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# Dance Transitions: What Forms of Technology Best Support Professional Dancers as They Learn New Movement Styles?

Elizabeth Walton      Wendy E. Mackay

<sup>1</sup>Université Paris-Saclay, CNRS, Inria, LISN  
91400 Orsay, France

walton@lri.fr, mackay@lri.fr

## ABSTRACT

Most current dance support technologies focus on dancers, teachers or choreographers who are engaged in a single activity. We are interested in creating tools that support professional dancers over longer periods of time, as their careers and personal practices evolve. We interviewed 12 professional and pre-professional dancers about a critical moment in their careers: the transition to a new dance style due to shifting interests, ageing or injury. We identify three key challenges—overcoming habits, learning new forms of movement, transitioning over time—and their strategies for addressing them. We argue that successful tools must help dancers change their mentality about new movement styles, rather than focusing solely on movement mechanics. We suggest three possible implications for design: develop “movement substrates” that handle multiple movement representations; integrate learning and reflection in a single session; and create movement definitions through movement. We conclude with a discussion of directions for future research.

## CCS CONCEPTS

- Human-centered computing → Empirical studies in HCI.

## KEYWORDS

Dance, Movement Support Tools, Transitions

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## 1 INTRODUCTION

We are motivated by a dance phenomenon previously unexplored within Human-Computer Interaction (HCI), but extensively present in professional dance: the transition from one dance style to another. Whether due to personal interest in dance [52] or parental interest in the benefits of dance training [9], children usually start studying ballet at a young age. Classical ballet is generally considered a good foundation for dance technique [1], so students interested in pursuing dance professionally tend to start with ballet training. However, not only is ballet very challenging technically, but jobs with professional ballet companies are scarce and highly competitive [52], and many careers are interrupted due to injuries [4] that can shorten or end a dancer's career [49]. As a result, many dancers leave ballet at some point in their career and transition to another style of dance. We argue that better understanding how people adjust to such transitions offers an opportunity for fundamentally reassessing the design of dance support tools.

When dancers struggle to learn new movement styles, they must also counteract their earlier training and ingrained habits, a process very different from the challenges they faced as novices learning each movement for the first time. Even though changing dance styles is extremely common, and professional dancers' careers depend on their success, the transition process itself remains unsupported, and each individual dancer must chart his or her own path. We therefore see an opportunity not only for the design of supportive technology, but also to add to our understanding of how to design for dance training in general.

In order to create effective technology, we must first understand dancers' lived experiences as they transition from one dance style to another. Our research questions are:

- What specific steps do dancers take to transition from ballet to a new dance style?

- What are the key obstacles they face?
- What are their key strategies for overcoming these obstacles?

Our goal is to use the insights gained from this analysis to inform the design of future technologies that can support such transitions. After first reviewing related work, we describe the results of an interview study with 12 pre- and fully professional dancers who transitioned from classical ballet to a new dance style. We conclude with three main implications for design and directions for future research.

## 2 RELATED WORK

Most dance support systems focus either on helping dancers learn new movements or helping choreographers create new works. Here, we focus on dance learning and choreography tools that have been assessed by pre-professional and professional dancers. Though some choreographers have embraced technology in their creation practice, many choreographers [43] and teachers [48] remain wary of integrating tools into the studio. We thus finish with an overview of the tools available to support dancers outside of the studio, in their professional careers.

### Support for Learning Dance

Multiple researchers ([32], [47]) augment the dance studio mirror with Kinect body tracking and movement recognition, which gives the dancer feedback as to the success of their performed movement. Others technologies include wearables [44] and online annotation capabilities ([43], [13]). Other researchers discuss the potential of artificial intelligence within the dance classroom ([50], [46]) as relevant technologies continue to be improved ([27], [29]). These systems, meant specifically for pre-professional and professional training, support dance style training for techniques with set movement vocabularies, such as classical ballet. Additionally, these systems fit into more traditional methods of dance teaching (see Raheb et al. [36]).

As dance teaching practices have evolved away from more traditional methods, researchers have increasingly embraced technology for reflection and self-evaluation [36]. Some designs allow the dancer to view themselves, but with a delay [35]. Others employ mixed reality that let dancers view themselves from different viewpoints ([53], [23]), see different augmented versions of themselves [37], or overlay a score (a tool still used in collegiate dance training)<sup>1</sup>. Alaoui et al. [2], in collaboration with the dance company Emio Greco|PC, developed a screen-based system which visualized certain movement qualities with a mass-spring system, allowing dancers to learn and experiment through computer

recognition of these qualities. Grosshauser et al. [22] sonified specific jumps via a system based on foot pressure that added another layer of information for communication and understanding of each movement. Soga et al. [25] created WebDance3D Dance Composer to generate contemporary movement sequences for sequence learning support and movement transition reflection. We are interested in the potential of tools that support reflection and that are not grounded in any specific vocabulary or technique, such as those used in mixed reality systems.

Beyond learning movements in a specific style, annotation-based tools support the common activity of learning previously created dance pieces that will later be re-staged and re-performed. The Choreographer's Notebook [43] allows for multi-modal annotation by a choreographer and dancers during the dance re-staging and performance preparation process. Riviere et al. [38] explored decomposition of choreography into segments with their iPad-based system MoveOn. They later studied the role of MoveOn in the ecology of artifacts in a real-life, 12-month dance re-staging of *Frame[d]* by Sidi Larbi Cherkaoui [39]. Although dancers who transition across styles usually study the movements for a particular technique within a particular choreography, we are interested in supporting the professional dancer outside of a specific classroom or theatre settings, but rather in their personal practice and development.

Each of the above tools offer the dancer a specific way to assess their own performance and progress as they learn. However, none focus on the "unlearning" that is required when transitioning from one dance style to another, nor do they account for the process of learning over long periods of time.

### Support for Choreography

Alaoui et al. [3] identify four categories of choreographic tools: reflective, generative, interactive and annotative. With advances in artificial intelligence, recent choreographic systems encapsulate both generative and interactive categories: the system can generate new contact and respond to the dancer during the interaction. For example, choreographer Wayne McGregor teamed with Google to create Living Archive<sup>2</sup>, an AI agent trained on a massive database of rehearsal and performance video which works with a dancer for choreographic creation. Similarly, choreographer Louise Crnkovic-Friis teamed up with a data scientist to explore choreographic opportunities with an AI-based partner [12]<sup>3</sup>. Choreographers continue to push the limits with interactive, generative technologies; however, we focus on supporting the dancer and not a specific choreographer's practice.

<sup>1</sup><https://dance.osu.edu/labnlangs>

<sup>2</sup><https://artsexperiments.withgoogle.com/living-archive/>

<sup>3</sup><https://peltarion.com/customer-stories/teaching-ai-to-dance>

To support any choreographer, a variety of technological tools exist, mostly in the form of video annotation. Tools like PM2GO (previously named Piecemaker) by Motion Bank<sup>4</sup> and DanceNote<sup>5</sup> support rehearsal documentation during piece creation, inspired by the rehearsal process of companies such as the Forsythe company. The Creation Tool from the Transmedia Knowledge-Base even supports multi-modal video annotation [7]. Knotation, an ipad-based tool created by Ciolfi Felice et al. [11], supports choreographic ideation, which includes the possibility of combining video and supporting text to sketch choreographic ideas. Unlike the others, the Whenever Dance Toolbox includes a set of tools for movement reflection and generation<sup>6</sup>. Though these tools can be appropriated by any choreographer, they do not support personalization, lacking the ability to take into account any information about the dancer.

HCI researchers study dance creation, creativity, and collaboration in the wild [41] through the deployment of creativity support tools (CSTs) for choreography. Ciolfi Felice et al. [17]'s deployment of Knotation in a choreography course highlights the role of the technology and its impact on the definition of other roles within the players and theirnotated artefacts. Hsueh et al. [26] worked with this theme thoroughly when studying real-world collaborative choreography and composition with artefacts. Masu et al. [33] studied an ecology of interactive sonic artifacts in choreography, uncovering the mutual influence of technology and choreography and the added necessity for the dancer to learn the inner workings of the technology well enough for playful interaction. Exploring the development of technology with performers also reveals play and tension between the body and the system, whether they develop together through intercorporeality [15] or limit each other [16]. Rodger et al. [40] study music instruments beyond the *musician-as-user* and *instrument-as-device* paradigm. Similarly, these works move beyond developing the best tools for the most creativity by studying how choreographic creativity unfolds in the real-world.

These tools either offer the professional choreographer a specific way to explore and implement their individual choreographic styles; or provide any choreographer with basic support for documenting and noting choreographic ideas. Research on similar tools in the wild highlights the greater complexity of roles and relationships between players and artefacts within a specific context. However, they do not address the needs of dancers who search for new, interesting movement with their bodies with previously trained

<sup>4</sup><http://motionbank.org/en/event/pm2go-easy-use-video-annotation-tool.html>

<sup>5</sup><https://www.lafabriquedeladanse.fr/dancenote/>

<sup>6</sup><http://badco.hr/hr/publications-item/whatever-dance-toolbox/>

movement patterns, nor do they question the professional practice of a dancer in a personal, developmental context.

### Outside the studio: How Professional Dancers Use Technology

The global pandemic required dancers to revert to training from home, with a corresponding change in their use of technology. Dance classes became virtual, such as the postmodern Trisha Brown Dance Company's<sup>7</sup> and the contemporary Batsheva Dance Company's<sup>8</sup> use of Zoom<sup>9</sup>. Social media pages became a space for more than marketing and event planning. Companies began giving live performances online as well, either through their Facebook pages, such as at the Opéra de Paris Ballet Company<sup>10</sup>, as well as other platforms like Instagram and Youtube, like with performances of the contemporary dance company Rosas<sup>11</sup>. Dancers had access to pre-recorded performances on Netflix-like platforms such as Marquee TV<sup>12</sup>.

Outside of appropriated social networks and video streaming platforms, few tools exist to support dancers in their professional career outside of the studio. One such tool, numeridanse<sup>13</sup> is a community-based platform that not only contains a library of recorded dance performances in a variety of styles, but also podcasts, compiled documents, virtual expositions, and more. To support artist networking, artists and co-founders Ramita Ravi and Nick Silverio, created Artswrk<sup>14</sup>, the professional network for artists. We include the potential for technological support in this form when examining the dance transition process.

Although the above tools have helped mitigate the challenges posed by the pandemic, it is uncertain whether or not they will support the professional careers of dancers in non-pandemic life. We therefore believe that it is necessary to uncover the needs of professional dancers in their personal practice as it develops over time. To do so, we search for answers directly at the source: by talking to the professional dancers themselves.

### 3 INTERVIEW STUDY: DANCE TRANSITIONS

Current dance support technologies take advantage of each technology's specific capabilities, especially the capture and representation of movement. However, simply because the technology *can* do something does not mean that that functionality is appropriate. One strategy for uncovering what

<sup>7</sup><https://trishabrowncompany.org/education/intensives.html>

<sup>8</sup><https://www.gagapeople.com/en/ongoing-classes/>

<sup>9</sup><https://explore.zoom.us>

<sup>10</sup><https://www.facebook.com/operadeparis/events>

<sup>11</sup><https://www.rosas.be/fr/news/855-idrummingi-live-stream>

<sup>12</sup><https://welcome.marquee.tv/>

<sup>13</sup><https://www.numeridanse.tv/accueil>

<sup>14</sup><https://artswrk.com/>

dancers *actually* need is to move away from the well-defined characteristics of a particular dance style, and instead study the details of how dancers transition from one style to another, with particular emphasis on the process they follow, the obstacles they face and the strategies they develop to overcome those obstacles.

We identified pre-professional and professional dancers who had transitioned from ballet to a new style of dance, and interviewed them to discover how they managed the transition process. We were interested in collecting detailed stories of their process, especially actions taken during classes or rehearsals and the moments when they found the new style particularly difficult, in order to inspire ideas for the design of new dance support technology.

## Recruitment

We developed the following specific career-related criteria for recruiting participants:

- at least four years of training in classical ballet at a high level, pre-professional program;
- a complete break from classical ballet, including an end to performing, although we included participants who continued studying ballet as a form of body strengthening; and
- at least five years of studying, performing, or teaching in a new dance style.

Our goal in choosing the above three recruitment criteria was to select truly expert dancers who have successfully completed a major style transition, while ensuring diversity across their experiences. We chose participants with a minimum of four years of high-level classical ballet training, since this generally aligns with a four-year high school or college program. Note, however, that their training usually began much earlier, as a child. We did not require dancers to have danced ballet professionally, which allowed us to include dancers who recognized the need or were forced to change styles, e.g. due to injury, before beginning a professional dance career. The third criterion was influenced by creativity research by Ericsson et al. [14] and Weisberg [51], which requires a minimum level of study to ensure expert-level experience. We required a minimum of five years of study of the new dance style in a qualified program, and a successful first step towards a professional career in the new style.

In order to avoid designing a one-design-fits-all system for a single teacher's or choreographer's practice, we wanted to uncover themes that span diverse practices, in a variety of contexts, and examine how they affect the dancer professionally, in their personal practice and their career. We chose to interview 12 expert dancers who all fit the criteria, to obtain a diverse range of experiences.

We initially recruited dancers who were acquaintances, after which recruitment "snowballed" [24] as dancers volunteered the names of friends and colleagues who fit the profile and were willing to participate.

## Participants

We recruited 12 pre-professional and professional dancers (7: she, 5: he) based in France (6), the United States (3), the Netherlands (2), and Belgium (1). All dancers had begun as classical ballerinas who then shifted to: professionals working in modern/contemporary dance(4), experimental/contemporary dance(5), tango(1), folk(1), and Alexandre-infused ballet(1). Dancers held roles as university students in pre-professional programs, professional dancers, choreographers, and/or teachers. Seven dancers held multiple positions, such as teaching while freelancing or dancing in their own works.

We sought, and achieved, rough gender parity, as well as a diversity of geographic ballet training, from both Europe and North America, and in participant roles, which ranged from advanced university students in pre-professional programs to practicing professional dancers, teachers and choreographers. Note that dance training, even that as highly structured as classical ballet, differs significantly across countries [19]. The 12 participants in the study trained or danced at 53 different dance institutions in the United States and Europe, including twelve ballet training programs, seven professional ballet companies, seven pre-professional "new style" training programs, and 27 professional "new style" choreographers/performance companies. Of these, only four institutions had more than one study participant, ensuring a high level of diversity in experience across participants.

All 12 dancers have in-depth knowledge of both ballet and a second style, with the latter clearly influenced by the former, as well as professional dance experience and their own personal practices. This allows us to see both the commonalities and diversity across their approaches, with rich details that can contribute to the design of interactive tools to support western professional dancers.

All participants agreed to having their interviews recorded and all signed an informed consent form. The procedures in this study were approved by COERLE, our organization's Institutional Review Board (IRB). Participants did not receive financial compensation.

## Setup

Dancers chose the location of the interview, which took place in a café (5), over Skype (4), in a dance studio (2), or the dancer's apartment (1). Although we preferred that interviews take place where there was space to move, we ultimately allowed the dancers to choose, since:

- renting studio space is both expensive and competitive [43];
- finding a time to talk with dancers is a challenge, since they often travel when working with multiple choreographers<sup>15</sup>; and
- discussing the transition experience can be very personal, and we wanted the dancers to feel as comfortable as possible.

### Procedure

We conducted 12 semi-structured, story interviews [30, 31], a version of the critical incident technique [18]. Each interview lasted between 50 and 110 minutes. We asked dancers to describe recent, specific moments when they were confronted with the challenge of learning a movement or concept that differs between ballet and the new style. We focused on these because dancers must directly confront their previous ballet experience in the context of the new style. We framed each interview in relation to the dancer's previous ballet training, and probed deeply into the approaches they tried. We also asked dancers about the role of others in the transition process, particularly teachers, choreographers and fellow students.

### Data Collection

We collected background information through a pre-questionnaire that asked about their training in both ballet and the new style, as well as their career path and current role. We audio recorded each interview and took hand written notes.

### Data Analysis

We first transcribed the audio from each interview and gave each dancer a unique code, from D1 to D12. We then conducted a reflexive thematic analysis [6] using a mixed approach, with both deductive (top-down) and inductive (bottom-up) approaches. The deductive themes were: specific transition steps from ballet to a new style; key pain points or challenges; key strategies for overcoming these challenges; and the role of external input. One co-author read through all of the stories and created codes to identify key themes, which were then discussed and verified with the other co-author. The deductive analysis focused on the specific approaches each dancer used during the transition process, including when and why they were used. We developed these themes from author brainstorm based on the objectives and research questions of this work. During the coding process, we remained open to emerging bottom-up themes, especially those related to the initial research questions. We considered the

location of the interview in our analysis, but we did not include it in the results since it does not relate to the objectives of this paper.

## 4 RESULTS

We identified three major challenges faced by the dancer: overcoming previous dance habits, learning new movement styles, and supporting transitions over time. For each of these challenges, we first describe the specific strategies they use, then who they turn to for guidance, and how they create a long-term practice that supports their growth as dancers. We conclude by mapping the overall transition process and discussing the dancers' need to change both their movements and their mentality in order to successfully transition to the new style.

### The Dance Transition Process

Each dancer described the progress of their careers, with a specific focus on when they first tried the new style, when they committed to it, and their current activities, professional or otherwise, in the new style. Most dancers (11/12) enrolled in ballet classes at a young age, before switching to a pre-professional training program (10/12) at a conservatory, specialized dance high school, or joint program with a professional company. Half the dancers entered a professional company directly (6/12), the rest studied at a university (6/12) before searching for professional opportunities. Dancers had their first exposure to the new dance style at different points during their career: One was a child (1/12), others experienced it during their pre-professional training (5/12), university studies (4/12), early professional experience (1/12), or afterward, while teaching (1/12). A few dancers officially switched to working and performing in the new style directly after their pre-professional training (3/12). Others shifted while in a university (4/12), during their professional career (4/12), or after they finished performing professionally (1/12). For some dancers, the style transition began within the past five years (2/12) while others began the transition ten (2/12), twenty (5/12), twenty-five (1/12), thirty (1/12), or even forty (1/12) years before.

Table 1 summarizes the career of each dancer, including their current style, the context of their transition, and how long ago they transitioned. The last column shows the technology they used, if any. Note that their limited use of technological support aligns with findings in the research literature about the low rate of technology adoption in dance practice [8].

### Overcoming Dance Habits

A key part of classical ballet training is to establish specific movement habits that become second nature to the dancer. When new dance styles require different types of

<sup>15</sup><https://www.danceinforma.com/2015/05/05/working-as-a-freelance-dancer/>

ID	New Style	Transition Timing	Years	Current Role	Technology Used
D1	Modern/Contemporary	Post Pre-Professional Training	10	Auditioning	Youtube, Music Players
D2	Modern/Contemporary	University	20	Teacher	Video camera, VHS/DVD
D3	Modern/Contemporary	University	5	Auditioning	Youtube, Music Players
D4	Contemporary	Mid-Professional Career	5	Dancer	None
D5	Contemporary	Post Pre-Professional Training	20	Dancer/Choreographer	None
D6	Tango	Post Pre-Professional Training	30	Dancer/Choreographer/Teacher	None
D7	Contemporary	University	20	Dancer/Choreographer	Excel Spreadsheets
D8	Folk Dance	Mid-Professional Career	20	Teacher	Video camera, Internet
D9	Contemporary	Mid-Professional Career	10	Dancer/Teacher	Video camera, Audio recorder
D10	Ballet/Alexander	Post Career	40	Teacher	None
D11	Modern/Contemporary	University	25	Dancer/Choreographer/Teacher	None
D12	Contemporary	Mid-Professional Career	20	Dancer/Choreographer	None

Table 1. Dancer's career paths, including the new dance style, when they transitioned, their current role, and any technology they used during the transition.

movements, dancers have to work hard to overcome their ballet-centric habits. The dancers reported that their most successful strategies involved either getting completely lost in something outside their body, or conversely, paying close attention to specific details of their body. These strategies open the dancer to experiencing new sensations and developing new movement instincts.

**Strategies.** When trying to unlearn a particular movement habit, all dancers (12/12) shift their focus from their own bodies to something outside the dance. For example, some increase the speed or frequency of a particular movement, or concentrate on the music's rhythm or melody. Others consider social aspects, such as interacting with their partner, or explicitly create physical constraints, such as restricting their ability to release their hands. D5 described creating a character and a specific context, and then mentally writing and revising a monologue. For example, he described a scenario involving movement at a café: *I'm going to take the glass, and all my fingers are touching the glass, and I feel the contact of the glass on my fingers, and now I'm going put it in my mouth...* He explained that he updates this monologue continuously so it remains novel and interesting, which lets his "movement instinct" take over: *For instinct to appear, you need to cheat on your brain...like keeping your brain really busy with simple tasks (D5).*

D6 also talked about "getting out of her head" by working with her partner: *You dive into the other. In tango, at once you have a bond with another body, you are not in a vision of you, you are in a relation to the other. [It] opens this channel...from there, I can escape in my head.* By focusing outside their bodies and how they look, dancers escape from constantly checking themselves and thus begin to experience new sensations.

Another strategy involves turning inward and developing a hyper focus on the inner workings of their body. For example, most dancers (8/12) described using specific, anatomically correct imagery to visualize their body; scanning their body and its circulating energy; or following the chronology of body parts shifting which make up a movement. D9 described working with a choreographer who integrates energy yoga with extreme slowness, so that dancers remain immobile for hours before moving in the final 30 minutes of a workshop: *It was only with this slow work that I could really feel...the weight of things, what it takes to raise an arm and feel...For me, that was the only way to feel that. (D9).* This strategy of hyper-listening to their bodies while resting or moving helps dancers reject over-learned movement habits and explore new sensations associated with the new dance style. Both strategies—focusing on aspects beyond the dance and looking inward to the workings of the body—challenge the assumption that optimal dance support technologies should focus attention on the dancer's movements.

**External Guidance.** Many participants are also teachers or choreographers who develop methods for exposing dancers to new movement styles, and guiding them away from existing movement habits. Several teachers (7/9) described their tricks and methods for opening dancers to new ideas, including leading dancers into a relaxed state, probing for their personal goals, and avoiding criticism. D10 explained that dancers aren't necessarily *open to something that might be completely the opposite of what they've heard their whole lives. [They'll just] consciously or unconsciously reject it...* His strategy is to *find out what their priorities are. If I can address one of those priorities...even if I don't think that's the most important thing...they'll open their feedback loop to me [and] start listening.* Similarly, D5 and D7 are choreographers who develop methods that guide their dancers to perform with the movement qualities they seek in their dance pieces.

For example, D7 created a piece which explores the movement learning process and muscle memory. She developed an exterior focal point: a lexicon based on the structure of verbal language and a dependency parsing algorithm from natural language processing: *This idea of taking the sort of linear, two-dimensionality of language, and putting it into your body so you're in this three-dimensional relationship to it.* (D7). Throughout the piece, dancers ‘cheated their brains’ by focusing on this lexicon and the sentence they were performing over and over. In this way, the lexicon developed by D7 guided the dancers so they could overcome their habits.

**Long-term Practice.** Dancers seek new strategies for breaking their habits over time. They may study Alexandre technique<sup>16</sup> to lose habits and find more relaxed movement or study Gaga movement language<sup>17</sup> and yoga, to focus awareness on sensations within the body. They may try the Feldenkrais method<sup>18</sup> to improve self-awareness or other techniques that force them to radically question their assumptions about ballet. Some dancers work with teachers and choreographers who integrate such techniques into their classes or creation process; whereas others study these techniques themselves as a self-improvement process.

### Learning New Movement Styles

All dancers (12/12) developed individual strategies for learning new movements, and established their own personal development processes. Strategies included reusing, then redefining known movement ideas; learning from the bodies around them, including their own; and imposing structure on themselves to help them better understand and explore new movements.

**Strategies.** All dancers (12/12) reported trying to understand new movements through the lens of their previously learned movements and definitions. They reapplied advice from former teachers, reused easier exercises, reappropriated terminology and body knowledge from their ballet training, and re-connected with basic features of the body, especially breathing, walking, and falling. D11 relies on body directions, drawn from classical ballet training (see Figure 1 [21]), to position her body in space even when performing modern dance: *Modern dance [involves] changing spatial orientation all the time...Knowing body positions has really taken the challenge out of learning movement in modern dance.*

D7 said she picked up movement strategies from her first contemporary dance classes: *To learn this movement phrase...I could try to parse out the shapes that I can see, that I recognize because of whatever training I've had, relying on some of these*

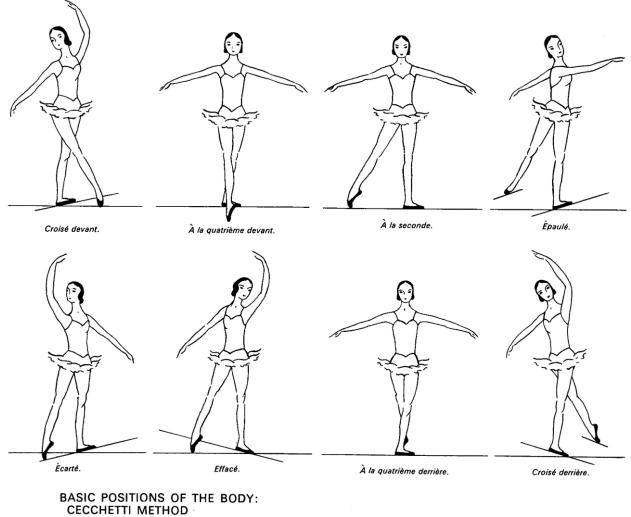


Figure 1. Cecchetti Body Positions: An example of the highly codified nature of ballet movement training.

*other tools that I have developed, and being able to learn classical movement.* D4 relies on her classical training and body functions such as breathing, to learn new movement styles. For example, she connects her breath to release her muscles, which facilitates falling during a performance: *Breathing, that's something that I think of a lot, how to dance with your breathing and how to make it help the movement.*"

Most dancers (8/12) look to their own bodies and the bodies around them to gain information and validation about their movement. When they enter the studio every day, dancers examine their aches and bruises to assess the success of previous attempts. They also watch each other to discover nuances in correctly performed movements. D8 described three phases for learning movement through observation: Analyze, Copy, Improve. He tries to teach students to: *Learn to visually recognize motion and movement: analyze, copy, and then transfer it into your own body, [until] it becomes natural.* This and other self-developed strategies help dancers gain information about how the bodies around them move, which helps them transfer external guidance from others to their own bodies.

Most dancers (9/12) described creating their own structures that help them understand new movements more deeply, such as questions and self-imposed constraints. For example, D12 established rules to help him improve his floor work, such as “glueing” certain body parts to the floor and then trying to complete certain movements. *[I] keep my head on the ground all the time and to go from one part to...the other part of the room. How do I do to keep my attention just on that, so that the rest of the body adapts? It gave me some kind of*

<sup>16</sup><https://alexandertechnique.com/at/>

<sup>17</sup><https://batsheva.co.il/en/gaga>

<sup>18</sup><https://feldenkrais.com/>

*rules to play with, that allow you to find this kind of relationship with the ground.* Creating such challenges lets dancers explore and play different aspects of each new movement.

**External Guidance.** Dancers attempt guidance strategies both inside and outside of structured class or rehearsal time. In particular, dancers with teaching or choreographic experience (6/9) develop strategies for guiding their students to discover new movements, such as using hand-picked imagery, posing questions, and providing history and context to specific movements or techniques. They also set aside space and time for exploring without pressure. For example, D8 encourages dancers in his folk class to examine themselves as he teaches a new movement phrase: *I ask them to talk, to tell me what I was doing...I say "Okay, what do you think yourself? How do you think you can solve your own question? Start by analyzing. 'What did I do? Where did I go? What can help you?" It only takes 15 minutes and I do budget that time.*

**Long-term Practice.** To reinforce the process of relearning, dancers seek strategies that enhance their training outside of rehearsal. Dancers take a variety of classes to train their bodies, especially those that encourage body awareness, such as the afore-mentioned Gaga movement language, yoga, and the Feldenkrais method. D11 highlighted the importance of hearing familiar advice reformulated in a new way: *There are things I had been doing for years and somebody would say it in a different way, and I would be like 'Huh'...an oral cue like that, something different, just made a difference.* Dancers also expand their movement understanding by cross training with non-dance techniques. D12 tries new sports, such as underwater diving and rock climbing, to discover new ways to use his body: *I'm trying to do more climbing now, and it makes me discover another relationship with my weight... and I think that informs me as a dancer.*

### Supporting Transitions Over Time

Dancers engage in activities outside of the studio and beyond their roles as dancers to facilitate their transitions over time. They question their beliefs by exposing themselves to new works and styles beyond classical ballet, seeking clarity in interest and different strategies. According to D12: *It's difficult to change one's tastes because it requires...re-questioning them [which] puts in doubt all the learning. It requires re-building something else. It's also why I went to see a lot of different styles.* For these dancers, discovering new artists and styles means deconstructing and reconstructing ideas about movement possibilities and approaches. Of course, this may include seeking guidance from others, and the process is fundamentally about making changes in their long-term practice.

**Strategies.** Dancers work to develop themselves as dancers throughout their careers, by exposing themselves to a diversity of works and exploring their own work through different channels outside of dance performance and creation. Dancers need diversity in classes, teachers, and audiences (such as dancers from other styles as well as other artists and non-artists), with differing levels of radicality. Additionally, dancers mentioned exploring other channels beyond dance to develop their practice including: creation, teaching, academic studies, verbalization and discussion, as well as developing their own, proper language to put body knowledge into words. D9, who had completed a master's degree as well as dancing professionally, explained how his academic studies feed his career: *I'm studying more theories and being in other environments. I realize I can push my creativity by being in another landscape, too.* Dancers find new sources of creativity even outside of the studio, exploring other channels to frame and talk about their work.

Figure 2 summarizes the key findings with respect to the challenges dancers face during style transitions. In order to overcome unwanted movement habits, dancers either "cheat their brains" by focusing on external features, such as rhythm, speed, or a movement script, or focus intently on the inner workings of their body. External guidance from teachers and choreographers helps dancers open up and find external or internal focuses. Over longer periods of time, dancers study specific techniques for breaking habits and increasing body awareness. When learning new movements, dancers re-examine their previous training, as well as analyze and translate the movement of their own bodies and those around them. They also develop questions and challenges to better understand the new movements. They rely on external guidance to create a space for self discovery, where teachers and choreographers prompt them with guided questions, imagery, or history, and develop classroom or studio environments that encourage exploration. Over time, dancers expand range of movement by working with new teachers and choreographers, or trying non-dance body training, such as sports. To facilitate style transitions over longer periods of time, dancers seek diversity in their dance experiences, working with new people and radical styles, but also exploring new creation, teaching, discussion and academic channels, in-and outside the arts community. Before examining how these results might affect the design of dance support technology, we need to address one key additional element: changing the dancer's mentality.

### Changing Ingrained Mentalities

A key observation is that transitioning to a new movement style causes dancers to fundamentally question their ingrained assumptions about dance and its greater context.

	<b>Overcome habits</b>	<b>Learn new movements</b>	<b>Transition sustainably</b>
<b>Strategies</b>	<ul style="list-style-type: none"> <li>• Outer body focus</li> <li>• Inner hyper body awareness</li> </ul>	<ul style="list-style-type: none"> <li>• Relate to <b>previous training</b></li> <li>• Draw from the <b>body(s)</b></li> <li>• Explore through <b>structure</b></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Diversity</b> in experiences</li> <li>• Explore other <b>channels</b></li> </ul>
<b>External Guidance</b>	<ul style="list-style-type: none"> <li>• Help dancers <b>open up</b></li> <li>• Guide through practice</li> </ul>	<ul style="list-style-type: none"> <li>• Create a <b>space for self discovery</b></li> </ul>	Not applicable
<b>Long term</b>	<ul style="list-style-type: none"> <li>• Study <b>specific techniques</b> to break habits</li> <li>to increase body awareness</li> </ul>	<ul style="list-style-type: none"> <li>• Diverse <b>cross training</b></li> </ul>	Not applicable

**Table 2.** Dancers adopt various strategies to support their style transitions, with external guidance from teachers and choreographers, as well as adopting new techniques to support the long-term evolution of their dance practice.

Dancers develop a “ballet mentality” surrounding the intense training they experience as children. Pre-professional dancers must commit 100% to their training, partly because of ballet’s difficulty and need for precision, and partly because they start very young and develop their personalities and life expectations during this time. D12 described how, in certain intensive, boarding school training centers, *either you go all the way through it, or you completely break*.

The dancer’s ballet mentality encapsulates not only ballet itself, but also the context of training in technique, choreography and performance. When former ballet dancers face a transition to another movement style, due to injury, age or lack of adequate level, they find themselves fundamentally questioning values they previously accepted without thought, reassessing their assumptions about the body, performance, training and relationships, as well as the codification of ballet and its emphasis on creating the perfect image. Ballet focuses on externally visible results and the necessity of providing a “good” performance for the audience. It emphasizes aesthetics, as dictated by an “all-knowing guru”, and values a single, standardized language that captures the essential components of ballet.

However, when encountering other dance styles, either equally formal such as tango, or more open-ended, such as contemporary, dancers must reassess their own assumptions about dance. Each new movement forces them to confront their earlier beliefs and challenge or accept guidance provided by teachers and choreographers. Their daily experiences with the new dance form contributed not only to learning specific new skills, but also served to change their dance mentality. Explaining movements in terms of the new style also helped expand their understanding of their own ballet training, and reconstruct their beliefs. For example, D2 spoke of learning to place her arms in second position in both ballet and contemporary dance, using the metaphor of jellyfish suckers on her arms: *They lengthen, they slurp... so your*

*arms are gathering the oxygen.* She explained that metaphor encourages contemporary dancers to open their arms wider than in ballet and move them into “sensing mode”, where the view of one’s arms shifts from holding to sensing. *It’s not like you’re moving your body but your body is moving the air. You really get this in sensing mode, and if they’re in this sensing mode, they’ll use the broadness.* (D2) She noted that using this metaphor changed how she viewed her body in space—the new imagery accompanying the movement sparked an “aha” moment with a new understanding.

Every period of time spent working on a new technique, or with a new choreographer creating a new piece, offers new opportunities for questioning their existing beliefs. For example, D3 studied the Graham technique<sup>19</sup> for four years at a conservatory. Her professor taught her new ways of visualizing and using her body that caused her to question key beliefs about ballet:

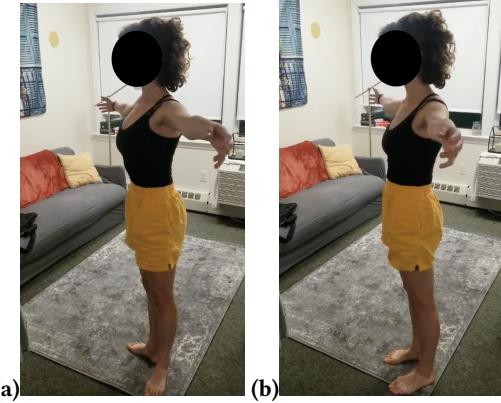
- A new definition of alignment led to a new view of the perfect body for ballet.
- A new way to use the pelvis led to a new “goal” of movement (to eat up space vs. to control the movement).

Figure 2 shows D3 demonstrating the differences in alignment between ballet and Graham Technique. Dancers in this situation acquire new movement examples and develop a deeper understanding of the new movement style, which they compare and analyze with respect to their ballet training.

As time passes, dancers begin to break down their old beliefs and develop new ones, which fundamentally changes their mentality concerning professional dance. D5 laid out a timeline of this change:

“Prince of ballet” → *pushing my limits inside the ballet vocabulary* → *using the pain I knew how to handle from*

<sup>19</sup><https://marthagraham.org/history/>



**Figure 2. D3: Comparing ballet alignment vs Graham alignment**

*ballet → the somatic approach that I'm now in...to let the body take control over you.*

These dancers all questioned assumptions grounded in their ballet training at different times in their careers, before settling on an approach that makes sense for their current dance practice.

Dancers felt they had to change their mentality in order to “succeed” in performing movements in their new style. D1 hesitated when first confronted with a new *frufru* movement approach in a workshop about the Rubberband method<sup>20</sup>. She contrasted the presentational focus of ballet to the Rubberband method’s focus on movement influenced by internal systems within the body. However, as she watched company members, she realized that this new approach allowed dancers to move with vastly different qualities: *I didn’t realize how much of a difference approaching it that way changes your aesthetic...it sounds silly: ‘Oh I’m just doing this imagination thing, like, it’s fun’, but when you watch people, it completely changes how they execute everything and how it looks.* (See Figure 3 where D1 illustrates the difference in the tendu movement.) Dancers need to accept or believe in the teacher’s or choreographer’s approach, before they can fully commit to and perform the movement “correctly”.

A dancer’s mentality develops over time, through new experiences or taking classes where the dancer encounters a movement or idea that makes them reflect on their existing beliefs before performing it. The dancer deconstructs their mentality and then rebuilds it into a new one, influenced by the context in which they learned the movement. Different aspects are deconstructed and reconstructed over time, according to the particular experiences of each dancer.



**Figure 3. D1: Comparing ballet tendu vs Rubberband tendu**

Experiences such as studying the Graham technique offer opportunities for deconstructing and reconstructing different concepts of dance.

## 5 IMPLICATIONS FOR DESIGN

Table 3 summarizes the key design considerations associated with each of the three key challenges faced by dancers. Next, we suggest three possible design directions that are inspired directly by the study results, and encourage designers to explore other possibilities that go beyond the traditional focus on capturing and correcting individual movements.

**Design for Multiplicity of Movement Representations.** For a sustainable style transition and career, professional dancers continuously explore novel approaches, and therefore novel frames through which to view movement. For habit breaking, dancers study specific techniques focused on developing body awareness. For relearning different movements, dancers search for a variety of teachers, techniques, and even movement activities beyond dance to gain novel descriptions, viewpoints, and sensations. Throughout their careers, dancers explore their practice even beyond the dance studio, re-questioning their beliefs through interaction with non-dancers. Approaching each transition challenge expands their movement experiences at some level.

Current dance support tools usually focus on a single style, such as classical ballet ([32], [47]) or Double Skin/Double Mind [2]. However, comparable movements, such as relevé and expanding, exist within both of these dance styles. This suggests that tools for supporting transitions by professional dancers should include a multiplicity of movement representations, from a variety of sources, ideally from each of the fundamental movement styles, plus other, different dance styles. This offers dancers a space for questioning their current understanding of each movement, and allows them to compare or combine multiple frames, including their previous framing.

Some dance styles do not include comparable movements. In such cases, we recommend that designers identify diverse

<sup>20</sup><https://rbdg.ca/en/rbdg-method/>

	Overcome dance habits	Learn new movement styles	Support sustainable transitions
Design Considerations	<ul style="list-style-type: none"> <li>• Support inner reflection</li> <li>• Support outward reflection</li> </ul>	<ul style="list-style-type: none"> <li>• Incorporate previous experience</li> <li>• Include multiple bodies</li> <li>• Offer challenges</li> </ul>	<ul style="list-style-type: none"> <li>• Beyond dance training</li> <li>• Explore other channels</li> </ul>
Role of Technology	<ul style="list-style-type: none"> <li>• Guide dancers</li> </ul>	<ul style="list-style-type: none"> <li>• Support experimentation</li> </ul>	Not applicable
Long term Use	<ul style="list-style-type: none"> <li>• Variety of specific techniques:</li> </ul>	<ul style="list-style-type: none"> <li>• Diversity in techniques</li> <li>• Diversity in teachers</li> </ul>	Not applicable

**Table 3.** Designing for the real-world, transition process requires actively considering the strategies dancers adopt in both the short and long term and reflecting on the potential role of technology.

other sources, such as approaches by different teachers or diverse ways of visualizing the body, so dancers find new ways to perceive and describe each movement. Exploring multiple viewpoints, including first and third person, can help dancers explore the mapping between their proprioceptive sense of their own movement, and the movement as it is viewed by others. Increasing the number of modalities lets dancers better define movement through their different senses, thus increasing their understanding. We argue that, instead of focusing on single ‘correct’ movements, professional dance support systems should instead offer a multiplicity of movement representations that allow the dancer to explore, reflect and more deeply understand each movement being learned.

**Balancing Learning and Reflection Within a Single Session.** When dancers acquire novel movement phrases, either to overcome habits established from an earlier dance style or to learn completely new body movements, they come up with personal strategies for exploring and understanding them. For example, D5 and D7 define a new movement phrase by writing a relevant monologue or developing a corresponding vocabulary. They explain that dancing these phrases from an exterior focus effectively “cheats the brain” and opens the body up to new experiences.

Learning movement in the new style requires two contrasting activities: learning and adopting the basics of the new phrase as required by the new dance style, and exploring and gaining a deeper understanding through self questioning (D8), searching for information through nearby bodies (D8), or exploring and leveraging previous knowledge (D4, D7). Although these goals differ, each movement learning action involves aspects of both: dancers structure movement to explore, and explore to improve movement structure.

Unlike current interactive dance systems, which usually focus on a single teaching method [36], these findings suggest that a single dance support tool should include both traditional/mimesis and reflective/generative teaching methods, ideally within the same session. For example, dancers could interact with different approaches, perhaps beginning

with mimesis for basic movement acquisition, followed by activities that encourage reflection and further exploration. Designers could develop a logical chronology and timing for each phase, depending on the dancer’s specific goals and preferred styles of interaction. Learning a new style of dance requires dancers to appropriate movement structure from the exterior and use it to explore sensations within themselves; therefore, we recommend supporting both phases, with differing methodologies, in one support tool.

**Creating Definitions for Movement—Through Movement.** During their transition between dance styles, dancers must deconstruct and reconstruct ideas about dance movements and concepts, and give them new names and definitions. Defining movement through body scans and monologues, for example, can help break undesired movement habits. When learning new movements, dancers often draw from their existing dance vocabulary to understand the new style. Over the long term, dancers develop their own practice, which includes developing methods of verbalizing their approach and beliefs, with their own personal vocabulary, which they use to discuss the new style with other dancers, teachers and choreographers. Changing mentalities requires changing how each dancer thinks about and discusses movement, training, context, and relationships, and redefining movements at each challenging point during the transition.

We recommend systems to support this re-defining process through movement-based demonstration and reflection. Dancers could demonstrate different variations of movement to the system and have that reflected back to them in any of a number of different media. This back-and-forth would give dancers an ‘outside’ perspective of their own movement, but in different forms. This communication of set movements through movement does not put words in the dancer’s mouth, but instead gives them new ways to view their own body and the ability to develop words themselves from what they see and feel from imitating, embodying, or reacting to the system’s interpretation.

## 6 DISCUSSION

This study offers a deeper understanding of the process of transitioning from one dance style to another, and adds to our understanding of the longer-term evolution of a professional dancer's career. It also reveals promising directions for design that go beyond the conventional paradigms of dance learning support tools. It participates in the discussion of current challenges in dancer-system interaction design. The next section discusses how the results of the study can help us imagine novel structures for designing dance learning support and continue to develop an understanding of the balance of control for dancer-system interaction. We finish with an overview of our study limitations due to methodological choices.

### Movement Substrates support diverse movement representations

We use a generative theory approach [5], based on the concept of *substrates*, to provide a theoretical foundation and generate a flexible structure for managing the proposed multiplicity of movement representations. A substrate *contains information and applies constraints to it, reacting to changes in both so as to generate new information* [10]. Substrates also define relationships between data within and across different substrates. When designed well, substrates offer a simple and flexible interactive structure for representing different types of user-relevant data, in a form that users find easy to understand and manipulate. For example, Garcia et al. [20] developed interactive paper substrates that let contemporary music composers generate their own interactive structures to create highly diverse music compositions; and Maudet et al. [34] developed graphical substrates that offer designers powerful, interactive structures for creating and manipulating different layouts for both paper and digital formats.

We propose a novel approach—**movement substrates**—that contain representations of specific movements or dance phrases, and define the constraints and relationships among them. For example, a text-based movement substrate would provide each movement with a name and a third-person text definition. These movements would then be cross-linked to other definitions of the “same” movement as defined by other dance styles, teachers, sensations, etc. Dancers and choreographers could apply constraints that would reveal novel frames for viewing and understanding each movement, creating space for surprises.

A visually based movement substrate could include visual representations of the above movements, either with real-world video clips, motion-capture representations, animated illustrations, or computer-generated visualizations. Similarly, an auditory movement substrate could include diverse sonic

representations of the movements, from recorded sounds and music to computer-generated audio. Both of these substrates, if linked to the text-based movement substrate, would offer dancers a wide range of possibilities for exploring new movements, from a wealth of different perspectives. Building a platform that supports these movement substrates would allow dancers to communicate with the system, without being forced to follow a particular technique or teaching method.

Movement substrates could also take advantage of different external views to define movements, and allow dancers to store and define personal movements, inspired by their own internal sensations. The “Moving and Making Strange” methodology [28] defines three perspectives necessary for movement-based design: The mover, the observer, and the machine. Movement substrates would use the observer definition to enhance communication between the user and the machine; and both the user and the system could maintain movement definitions that map to the observer definition. Movement substrates could thus support efficient communication between dancers and the system, while also allowing for personal movement definitions.

A movement substrate platform could also support **definition-making**. Unlike sense-making, which is “*an activity in the analysis of a large or complex amount of information*” [42], definition-making occurs when dancers develop their own understanding of a movement and choose descriptive words that capture that understanding. Interacting with a single movement through different substrates would allow dancers to continually update their personal movement definitions. This would allow professional dancers to define and re-define movement, both as part of their own re-learning process, but also to support teaching and choreography.

We found that dancers continuously approached and reapproached movements in the context of their daily classes and rehearsals, in order to understand each movement more deeply. In particular, their experiences with movements in the new style led them to discover new insights about their ingrained beliefs with respect to the old style, which in turn helped them redefine those beliefs and the “successful” completion of the desired movement. Interacting with movement substrates would also provide a platform for helping dancers to question their beliefs about particular movements, both as they first learn them and over time. This would help them to break down and reconstruct their ballet mentality and make sense of each movement with respect to the new dance style. Movement substrates could thus serve as a structure for helping dancers explore and re-interpret their beliefs about dance.

### Shared Control Between Dancer and System

Studies of current dance learning highlight the challenges of balancing control between the dancer and the system. For

example, Raheb et al. [36] compare the traditional methods of teaching dance, *where the teacher makes all the decisions and the learner follows these decisions* to more generative and reflective methods, where the teacher proposes a task or time for improvisation, offering only a cue about where to start. They described their experiences with Choremomorphy [37], a reflective system, and found that most expert dancers who interacted with it wanted to control the visualizations. However, one dancer said: *Each avatar triggered me in a different way. So, my movement was affected by the avatar. I really liked it, because I was discovering all the time new movements.* For this dancer, the surprising visualization led to discovering new movement. Trajkova and Cafaro [47] studied expert dancers' use of their more traditional, Kinect-based ballet teaching system, and found that they wanted to control the camera view so they could focus on known bad habits. However, they might have discovered other, more surprising perspectives on their movements if the system had proposed alternative camera views. These examples show the on-going tension between controlling the system to specifically address a known problem, and generating surprise that sparks new insights about each movement.

The results of the study highlight the challenge of choosing how to allocate control: Dancers are clearly willing to sometimes hand off control to an external guide when they are hunting for new movement possibilities. However, they are only willing to do this within the context of a temporally restricted session, after which they reassert control. Dancers also actively seek some methods, but are uncomfortable with or even fully reject other methods, even if suggested by an external expert, such as a teacher or choreographer. Dancers not only seek out specific teachers in order to challenge themselves, but also actively set constraints for themselves as they learn or relearn movements, and figure out personal ways of defining movements that make the most sense to them. This implies that dancers need to be able to choose when to accept external guidance, and when to maintain control over their own learning, especially with respect to their long-term definition of their own dance practice.

Successful systems for supporting dance transitions should thus offer dancers a choice with respect to their level of control. For example, delegating control to an external guide is most appropriate when helping dancers overcome unwanted habits, with either internally or externally focused directives. For example, a recommender system could ask questions or propose movement-specific challenges for the dancer to follow, based on their individual goals and past behavior, as well as more general recommendations from external experts. This would provide the dancer with new channels to explore and help them challenge their existing beliefs. By contrast, other systems could offer the dancer full control over which performances or academic programs to follow,

and the dancer could decide how much time to spend exploring a particular movement, or experimenting with proposed questions, constraints or suggestions. Exploring a system based on movement substrates would allow dancers to pose their own questions, make their own comparisons, and allow themselves to be surprised by new associations and ways to approach dance learning.

### Study Limitations

**Choice of dance styles.** We chose to focus on a previously unexplored aspect of professional dance training, the transition from one dance style to another. The advantage of this approach is that it can shed light on both the original dance practice, in this case classical ballet, and the new dance style, since dancers are, by definition, in a state where they are forced to reflect on each.

We chose ballet as the foundation dance style, because it is both very common, and because it provides a shared basis for comparison across dancers. Dancers who begin with other, less formal dance training may experience the transition to a new style differently. The majority of dancers in this study transitioned to modern or contemporary dance, which is perhaps not surprising given the roots of these styles as a rebellion against the perceived imperialism and rigidity of classical ballet [45]. However, even those dancers who pursued other dance styles described how they rebelled against ballet and sought to deconstruct it before reconstructing a new dance mindset. Thus these data should be viewed from the perspective of dancers who have, at least partially, rejected their original dance training. The perceptions of current ballet dancers may differ greatly.

Of course, all of the participants were trained in a western dance tradition, and dancers from non-western traditions may have very different experiences. We leave it as future work to study whether this process of critiquing one's original movement training, with a corresponding need to learn new movements, break existing habits, and change mentalities, followed by a renewed appreciation of the original training, applies to other movement transitions.

**Verbal Reports of Physical Activity.** One of the difficulties in asking dancers to talk about dance is that dance is a very physical, embodied activity, and many dancers lack adequate words to describe their experiences, and may not even be conscious of their own learning strategies. However, one of the advantages of this particular study design is that participants have been forced to reflect consciously about each dance style, as they unlearn one and learn the other, thus making it easier for them to communicate their experiences.

Although it would have been easier for participants to reflect on specifics if they were physically in a dance studio,

the private (7/12) or even public (5/12) locations did not necessarily inhibit physical demonstration, as seen in figures 3 and 4. We also argue that the story-based interview technique, which explicitly asks participants to walk through recent, memorable experiences step by step, largely mitigates these disadvantages, since dancers could describe, sketch, or demonstrate what they meant.

**Research Design Limitations.** The benefit of an in-depth qualitative study of a limited number of expert dancers is the ability to gain rich insights into both their common and unique experiences. In this case, the small number of participants has clearly demonstrated the highly diverse nature of dancers' experiences and needs, and suggests the need for correspondingly diverse interactive tools. This study offers a preliminary example of how studying the transition between two practices can shed light on each, but would require a much larger study to make strong claims about how all such transitions occur.

## 7 CONCLUSION

We are interested in designing more effective tools to support dance learning by pre- and professional dancers. We focus on a common but as yet unexplored phenomenon, i.e. when dancers transition from ballet to a new style of dance. This transition forces dancers to explicitly reflect on each dance style, making it easier for them to share their insights. We conducted a study with 12 dancers who had transitioned from early, intensive ballet training to a different dance style, due to injury, ageing or lack of opportunities as a professional ballet dancer. We wanted to identify the specific steps they take during this transition, the key obstacles they face, and their strategies for overcoming those obstacles, in order to gather deeper insights for designing new dance support technology.

We found that dancers go through three key phases: overcoming ingrained habits developed during their original ballet training, learning new movements, and seeking external movement techniques to help them transition in a sustainable way. At each step, they develop their own personal strategies, within and outside the studio. Instead of focusing on the mechanics of each new movement, they instead look outward beyond the current dance, or develop a hyper-awareness of the inner workings of their body. They also seek external guidance from teachers and choreographers, who develop methods for challenging their existing beliefs and supporting experimentation. Finally, they all explore a wide variety of movement-based activities, including other dance styles, meditation techniques and sports, to give them a solid foundation for continuing to evolve their personal dance style. Critically, they all struggle to counteract their ingrained mentalities, before they can successfully perform the new style of movement.

These obstacles are not linked to any particular movement phrase, style, or choreographer, but rather to the dancer's personal practice. These results challenge the conventional wisdom about how to design technologies for dancers, which usually focuses on the aspect of dance that today's technology can most easily capture—the mechanics of the dancer's movement. For these advanced dancers, this approach is exactly the opposite of what they need. Instead, they need exposure to new ideas, with a space for exploration and a path for continuously learning new aspects of the dance style over time.

Studying this transition phase offers deeper insights than studying dancers who are fully committed to a single style of dance, since we can learn from the ways they question their own assumptions, both about ballet and the new dance styles they attempt. Even though this process of contemplation is most apparent during the transition period, we believe it is relevant for all dance learning.

We also suggest three key design implications for the design of learning tools for pre- and professional dancers. First, we propose a novel approach—**movement substrates**—that contain text-based, visual and auditory representations of specific movements or dance phrases, with a corresponding set of constraints and relationships to interconnect them. This would allow dancers and choreographers to explore different representations of the “same” movement as defined by other dance styles, teachers, sensations, etc., and discover novel frames for viewing and understanding each movement, creating space for surprises. Second, we argue that dancers should be able to choose their level of control over the system, from explicitly delegating control to an approved external guide, e.g., to overcome unwanted habits; to actively exploring the movement space, and experimenting with new constraints or alternative movement representations. Third, we propose letting dancers define and demonstrate their own movement variations, which would create a personal movement space for them to explore. Their movements could be reflected back to them verbally, graphically, auditorily or tactically, using the “making strange” approach to gain an outside perspective and deeper insights.

In the future, we argue that designers should look beyond current systems that prioritize movement capture, and instead create dance support tools that help dancers overcome ingrained habits, learn new movements, and find strategies for changing their mentality, both in the short and the long term. Beyond this, designers should consider supporting a full range of dancers' ways of interacting with movement, where learning dance is not viewed as simply the physical act of moving one's body through space, but rather as a rich, complex and ever-changing set of strategies for sensing, describing and embodying movement, that can benefit from a highly diverse set of multi-modal interactive tools.

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