Right: The character design screen of Bitmoji, a personalized character creation tool used on Snapchat.

roller coasters. Following the expanded notions of time and space described in Chapter 2, tools could be designed to enhance the experience *around* such contexts, such as waiting in line for a roller coaster, or practicing a lecture presentation.

7.4.2 Authoring Systems

As we learned in Chapter 5 and Chapter 6, practitioners working in performing contexts use unique creative strategies, and may benefit from technological systems designed specifically for them. For example, expanding the techniques described in Chapter 6, practitioners could introduce additional jigs into their workflow, and designers could add support for software jigs to additionally constrain, define, and shape movement (Tian et al., 2021).

An important next step after creating and capturing such movement qualities, is to make these movements available in *libraries of motion*. Similar to the way that communities built around sharing 3D models revolutionized 3D printing, shared movement paths could revolutionize the authoring of digital characters across domains. Imagine the ability to define the movement of an avatar in a virtual reality world, or of a livestreamed digital character, or of a custom AR filter on TikTok [1] or of an animated Bitmoji [2] shared on social media through custom and remixed movements (see Figure 7.3). One primary goal of this project was to increase the accessibility of animation. A future tool could be designed to use either computer vision or the sensors in a phone to lower the threshold for participation in animation even more. As remote work becomes more the norm, the ability to customize our digital avatars will continue to become an important space for self-expression.

[1] A popular video-based social media platform

[2] A personalized character creator used on Snapchat.

In addition to movement as a potentially rich design space, sound represents an under-appreciated area of exploration. Sound designers need to engage in a highly iterative design process while developing the 'sound landscape' of a movie (for example), and providing authors for tools to remix, manipulate, record, and generate sounds for use in video and film could elevate this medium as a first class design material. Many music and foley artists already keep collections of "found" audio clips (One well-known example is the way Billie Eilish and Finneas incorporated a recording of a dentists' drill, or the beep of a traffic light notification into their music), and I envision a broader engagement with both movement and sound as design materials. For example, imagine being able to quickly design the wave your Bitmoji does in a conversation with a friend. I imagine tools that support both 1) an increased engagement with movement across many contexts: animation, application design, and social media, and performance as well as 2) a way to easily share, remix, collage, and subscribe to movement streams.

Pre-production represents a rich space for potential design. Animators often need to search for animation clips that represent a particular emotion or scene for which they are designing. A search engine that would allow an animator to search through a collection of movie clips for a character type and emotional state, (e.g., "young man angry crying") would allow them to quickly access multiple 'real-life' examples for use in a new animation. (This was a tool specifically described and requested by the expert animator I interviewed in Chapter 6). Another version allows a performer to perform a motion, and allow the system to automatically match the action with similar ones in the "Motion Library".

7.4.3 Asking Audiences Directly

For some reason, the fields of Audience, Theatre, and Performance studies have long had a contentious relationship with directly asking audiences about their experiences (Freshwater, 2011). Surveys, interviews, and campaigns to understand how audience members experience a show seem to primarily fall under the purview of marketing, rather than research. As such, data-collection methods that ask the audience about their experience has become almost anathema among audience studies researchers.

Mimicking the way the design of computing systems has evolved to value user input, and has developed validated techniques and methods for eliciting user feedback, future projects should seek to design "audience-centered" data collection methods, which would be valuable to both the fields of HCI and Audience Studies. I foresee a potential for HCI researchers to incorporate their deep understanding of and respect for participants into systems that collect diverse forms of audience feedback. Similar to the way HCI researchers don't always directly ask participants what they want, but has instead evolved subtle and nuanced methods for assessing, observing, and measuring user experience that would be very effective in this situation. Such a perspective would additionally allow future designers to consider audience engagement with performances in the context of the entire evening: "where else audience members might go and whom they are spending the evening with" (Freshwater, 2011, p 31).

7.4.4 Understanding How the Audience Affects Performers

While many of the projects discussed in this thesis focused on the audience experience and how computational tools can enhance that, further understanding the way the audience affects performers is a fruitful area for future inquiry. Laurel (2013) reminds us that "the audience's audible and visible responses...are often used by the actors to tweak their performance in real time (this, by the way, reminds us that theatrical audiences are not strictly "passive" and may be said to influence the action)". Understanding how, why, and when performers use audience response to shape their performance is a very exciting area for future researchers to explore. Rather than only telling audiences about their own reactions, would it be possible to visualize or enhance audience natural responses to make them more visible to performers? Would performers also change their performance based on post-show audience interaction with these new technologies (such as the augmented playbill)? How might this support performers' long-term creative development?

7.4.5 Process-focused tools

As described in Chapter 5, performers have unique creative and motivational strategies which remain under-supported by creativity support tools. Here I briefly describe envisioned applications that operationalize a subset of these heuristics.

VocalVideo

Yesenia is a classical singer. With a concert approaching next month, she has been rehearsing for four hours each day, focusing on expression and emotion. Though Yesenia records, plays back, and reflects on the audio of her sessions, she feels stuck on a particular piece. One day, Yesenia uses the VocalVideo app to track her rehearsal instead and sees a video-only playback of her session. At first surprised by the lack of audio, Yesenia soon notices an issue with the shape of her mouth when singing a few phrases. The strategic omission of audio draws Yesenia's attention to a form-related problem that gives her a new avenue to focus on and improve her vocals in the days leading up to her concert.

Defamiliarization Engine

Somchai opens his recording from last night's performance. As he begins reviewing his dance clips, the thumbnails in the sidebar automatically update, each showing a different view: one applies an edge-highlighting algorithm to emphasize his body's outline; another uses AI to generate a cartoon version of himself; the third simply flips it along the vertical axis. Each acts as a window, providing a way for Somchai to see his developing dance technique with a new perspective.

Trash your first draft.

A story from my own background:

> **Author** I once had a laptop that would completely die if the power chord got unplugged. This was before the days of Google Docs, and I was not in the habit of feverishly hitting Ctrl-S frequently to save my work. After an all-day writing session, the chord got pulled – the draft was gone. 30 minutes of crying later I sat down to retype it. The second draft was without a doubt a vast improvement on the first.

For those who can't bear to give up artifact creation entirely, deliberately deleting them to start fresh may be another way to get some of the benefits of Strategic Forgetting and Omission-like strategies. Throw out your first draft completely and start fresh. A "counter-functional" (Pierce et al., 2014) system that stores a draft, but in an unreachable state might provide the emotional benefits of knowing it's "safe", and the editorial benefits of needing to start fresh.

Give your darlings a haircut

On the opposite side of the spectrum, some creators may find more emotional benefits in saving everything they generate. For these tender souls, advice to "kill your darlings" may be too harsh. Even as they edit, they may prefer to move all "deleted" lines to another file, operating under the fiction that it's not gone forever. While re-use may or may not ever happen, saving the pieces "for later" can give creators the courage to cut boldly. A writing tool that provides a more visible, permanent clipboard for storing these "amputated bodies" (in the language of Torres, Sterman, et al. (2018)) may support this need.

Aesthetic memories

Chantal is a storyboarding artist who works across low-fidelity mediums and interfaces with animators who work in high-fidelity mediums. Recently, Chantal has been experiencing a disconnect from the final animated projects developed from their low-fidelity pencil sketches. They feel like their sketches go into a void and emerge completely transformed, losing their artistic voice along the way. To redefine their practice around preserving their work, Chantal downloads a storyboard scrapbooking application, where Chantal can save snapshots of their low-fidelity sketches annotated with the associated stories, personal touches, and their favorite memory creating it. The aesthetically pleasing record of their work motivates Chantal to engage in their craft with more satisfaction, untethered to the final polished outcomes generated by the animators.

De-writer's-block

As a creative writer, Ines often feels burdened by "writer's block." Though she consistently carves out 1 hour a day to do free-writes, some days she produces ten paragraphs and other *days only a sentence or two, because nothing she writes meets her standards. Ines installs a text editor extension that helps her unleash her creativity when writing raw free-form text. When in "free-write mode", the extension detects when Ines is over-using the backspace functionality and when she keeps revisiting earlier parts of her writing. In response, the extension temporarily disables the backspace functionality and displays a gentle reminder on her screen to not judge her prior writing harshly, along with statistics about how much writing she has produced so far to foreground her progress. With the help of this extension, Ines learns more about her writing process and gradually adopts a judgement-free mindset, allowing her to produce higher volumes of free-writes without being immediately concerned about quality.*

Embodied Mode Switching

As she writes poetry, Ichika prefers not to focus on the overall structure – she never writes an outline. She lets the words arrive as they will, generating paragraphs organically. Later, when she's ready to start editing, Ichika reaches for her Head-Mounted Display. Her paragraphs are automatically placed around her in 3D space. She uses gestures to rearrange them around her, playing with the structure, seeing holes in the story she's building. She can zoom in to a paragraph, and rearrange it sentence by sentence, but typing is too effortful - this space is for editing, not generating.

AudioLight

As Kaspar finishes the first draft of his short story, he is eager to re-read and edit his work. However, after a month of focused writing, he has a tough time viewing his typed manuscript with a fresh perspective. Kaspar turns to the Audio-Light app, to engage with his work in a new light. The app prompts Kaspar to read his story out loud. As he vocalizes his written creation, his tone and pace reflect various emotions and reactions — delight, immersion, and at times, uncertainty. The Audio-Light app detects long pauses, sighs, and other expressions of confusion or hesitation in Kaspar's voice, marking them in a dynamic copy of the transcript alongside Kaspar's original short story text. Lines that Kaspar read at a slower pace are highlighted in a darker color. After his readthrough, Kaspar looks back at the highlighted and annotated transcript, notices previously neglected parts of his story, and reflects on what he realized at various points of the readthrough. Switching modes from typing text, to reading out loud and recording audio, to parsing a rich annotation of the transcript propelled Kaspar into a productive mode of iteration, as he rewrote, rearranged, and reimagined his short story in a new light.

Failure Celebration

Anjali is a creative photographer for an art magazine. During most photoshoots, Anjali produces over 1000 photographs with about 50 unique concepts, but heavily prunes her output before publishing only the top 3 best photographs. Anjali regrets the feeling of "wasted effort" and wonders if her discarded photographs have a life beyond the pruning process. At her next *photoshoot, Anjali wears some new headgear — the Photo Projector Cap, which can project existing photographs onto any photoshoot set. Loaded with Anjali's discarded photographs, the Photo Projector Cap reminds Anjali of past creative visions that did not make the cut but provide her with new photography inspiration when physically projected in a new photoshoot setup. For example, the angles in a previous photograph of some jumbo paperclips inspired the crisp layout of ribbons in one of her latest photographs, which made it to the top 3 for a recent shoot.*

Documountain

Myra is an independent design contractor who curates moodboards, designs typefaces, and produces brand assets. With over thirty years of experience with various companies, Myra is an expert at delivering standard design results but longs to be as creative and artistic as she once was earlier in her career. Wishing she could travel back in time, Myra revisits bins of her decades-old sketches and moodboards. She decides to use Documountain, a multimedia artifact documentation tool to digitize the precious artifacts from her prior work. Over the course of the next few days, Myra starts to add multimedia artifacts — images, video, audio, text, links, and more — of her ongoing projects into Documountain, where she can map the creative links between prior work and current work. Myra now sees Documountain as a living hub of her creative process, tracking her thought processes and evolving designs over time, which enables her to produce more inspired creative works every day.

7.5 Broader Impacts

My research emphasizes new hybrid approaches and values a diversity of expertise including computer scientists, performance studies researchers, novice designers, and educators. In fact, my work explicitly foregrounds this unique collaboration and argues it as essential in the creation of new and interdisciplinary perspectives. By combining deep knowledge of performance studies, new interaction techniques, compelling technology systems, and human-centered design, this dissertation is positioned to expand the design space for interactive computational systems.

This intersection of fields is also a powerful mechanism for engaging underrepresented groups such as women, aging populations, performers, other non-experts, and K-12 age children. My research identifies new recommendations for collaborations with diverse creative practitioners, new interaction techniques, new authoring mechanisms, and new design recommendations. Augmenting performance-based experiences with technological systems can enhance a theatrical experience, influence the way communication systems are designed, support the creative process, scaffold newcomers into healthy and effective creative practices, and enable new narrative structures.

Ultimately my goal is to create a space for those who consider themselves "non-": "non-professionals", "non-dancers", "non-singers". I want to invite them into a creative space of performance, provide them tools and systems to engage and create, to share and remix, to learn and grow and develop into joyful creators.

7.6 Summary

All three approaches presented in this dissertation acknowledge and celebrate the benefits of incorporating technology around – rather than into – performance. In Chapter 3, I identified design guidelines for incorporating technology around a formal, staged, theatre production. With Friendscope, I explored how social media can be understood as a site for performance. In Chapter 5 I identified four strategies used by expert creative practitioners as they manage their creative process. Lastly, with PuppetJig, I explore one embodiment of some of those creative processes in the context of animation and puppetry. By framing my findings as a Dramaturgical approach, I hope to encourage future designers to "sensitize" themselves to these concepts, without limiting their design efforts to those I've identified here. Instead, this work seeks to expand the collection of techniques for designing at the intersection of performance and technology.

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