Priming Haptic Values with Wearable Technology

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Abstract

This paper presents an account of practice-based movement research that led to the development and implementation of wearable technology designed to capture, express, and promote physical interaction. Our system is distinct in that it is designed to sensitize users to their own movement, stimulating a refined and granular understanding of its central elements. Using feedback in the form of auditory output, the technology augments the audience-performer relationship. This technologically mediated practice of attending to others has implications for use beyond artistic settings.

Key Words: wearable technology, physical interaction, dance partnering, biofeedback, embodied ethics

Introduction

The long-heralded ubiquity of interactive computing has finally arrived, enabling unprecedented volumes of social interaction across great distances (Janlert and Stolterman 2017). Yet as we move boldly into the 21st century, researchers in psychology and cognitive science are demonstrating that the quality of engagement with digital interfaces is heavily normative, particularly in the domain of social interaction (Dotson 2017). Indeed, it has been shown that the use of interfaces can inhibit full engagement with social experience, leading to poor empathetic awareness, recurring miscommunication, and feelings of disconnection (Dotson 2017).

However, the intermediation of contact by interfaces is not the sole cause for the diminution or reduction of social interaction. A lack of deep, granular understanding of physicality also contributes to the reduction and approximation of interaction. This deficit is exacerbated by the paucity of physical interaction in a broad sense, with the rise of ”touch starvation” as a growing problem where friendly (i.e. outside of intimate relationships) physical contact is considered socially inappropriate, or discouraged (Field 2014).

Dance, on the other hand, provides rich opportunities for exploring and enacting social and intimate touch. As a whole, dance and somatic movement practices highlight the creative possibilities of physical interactions. Although our initial appreciation of movement is often visual in nature, somatic approaches focus on increasing awareness of internal sensations and perceptions, including kinesthesia, proprioception, and interoception (Eddy 2016). Partner dance can be a particularly enriching environment to develop skills for physical communication, as well as deeper concepts related to ethics in physical interaction (Vidrin forthcoming).

While even verbal forms of communication have constraints (see for example Cooperative Principle and associated maxims in (Grice 1975), the affordances of physical communication are particularly situated in their immediate context. Because each partner’s awareness of potential developments is informed by a sense (proprioception) that extends into the other’s body, possibilities for coordinated movement (and the awareness thereof) are continuously modulated by intentional and involuntary changes. Posture, muscle tone, poise, frame, and distribution of weight, as well as emotional valence and arousal, are all features of this disposition. Anyone who has spent a minute on a dance floor, Judo mat, or crowded subway platform has confronted the complexities presented here—which are compounded by the fact that while it is obvious that some physical qualities have communicative importance, it is less obvious exactly *what* they are, or *how* to use them.

This paper presents an account of practice-based movement research that led to the development and implementation of wearable technology designed to capture, express, and influence the specific qualities of touch, orientation, and proximity in dyadic relationships. Pairing movement with technology is not new to dance or theatre practice (Eckersall, Grehan, and Scheer 2017), and as motion capture technology becomes more affordable, more dancers are taking advantage of these resources. While these systems record impressively detailed pose skeletons, which existing work often exploits to great effect, the tactile quality of communicative movement is difficult to derive from such data. We sought a system that could account for the internal sensation of movement related to physical interaction.

Practice-Based Research

Our generative process began by exploring the assumption that there are fundamental principles in physical interaction. Drawing from social, folk, and concert dance forms, we focused on non-verbal communication within partnered movement (e.g. foot patterns, lifts, and floorwork). The investigated movement material spanned culturally-saturated and affected forms—ballet turnout, for instance—to that most pedestrian of acts—shaking hands. Thinking and feeling through our possibilities, we wondered how to augment awareness of the internal sensation and perception of physical interaction.

To help illustrate awareness of the internal sensation and experience of movement, consider the following example. Imagine standing across from a partner, about a foot apart. Place your palm against your partner's palm. Slowly, without changing the angle of your elbow or shifting weight forward, push against your partner's hand. You and your partner use pressure to oppose each other, such that there is barely any visible movement. Maintaining contact, reduce the pressure, again with as little movement as possible. As an outside observer, activation of pressure should be barely visible. Perhaps if someone is standing very close, they can perceive the muscular activation, but, at a distance of more than a few feet, the states should be visually indiscernible. The experience of pushing, on the other hand (no pun intended), should be quite obvious for each partner. The *effort*, while robust and obvious from the inside, is barely perceptible from the outside (for more on effort see (Von Laban 1966). This experience led us to consider ways to render and augment these subtle physical shifts as they are experienced.

As we investigated actions such as pushing and pulling, coordinated rotation, and coming in and out of contact, we focused on different ways to initiate communication through non-verbal cues. To focus our study, we narrowed down on relative position (orientation to each other) and physical proximity. From our experiential investigation, we identified some qualities that are negotiated specifically through the conduit of physical contact. We wondered how these mutually-coordinated qualities are created through tactile communication. Such communication must, somehow, be encoded in the mutual force between two bodies. Helpfully, in many forms of dance, a major portion of the physical interface that transmits this force is located on the hands. This observation motivated our initial attempt to measure how communication happens through the physical connection of partnering: pressure-sensitive gloves.

In the attempt to render the invisible visible, a few considerations came to light. 1) There is no standard for capturing the meaning expressed in an interaction, just the force captured by the sensors. 2) Sensors embedded in gloves cannot measure a physical interaction with anything like the fidelity achieved in human sensory fusion (i.e. proprioception and touch). However, in the same way that a dancer can modulate their movement to make meaningful qualities more salient to a partner, they can also make them more salient to the sensors. That is, even when it is impossible to quantify a particular value, sometimes a related measure can be meaningfully used to modulate it. In this case, the measurement and expression of pressure attunes the dancers to more than just the pressure itself. Given the scalar (i.e. gradient, not just on/off) nature of pressure, we initially rendered the sensor readings as volume-modulated tones. In doing so, we sought to emphasize the bidirectional modality of touch, in which the exertion of force is continuously adjusted by adapting to the resultant sensed pressure.

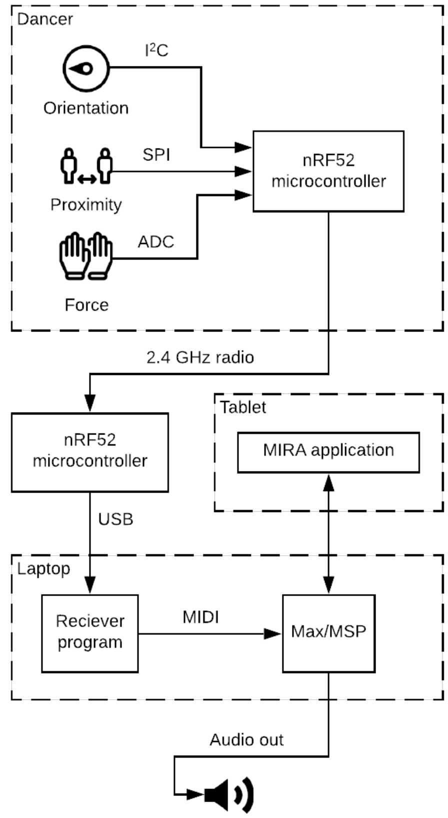

Figure 1: The wearable interface is built around the Nordic Semiconductor nRF52832, an ARM microcontroller with an integrated 2.4 GHz packet radio. A Bosch BNO055 inertial measurement unit measures orientation, a Decawave DWM1000 module performs two-way time-of-flight radio ranging, and hand force is measured by a custom large-format force sensitive resistor.

Creative Implementation

After designing this wearable interface, we realized we could be creative with the captured data. We focused on the scalar quality of feedback, playing with sound and light as outputs. To express the sensor readings in real-time, we determined that audio synthesis was a good choice in that it enables both observers and dancers to make full use of their highest-bandwidth sense (i.e. visual perception).

Within audio synthesis, we drew on basic principles of music theory, including changes in volume, pitch, and tempo. Changing pressure, for example, modulated the volume of a single tone. We added more sensors to capture some of the other (reasonably measurable) qualities we had identified: proximity, via radio ranging, and orientation, via electronic gyroscope. Because these new modalities didn't map intuitively to the synthesis we had been using for pressure (volume of a simple tone) we added other configurable synths, including a virtual "ratchet" initially mapped to the dancer's orientation, and repetitive base percussion with tempo modulated by the distance between dancers. To facilitate experimentation, we also programmed a tablet-based interface to configure the mapping between the sensors and synths. We then tried out this ensemble in a few different settings. We noted that the creative implementation had implications in performer-performer interaction, as well as audience-performer interaction.

Performer-Performer Interaction

The creative implementation of this system in the context of dance provides some important ways to understand interactive, relational bodily movement. On the one hand, movement does not need to be 'meaningful'—we can move with and next to others without any particular narrative goals or one-to-one mapping for meaning. Yet it is interesting to note that dancers working with our wearable technology seemed to become more sensitive to subtle physicality, which led to deeper interaction.

We noted that mutual control (for every force, there is an equal and opposite force) of an external, objective measurement seemed to naturally provide an anchor to ground discussion. We found that this anchor promoted focused iteration and physical experimentation of how the shared pressure, proximity, and relative position was informed by joint and individual decisions and experiences. We also noted a distinction in quality of movement, which we attributed to a difference between *pragmatic* and *epistemic* motivation on the part of the performers. In the former, movement is motivated by some directed goal (e.g. getting from point a to point b). In the latter, movement is motivated by a desire to understand the interaction itself. We believe that a concrete shared measure increases focused sensitivity for negotiating the minutia of physical interaction, priming a quality of relational communication necessary for ethical interaction such as care and empathy.

It became clear that individual emotional states of individuals have a significant impact on the feelings of connection within an interaction. Sometimes it was visually obvious from the outside, other times it was difficult to understand even from the inside why a particular movement felt disconnected. Thinking and feeling through our possibilities, we noted that receiving continuous feedback about subtle physical changes promoted more *committed* action. That is, with the auditory feedback, performers reported that they were more aware of the consequences of their action. This awareness led to focused reflection and subsequent discussion about internal states (e.g. emotions, psychology, etc.). Dancers reported that the technology helped access underlying ethical dimensions, such as feelings of care, trust, and vulnerability toward a partner.

The technology provided a platform by which novice dancers could transcend otherwise awkward situations, such as sustaining contact for longer than typically socially acceptable outside of intimate relationships. It is interesting to note that dancers who reported feelings of comfort were not necessarily more likely to attune to their partners and sustain partnered interactions for longer than those who felt awkward or uncomfortable. This was evidenced in experimental conditions where we asked dancers to find different ways to produce similar sound, or how small changes in movement could produce different sounds.

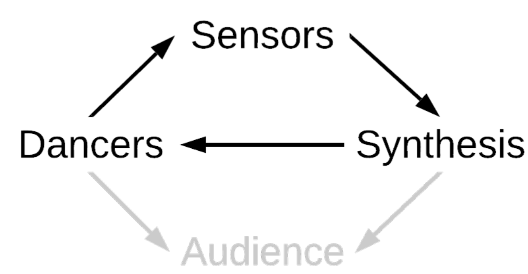

Figure 2: Relationships of influence. Synthesis can include procedurally generated audio signals, or live improvisation by a musician. The audience perceives some parts of the feedback loop, but are not integral to it.

Throughout the practice-based research with the technology, dancers traded off turns wearing the sensors versus controlling the sonic expression from the tablet. With an unknown and changing mapping between their actions and the sonic results, dancers needed to simultaneously attend to each quality measured to determine the current relationship. The external party's ability to change the volume or mute different synthesizers empowered them to wordlessly influence which qualities the dancers considered important.

We also experimented with further inter-mediation of the sensor readings, by using visualization to cue musician's improvisation of real-time accompaniment. In the simplest format, changes in pressure, proximity, and relative position modulated the size and thickness of a circle. The rendered image is read by a live musician, who adjusted point of contact, pressure, and pitch. We noted that this direction of practice-based research challenges the typical relationship of musician-as-accompanist, and further enhances the real-time interaction between musician and dancer by enabling each to define the parameters of responsiveness in both emergent and predetermined ways.

Audience-Performer Interaction

This technology was utilized in the development of performances from 2016–2019. In this time period, we made some discoveries about the continuous feedback of hand pressure, relative position, and proximity, which applied to both users and external observers (i.e. audience members). In particular, we noted that the system was useful for 1) sensitizing performers (reflexively to themselves, and responsively to each other) and 2) priming audience members to haptic values such as subtle shifts in quality of interaction.

While correspondence between sound and movement is commonplace to dance performance, our movement-driven audio synthesis inverts the usual presumption of "dancing to music". There are many precedents of this inversion (Dubus and Bresin 2011), but some details are worth mentioning. Choreography emerges from the choreographer's desires of both formal movement (typical) and the sound produced by the movement (atypical). That is, movements of a dancer's body are constrained not only by the aesthetics of their occupation of physical space, but also by the aesthetics of the mapping of that physical configuration onto the space of sensor measurement. For the audience, the establishment of a casual relationship between hidden and observed variables framed their interpretation, priming their interest in the mechanism (both human and machine) producing the relationship.

The framing of relation between dancers and the sonic expressions thereof elicited a variety of reactions worth noting. Some of the reactions were aesthetic. Some audience members perceived the emergent act of relating and shared attention through dance as poignant enough to elicit tears. For the dancers, performances were perhaps characteristic of good partnering, but not exceptionally notable. We could attribute the tears to a novel interpretation of the act of dancing becoming salient to the audience, rather than any particular novelty in the performers' actions. Other reactions were more epistemic. After performances, some audience members wanted to know exactly what was happening. This wasn't unreasonable, given the fact that choreography tended to be quite stationary and subtle. The experience of the mediated performance elicited questions about the significance of physicality on trust and vulnerability between performers. A number of audience members even expressed a desire to know how trust functions in the quality of physical interaction, beyond merely a mental state or attitude.

Throughout demonstrations and performances, it is also worth noting that a number of creative technologists expressed interest in making the technology more aesthetically pleasing (i.e. less wires and smaller hardware), which we understood as attempts to further "mystify" the technical aspects. We firmly believe, however, that this work is useful when dancers return to their bodily experience after using the technology to attune to one another, rather than creating a paradigm where people attend more to the technology than to their partners.

Conclusion

Our system is different from many other motion capture systems in that it is designed to 1) render elements of kinesthetic experience visible (rather than purely external movement), and 2) sensitize users to their own movement. Both of these work to stimulate understanding of physical interaction in a refined, granular way. By maintaining the body as the interface of physical interaction, our system, though quite simple, facilitates awareness of the internal sensation and perception of physical interaction. We noted that this awareness has certain social-emotional benefits, such as encouraging thoughtful reflection about individual experience and subsequent discussion of shared experience. We noted that this contributes to effective and ethical interaction, both physically and verbally. Our hope in sharing this practice-based research is to open discourse about the utility of technology that returns users to their bodies, as opposed to the myriad devices that distract or remove individuals from inner somatic experience.

We see this system as a tool for entering into physical dialogue, more than a crutch on which individuals can rely to do the sensing work for them. Given this mediated practice of attending to others, this technology has implications for use beyond artistic settings. Such uses extend to movement interventions for diverse populations in artistic, clinical, and professional settings, including professional performers, patients with movement disorders (especially stroke rehabilitation (c.f. (Schmitz et al. 2018)), and individuals who seek to develop novel and unique strategies to communicate efficiently, effectively, and ethically.

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