



Towards Inclusive and Interactive Spaces for Breakdancing

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Abstract. This paper provides a critical reflection on performance gestures within the context of “breaking”, explored in the process of constructing an interactive system using design methodologies drawing on the framework of “defamiliarization”. Through a user study conducted as exploratory dance sessions with female practitioners of breaking, we observe the relationship between movement and music generated by the Interactive Breaking Music System (IBMS). We question how practitioners embody breaking aesthetics in the gestures that emerge from their interaction with the IBMS and how this system might be leveraged to create a welcoming environment for b-girl practitioners, and possibly subvert or transform gender norms from breaking culture that manifest through movement.

Keywords: Hip-hop · Gesture · Interactive space · Feminist HCI

1 Introduction

From the perspective of embodied music cognition, listening is a full-bodied phenomenon from which a complete understanding of musical gestures and performance interactions emerge [1]. Research in this area employs multiple methodologies which are informed by critical reflection on the relationship between movement and music, including how the aesthetic of these movements or gestures change based on the music that is playing. This perspective strongly informs the research work presented in this paper.

In the world of dance, breakdancing or “breaking” is one of the four original elements of hip-hop [2]. In dialogue surrounding hip-hop culture, it is argued that it is important to understand the relationship between movement and sound in order to fully understand the medium/genre. According to Fogarty, “...the shift away from considerations of music has resulted in a lack of understanding, in both theatrical criticism and the institutionalism of breaking, of how hip hop aesthetics integrate the two” [3].

In this paper, we seek to understand the coupling of these movement/sound relationships in the context of breaking practice, and how modifications of

this via an interactive system subvert or expand commonly held practices and assumptions in this genre. We ask: How do practitioners embody breaking aesthetics in the gestures that emerge from real-time interactions with a sound-generating system that varies from highly similar to highly different from the traditional music found in breaking? To this end, this research paper observes gestures and movements in different interactive breaking contexts and explores similarities in relation to established hip-hop practices. Of particular interest, in this study are practitioners who identify as b-girls.¹ A second research question we ask is: How might an interactive system be leveraged to create a welcoming environment for breakers of differing genders? We present the system design and discuss the outcome of our initial exploratory study involving b-girl practitioners. We begin with a review of literature in hip-hop scholarship and human-computer interaction, followed by a theoretical background of our methodologies, and then an outline of our system design and description of our user study.

2 Gender, Sexuality and Breaking: A Literature Review

The relationship between gestures and interactive spaces is apparent in general,² but how might they affect one another in the context of breaking? Even more directly, here we ask how gender norms in breaking culture, which manifest through established gestural language, might become subverted or otherwise transformed in this interactive context. To approach this, we first need to understand the forms of gendered cultural idioms related to gesture that emerge in this context. To this end, we now provide a review of literature in both hip-hop scholarship and academic discourse on technological engagements to ground the discussion.

2.1 Origins and Challenges

In “Getting off: Portrayals of Masculinity in Hip Hop Dance in Film,” LaBoskey discusses the strong expression of masculinity and machismo in hip-hop culture. She mentions the influence of gangs on the rise of hip-hop as she explains the gestures used in the competition aspect of breaking:

Dancers employ gestures through the dance that are intended to encourage a rebuttal from the opponent. Young males often grab their crotch to symbolize greater virility than their opponents. They point or stare at their rivals in direct threat, or simply move toward another individual, violating his personal space and thereby threatening him. Such taunts often trigger outbreaks of actual violence. Hip-hop dancing is, in essence, a battle. It is a translation of gang warfare into the language of dance and physical expression [4].

¹ ‘B-girl’ is a term referring to women specializing in the street dance style of breaking.

² An interactive space is defined here as both a physical space that accommodates interactions between people as well as the computational system that interprets their movements and produces media output.

LaBoskey traces the origins of hip-hop as a vernacular style of dancing in the spirit of the adolescent boys who created it and posits it as an escape from gang violence.³ Using such gestures involving the male genitalia to demonstrate power and dominance encourages heterocentric breaking spaces to develop. Jagose states with reference from [6], “queer theory offered a way of thinking about lesbian and gay sexualities beyond the narrow rubrics of either deviance or preference, ‘as forms of resistance to cultural homogenization, counteracting dominant discourses with other constructions of the subject in culture’” [7]. We seek to explore ways of promoting meaningful exchanges between gestural action and interactive spaces, in the course of advocating for a more flexible and inclusive space in the context of breaking.

2.2 Hip-Hop and Feminism

B-girls face contradictory notions of gender performativity because of the aforementioned heteromascuine structures upon which breaking culture is built. According to Johnson, “B-girls are situated between two competing notions of heterosexual femininity: one is the pornification of women in Hip Hop, and the other refers to “normal day life” expectations of polite, ladylike behaviour” [8]. Identifying as a b-girl also means identifying as an outlaw because b-girls are constantly negotiating notions of gender performativity as well as breaking’s inherent qualities imposed and interpreted differently on women’s bodies [9].

Morgan, Jamila, and Pough are some of the first writers to circulate the term ‘hip-hop feminist’; they believe hip-hop culture and rap music, both stemming from Black culture, hold radical and liberating potential that should be tapped by the contemporary feminist movement to speak to younger feminists, particularly those of color [10]. Peoples further explores the relationship between hip-hop and feminism and the contested nature of the term “hip-hop feminism” [11]. According to Peoples, many women are hesitant of exploring feminism’s possible benefits due to its racist, homophobic, classist, and xenophobic beginnings [12]. It is these challenges that inspire us to ask here if decontextualizing breaking movements and gestures outside the movement/music norms of the culture might provide opportunities to challenge and question the status quo.

2.3 “Queering the Dance Floor”

As argued by Durham et al., breaking culture operates under a heterosexist structure wherein heteromascuine engagement is normalized, devaluing performances and contributions by those marked as ‘other’ [13]. Gunn discusses the ability of the format known as ‘all style’ dance ‘battles’ to call into question the bodily performance organized through gender to deconstruct, disrupt and

³ Serouj Aprahamian challenges this deeply rooted narrative in hip-hop culture to question the reliability of the source as well as to understand the implications this has in society (see [5] for more background on the street gang narrative in hip-hop culture).

expose the hierarchized distinctions in hip hop culture, or what she refers to as ‘*queering* the dance floor’ [14]. All style dance battles are a type of event that feature specialized dancers from a variety of different street dance style backgrounds, such as waacking, popping and locking, house, krumping, and breaking, competing with and/or against one another by improvising to a diverse range of music mixed live by a deejay [15]. In all style dance battles, the significance of heteromasculine gestures to present dominance over an opponent is decontextualized. Through spaces like all style dance battles and hip-hop theatre festivals, there is great potential to innovate ways of inviting an even more diverse crowd into breaking spaces. This leads us to consider if a similar decontextualization is possible through the integration of interactive movement/music systems.

3 Methodology

Driven by the first author’s personal experience in breaking culture and practice, this work is grounded in a strong conviction that this context could be made more inclusive, particularly with respect to participants coming from a broad spectrum of identities related to gender and sexuality. This paper presents results from a larger project that is grounded in five complementary areas: critical AI studies, working with machine learning techniques, interactive media development in challenging “real-world” contexts, and the use of qualitative methodologies for rigorously assessing participant experience. Our goal is to contribute a critical assessment of contemporary machine learning techniques on the one hand by testing them in this context, while simultaneously contributing to breaking practice and culture through their application, with the goal of providing new language, insights and an interactive art platform that engenders new and exciting approaches through a consideration of the long-held challenges and prospects of the breaking context in tandem with the design approach.

3.1 “Designing for Obliqueness”: Tensions Between HCI and Arts/Culture

In “HCI as heterodoxy,” Light explores different possibilities of designing digital tools by drawing insights on Queer Theory to challenge readings of gender as well as promote the tactic of queering in investigating resistance to the status quo [16]. The author defines ‘queering’ as a way of treating something obliquely: to steer into an adverse or opposite direction of the norm [17]. Further, Light alludes to Trauth et al.’s proposed criteria for conducting gender research “to engage in research flexibility; challenge the hegemonic dominance, legitimacy and appropriateness of positivist epistemologies; theorize from the margins; and problematize gender” [18]. This is in a similar vein as the concept of *Designing for obliqueness*, described as a practice (without the promotion of poor technical or interaction design) to forget, cheat, elude, and obscure the ‘straightness’ of machine thinking and conservative stance in the Human-Computer Interaction (HCI) discipline: the privileging of values in favour of effectiveness and efficiency,

and the validation of risk averse research that stays close to the agenda of dominant interests [16].

From a movement and computing design perspective, we argue that the *Defamiliarization* approach in movement-based interaction design is an example of queering the familiar, or traditional, perspectives [19]. This approach relies on varying normal movement patterns and processes to destabilize a creative user's habitual ways of thinking about movement, to reorient their experience, and to nurture an important component of improvisation – open-ended play [20,21]. Similarly to Light's concept, Defamiliarization's goal is to avoid conforming to established design models driven by overly-proscribed gestures and movement patterns, a priori. We approach this study through the lens of defamiliarization both in terms of our interactive design decisions as well as in the user study that followed, through the introduction of an interactive system that served as a defamiliarizing element by replacing standard breaking music, subverting expected movement/sound relationships in the process.

While there are creative opportunities in integrating technology in art, Fdili-Alaoui and her collaborators in *SKIN* (a choreographic interactive dance piece) recognize that there are also tensions emerging from these opportunities. In "Making an Interactive Dance Piece," Fdili-Alaoui discusses her anti-solutionist approach in conducting research and creating an interactive dance piece [22]. She states:

Moreover, I inscribe my work in a lineage of previous HCI approaches that go beyond the usual artificial problem solving. [...] In anti-solutionism through design fiction, Mark Blythe reveals the most influential scenarios in HCI that addresses the "monsters" of work in the twentieth century supported by technology. According to him, this is due to the fact that HCI is an applied discipline funded according to the impact and relevance of the work to industry. He argues that there are many monsters worth fighting and one can see a variation on this plot in critical design where the "monster" is the lack of informed debate [23].

Fdili-Alaoui presents this perspective as a way of navigating between standardized HCI methods or productions and creative projects, while negotiating whether technology serves or subjugates the dance in the process [24,25].

3.2 Moving and Making Strange

The Moving Making Strange (MMS) methodology, developed by Loke and Robertson, for designing movement-based interactions that are focused on the lived experience of movement and its felt, kinaesthetic experience [26]. Loke and Robertson state:

The emphasis on understanding the felt experience of moving and keeping it alive within a human-centered design process that shifts back and forth between the multiple perspectives of mover, observer, and machine is an

effort to provide a balance to the extensive amount of existing research from a technology-centric perspective (i.e. computer vision and motion analysis) [26].

The MMS methodology is grounded in similar principles as those proposed by Light as well as Fdili-Alaoui’s anti-solutionist approach. The practice of designing for obliqueness and other human-centered approaches in HCI can be seen as a design analogue to the notion of ‘queering the dance floor’ laid out by Gunn. These approaches attempt to mitigate the structural hegemony present in their respective fields. We import these principles from a design perspective. From an evaluation perspective, this research study follows the structure and principles of the MMS methodology by understanding the perspectives of the mover, the observer, and the machine in order to ground our focus on the process of inquiry and exploration.

4 Interactive System Development

We created a movement-to-sound system that we refer to here as the Interaction Breaking Music System (IBMS) to examine relationships between movement and gesture, as well as perceptions of engagement, agency and connectedness by b-girl participants.

4.1 Gesture and Mapping

The notion of “gesture” becomes more complex as input physical gestures undergo a process of translation during interactive sonic performances [27]. Physical gestures are processed and translated across a network of computers and sound synthesizers, having potentially multiple layers of mapping, conditioning and transformation [28]. With reference to Godøy, Donato et al. state:

Music can invite certain gestures that are often encouraged by timbral and dynamic qualities of the sound, by mimicking the action that might have produced them, or the gestures evoked by the music which might not necessarily refer directly to the production or sound qualities [29].

This speaks to the experience of “sound tracing” higher-level attributes while listening to music. Caramiaux et al. argue that combining the use of machine-learning techniques and theoretical frameworks from an embodied music cognition perspective contextualizes the link between music perception and human actions to establish gesture-sound relationships; they defined three different mapping strategies in order to have a better understanding of these relationships:

- *Instantaneous* mapping strategies refer to the direct translation of gesture to sound features or parameters, and vice versa.
- *Temporal* mapping strategies morph the translation and adaptation of temporal profiles, timings, and event sequences between the gesture and sound data streams.

- *Metaphorical* mapping strategies refer to relationships determined by metaphorical or even semantic aspects, which do not always rely on changes between gesture and sound [30].

As noted above, people’s movements – both higher level tracing and more direct action-sound gestures – convey information about perceived sonic moving forms while listening to music (see Fig. 1). For this reason, this research study employs both instantaneous and temporal mapping strategies of three types: explicit few-to-many gesture-to-sound mappings, implicit mappings learned via machine learning, and mappings of tempo changes, based on grouped data averages, with a longer temporal envelope.



Fig. 1. Photo of a participant dancing during study session.

It is well documented that more complex parameter mappings often lead to more intuitive and expressive results [31]. The complexity of the IBMS is tied to this combination of mapping strategies, allowing intuitive use while providing a challenge for b-girl practitioners to find ways of negotiating between exploratory movements and familiarity with breaking aesthetics, i.e. the mapping choices explicitly play with the principle of defamiliarization in the breaking context.

4.2 Modeling vs. Tracking

Our process began by conducting and comparing a set of camera-tracking based experiments involving live webcam feedback and one pre-recorded dance video using both machine learning models and lower-level computer vision methods. These initial experiments provided insight into which data-capturing method is

most appropriate and efficient to use in our project. We began by examining some promising contemporary machine learning models, specifically Body Pix and PoseNet. Body Pix is a real-time person segmentation, while PoseNet is a real-time human pose estimation using the TensorFlow library. We decided against these models for two reasons. First, we discovered that running them caused a heavy load on the GPU in combination with other programs to run the IBMS. With the research being conducted online, our capabilities to connect telematically with participants and record the session via Zoom would have been strained. Second, and most importantly, because Body Pix and Pose Net have been trained on bodies and/or movements that are not similar to that of breaking, the models were not able to track the dancers' movements in real-time with great accuracy. We tested this by feeding the model a breaking practice video featuring moves that transition from a standing position to the ground level. We found that, during those transitions, the Pose Net model would sporadically appear on the screen in an attempt to track the body; however, it would try to assume an upright, standing position even when the dancer is on the ground. In the case of Body Pix, We tested its real-time tracking accuracy by moving at different speeds within the camera's view. We found that body segmentation would get mixed up while turning around.

Instead, we developed the system using computer vision libraries found within Max/MSP and Jamoma [32].⁴ Developing the IBMS in this way shifted the focus away from potentially normative body-models towards more open-ended data outputs that sensed a wider range of unexpected movements. In the words of Light, using this more low-level tracking method allowed more space to obscure, elude, and cheat, which inevitably provided flexibility in the resulting interaction design [16].

4.3 Feature Extraction and Mapping Design

Due to recent circumstances around the coronavirus disease (COVID-19) outbreak, the research project shifted away from the use of Kinects in a single space, and instead focused on systems that could be engaged with telematically. This involved extracting movement data from participants' webcams and applying low-pass filter thresholding and noise reduction in order to produce a simplified "essence" of a persons movements within the frame. This is represented by an all-purpose motion image generator/analyzer which is then sent to a 'motiongram module' as seen in Fig. 2. A motiongram is typically used to display motion over a period of time similar to a two-dimensional spectrogram [33]. In our explorations, we found that this transform could be exploited to provide a more reliable tracking feature than raw values in both X and Y dimensions. In particular, we independently extracted the horizontal and vertical motiongram data (producing vectors of 1×100 and 100×1 respectively) and used these to

⁴ Jamoma exists as a package in Max, which is a programming language commonly used for developing interactive music systems and other systems within the interactive realm.

further extract the quantity of motion (QoM) [33] of the movement’s vertical motiongram and horizontal motiongram. By capturing data this way, we move the focus away from attempting to achieve a highly accurate model of human body using machine learning methods, and instead focus on understanding the more low-level dynamics of movement with relation to sound. We then apply *this* data to machine learning methods during the mapping process.

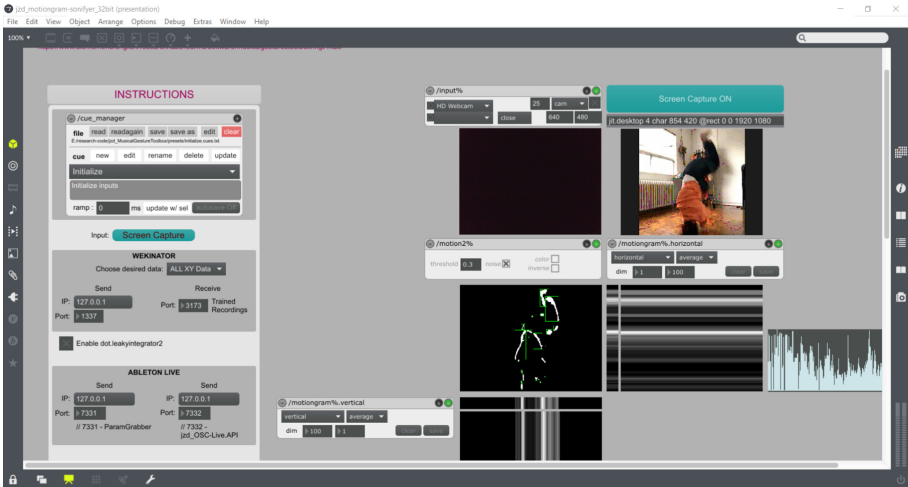


Fig. 2. Screenshot of the project’s Max patch.

This processed X/Y QoM data is then parsed out into three distinct streams: smoothed using an exponential smoothing method (X_s/Y_s), instantaneous velocity (X_v/Y_v), and instantaneous acceleration (X_a/Y_a), values. These values are used directly, and are further used to train a continuous neural network input/output mapping using Wekinator [34], which subsequently maps these values into an Ableton Live set as Open Sound Control Messages (OSC) through Max for Live (M4L) tools (ParamGrabbr by Showsync and a simple M4L instrument created for this project that allow for communication between Max and Ableton). The IBMS features a complex combination of implicit mapping using machine learning and explicit ‘one-to-many’ mapping strategies using these parameters, such that one variable is mapped to multiple device parameters through both means at any given moment, as depicted in Fig. 3. For example, the variable ‘wek-xv’ (Wekinator output of x_v) is mapped to parameters including reverb, probability of variation, decay, delay time, distance and filter cutoff across multiple tracks within the Live set.

5 User Study

This research employs one-on-one and group dance sessions with 8 b-girls, involving improvised movements to traditional breaking music – these are highly rhythmic songs that incorporate elements of funk and hip hop, typically those with a fast bpm and long drum breaks/solos – as well as the interactive breaking music system (IBMS) via Zoom. These study sessions are followed by individual or group interviews to reflect on participants’ experience of the session as well as their experience as a b-girl and/or their experience of breaking culture in general.

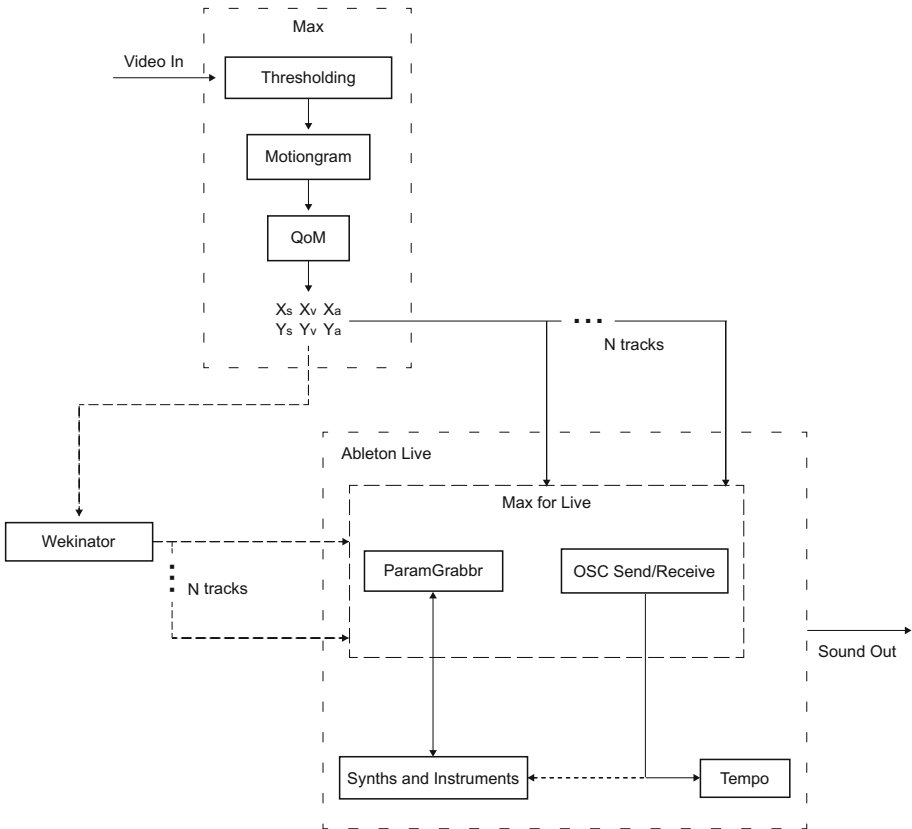


Fig. 3. Interactive breaking music system’s mapping control structure.

5.1 Study Structure

In this study, participants were invited by the first author from within their personal network of dancers in the Toronto area – all of whom were informed about the interactive nature of the music system and gave their written informed

consent to participate in the study. Each dancer had at least 5 years of breaking experience and were between the ages of 20 and 40. They were asked to improvise to (A) traditional breaking music – which included “Give It Up Or Turnit a Loose” by James Brown, and “Apache” by Incredible Bongo Band – and (B) music generated by the IBMS with different tempo settings: B1) unchanging tempo at 118 bpm, B2) accumulated/averaged movements which, after a threshold value, triggered a tempo of either 118 bpm or 90 bpm, and B3) tempo changes continuously with dancer movement in the range of 20 bpm to 118 bpm (see Table 1). Individual dance sessions were conducted with the following structure: 10 min of dancing to A, and 10 min of dancing to B2. This was followed by two group sessions of size 4 and 3 (unfortunately one of our participants was not able to attend the following session). This group dance session followed a similar structure: 10 min of dancing to A, 10 min of dancing to B1, and 10 min of dancing to B3. These sessions were held online to allow dancers to participate from wherever they felt the safest during the pandemic.

Table 1. Study structure

	Individual	Group
A - Traditional breaking music	10 mins.	10 mins.
B - Music from IBMS		
1 - unchanging tempo (118 bpm)		10 mins.
2 - trigger tempo (90 bpm/118 bpm)	10 mins.	
3 - continuous tempo change (20 bpm–118 bpm)		10 mins.

The tempo settings were changed to B1 and B3 for the group dance sessions to observe how dancers would react to music without a stable tempo, and to gradually introduce them to B3, B1 was used as an intermediary setting between the music they were familiar with and an extreme setting of the IBMS. Each dancer was initially asked to raise their hand before the start of their round to avoid everyone dancing at once; however, an interesting emergent phenomena occurred: dancers instead took turns by ending their round with a gesture that the next dancer would emulate at the start of their round.

As discussed earlier, we entered the study with two main questions:

- RQ1 Would practitioners embody breaking aesthetics in gestures that emerged from interactions with IBMS, and how would this vary across states?
- RQ2 How might the IBMS be leveraged to create a welcoming environment for b-girl practitioners, and possibly subvert or transform gender norms from breaking culture that manifest through movement?

Because breaking music typically employs steady rhythms at a fast tempo, we hypothesized that non-breaking music with a sudden change to the tempo (B2) or an “inverted” tempo that is driven by dancer movements (B3) would encourage

a defamiliarizing experience for the participants. All three of the non-traditional interaction states were presented to the dancer participants.

Following principles of qualitative methodologies including Grounded Theory that seek to allow emergent narratives to arise organically [35], general questions were asked during the individual sessions that were then updated for the group sessions based on trends found within participant responses. The initial one-on-one sessions focused on general questions of participant experience, comparing to “normal” breaking spaces, and comfortability with both using existing breaking moves and trying new moves in this context. The group sessions updated the questions to address emergent trends, which we further discuss in the next section.

5.2 Results

With respect to RQ1, the first author, as a practitioner in the field, observed that there were moves that would only be present in breaking in general – these included six-steps, hooks, back-rock variations, and threading. People seemed more on “autopilot” with state A in terms of producing standard breaking moves, meaning that they were more likely to perform movements from muscle memory rather than trying new ones. This was supported by participant responses, including the following:

For the traditional music, because those are songs I've literally practiced to or like battled to, my rounds are more traditional breaking like this top rock, footwork, freeze. But for the experimental music, [...] I felt like I was experimenting with different movements and like of my qualities and just kind of like going into the void. Just putting my body and places are carrying through with the momentum and just going somewhere like unfamiliar....

This implied that state A did not present an environment where the participant felt free to explore new movements, whereas the B states – or what they called “experimental music” – did. Because this research explicitly foregrounded breaking, participants were more inclined to at least attempt breaking movements, and thus it is unsurprising that all B states seemed similar in terms of initial presence of breaking gestures. In reaction to the experimental music, another participant noted:

I used one sound reference to kind of like, locate myself in the music, and in my movement. Like there was that constant beat [recurring sound] kind of going through the whole track.

Nonetheless, they seemed to be mediated by or driven by the music that was produced by the system. The explicitness of breaking in this study, however, posed an interesting trade-off. One participant noted:

This is a specific study about breaking so I kind of had to bring myself back to that.... So, although it was nice to break to a non-traditional breaking sound, it still felt like I was overthinking, or I was thinking a little more

for the experimental sound. Whereas for the traditional sound, I was like okay yeah I know how to dance to this. So...it didn't make me think more than I did when I was dancing [with] the experimental sound.

Although the nature of the study forced the participant to be conscious of their movements in order to fit what they deemed as breaking, which made it so that they inherently embodied breaking aesthetics in their gestures initially, they were also forced to be more aware of their thought-process on the movements they were making while interacting with the IBMS. One mentioned about their interaction with the IBMS during B3:

When the experimental music was on, at one point, I was like maybe I'll pretend I'm water, and then as soon as I started [...] contemporary dance starts coming out. I was like 'Okay stop that. No water today.' When traditional breaking music is on, I'll never think "Oh, what are some experimental things I can implement right now. It's more like what moves could I do. Can I try this move, maybe?"

This participant tried new ways of exploring movements by attempting to follow a different form of moving when dancing to what they determined to be experimental music. This meant trying more fluid motions, which made their experience in contemporary dance to unintentionally influence their movements and forced them to negotiate between dance aesthetics of breaking and contemporary dance. These results lead us to believe that an initial answer to RQ1 is really more about how practitioners negotiate with breaking aesthetics, taken as an initial starting point, via gestures that emerge only from their interactions with the IBMS. The process of “inverting” the tempo by making this an interactive variable, in the tempo ranges we examined, does indeed seem to be an important element that links breaking with the “experimental” spaces entered into by participants.

With respect to RQ2, the IBMS was seen to foster a supportive and non-competitive space through which participants were able to play freely. This parallels broader reflections on the benefits of an all b-girl environment for breaking. One participant recalled encountering the emphasis on competition in Toronto's breaking scene during their first few years being involved with the community:

When I came to Toronto, I was like, you know, everyone's just practicing for competition. I was like, is there even room to, like, vibe and have fun? [...] I found the b-girl community was just so supportive right away. And the b-boy community, it took me four years to, like, penetrate it.

They felt that the competitive environment made it harder for them to integrate with the overall breaking community, as opposed to b-girl spaces where they felt accepted immediately, especially when their intention was not to participate at every competition. During the group dance sessions with both B states, 5 out of 7 participants noted they felt encouraged to play. One participant explained:

I felt like with the experimental music I want to play more with stuff [...] because it's not like a break [beat], I don't feel that competitive, or that battle kind of energy so I'm not like trying to do my hard [moves]. I just want to kind of play.

The lack of competitiveness in the space allowed them freedom to play and explore movements while interacting with the IBMS, and therefore provided a space where participants were not judged on the execution and technicality of movements. In short, participants noted that an all b-girl space in general increased a sense of support and inclusion, and the IBMS was seen as providing a similar function through its linking between breaking-appropriate musical context and invitation to explore new “experimental” moves.

5.3 Discussion

Our research questions were aimed at investigating the potential of the IBMS to subvert gender norms of breaking movements in order to facilitate more inclusive breaking spaces. The tempo settings of B2 and B3 both encouraged movement-making processes that differ from the dancers' typical practice routines. The tempo setting of B2 presented sudden changes to the generated interactive breaking music, forcing participants to adopt to the new tempo. Further, responses suggest that B3 provided a more defamiliarizing experience due to a direct mapping from dancer movement to (smooth) continuous changes in tempo, in the range of 20 bpm to 118 bpm. Because breaking music traditionally has a fast and stable tempo, these settings posed a new challenge for dancers to move and create movements outside of what they are used to, while smooth transitions allowed dancers to make continuous adjustments in the moment. In light of participant responses, we believe that the root of a complete answer to RQ1 lies in considering the process of negotiation between breaking aesthetics in gestures that emerged from interactions with the IBMS, and gestures that are “brought” into the session a priori as a starting point. Participants' experience of the sessions can be seen as defamiliarizing, based on subject feedback that the IBMS made them become more aware of their own movement-making process – something that they normally would not have paid attention to at traditional breaking spaces. The IBMS thus encouraged them to be more conscious and introspective of their movements, yet (almost paradoxically) more comfortable in their own movements than they might feel at times in traditional breaking spaces. As a starting point to a fuller answer to RQ2, this is significant because the movements that breaking practitioners are familiar with were developed in a heteromale space. An interactive breaking space mediated by something like IBMS could provide a context where a practitioner feels they are properly “in” a breaking space, yet are naturally reflective of the dominant movement vocabulary while being inspired to try new movements that deviate from this. In further support of the need for such a space, the following were comments made by a participant reflecting on their experience in male vs. female dominated breaking spaces:

I feel like as a female, it's like it's really good practice to learn how to take up space, like through going to male dominated spaces. I've learned how to be more confident in myself and like how to take up space and, like, be grounded in my intention because of that, I can actually show up anywhere now.... I think I prefer b-girl spaces, but there aren't many b-girls dominated females spaces for breaking.

This highlights that female-dominated breaking spaces immediately felt more supportive because of the collective intention of improving their dance. Because the IBMS dance sessions focused on their experience as a group and in relation to one another, i.e. the broader interactive space that included framing context as well as the interactive system, the b-girls involved felt safe to telematically dance around one another. The lack of competitiveness allowed for more room to play and disorient their typical auditory and kinesthetic senses. The interactive breaking space can be seen as consisting of three distinct parts: the framing of the breaking context, the focus on “defamiliarizing” aspects of breaking movement from highly similar to highly experimental, and the system designed around complex mapping strategies and tempo changes that had this in mind. We believe that the synthesis of these three aspects shows the true potential for how a system like the IBMS could be leveraged to foster a more welcoming environment for b-girl practitioners.

6 Conclusion

Integrating technology in art interactive spaces that foster human-machine relationships opens up the possibility for dancers to explore a wide spectrum of movements they have never done (or possibly seen) before [36]. According to Berman and James:

...the tight coupling between the participants' behaviours may lead to interestingly unpredictable outcomes. For example, if the dancer imitates or extends the avatar's movements, her expressiveness and other aspects of her movement will influence the avatar's subsequent output, resulting in a feedback loop. The complexity of the interaction makes the outcome difficult to predict.... [36]

Similarly, women are able to make more space for themselves in hip-hop culture with the help of digital technology. Johnson argues:

The Internet becomes an especially powerful medium through which to redefine this discursive terrain, and to assert the interests and concerns of female Hip Hop practitioners. Jessica Pabon, a performance studies scholar writing about female graffiti artists, calls the Internet a system of visibility and communication for these women [37].

B-girls are able to sustain their identities in hip-hop culture through web videos and other specialized programming on the Internet, such as the webseries, “Strictly B-Girl,” that featured interviews with b-girls from across North America [37].

This study begins to explore this possibility at the intersection of these two worlds. The results are a promising first step that we intend to build upon in future iterations examining both in-person and telematic/networked contexts, towards building a data library of breaking movements for gesture recognition purposes, facilitating integrated IBMS and basic breaking classes/workshops over a period of time, and exploring more explicit and implicit mapping strategies using other low-level tracking systems that might amplify the defamiliarizing potential that we have initially observed in this study.

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