hipDisk – an interactive sonic system inspired by core-body gesture.

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Abstract

This paper describes the development and articulation of hipDisk, a musical interface that highlights, by making visible, the dynamic relationship between the wearer's hip and torso. The resulting interface effectively turns the body into an instrument by augmenting it with instrumental capabilities.

The hipDisk interface raises questions about the role of a direct exploration of, and response to, the physical affordances and capabilities of the body in the development of computer-mediated, interactive, sonic interfaces. The idea that such a focus can provide added value is discussed in relation to the hipDisk interface.

Keywords

HCI, full-body interaction, wearable interfaces, body dynamic, performance, soft and hard electronics, soft sensors, gesture-control, sound

Introduction

Possibly the most undignified musical instrument ever, *hipDisk* (see Figure 1) exploits changing relationships between torso and hip to actuate simple tones. Horizontal disk-shaped extensions of the body exaggerate, so make highly visible, the interdependent relationship of the hip and torso. Soft switches, strategically placed around the perimeter of each disk, allow the wearer to play a one-octave chromatic scale, and so play simple melodies, restricted only by core-strength and flexibility.

hipDisk was designed to inspire people to swing their hips and explore and extend the full range of movement available to them through a simultaneous, interdependent exploration of sound. In creating *hipDisk*, the objective was to move beyond limb- and digit-triggered switches and explore full-body movement for actuation. The resulting body-instrument interconnects choreography and composition in a fundamental way.

hipDisk sits within a broader research framework that explores the role of a poetic approach in the design of interactive interfaces, ranging from abstracted prosthetics through to invisible, virtual systems. This broader research targets not only sound output systems but also systems for the output of changes in colour, light and shape.

The paper begins with a brief survey of related research. This is followed by a detailed discussion of the conceptual and technical development of hipDisk. An evaluation of the instrument is then provided, along with an analysis of audience response. Finally, directions for further investigation are suggested.

Figure 1. *hipDisk*, demonstrated by the author.

Related Work

hipDisk is primarily related to the following research areas: human computer interface design (interaction design, HCI and CHI) – in particular wearable, gesture-controlled and sonic interface design. It is also informed by research into technical textiles and soft electronics.

The measurement of gestural input for the control of computer-mediated interactive interfaces has traditionally focussed on limb- and digit- triggered gesture. This is perhaps due to the complexity of multi-axis input. The softness and flexibility of the body's corporeal structure add to this challenge. Research into soft electronics and soft sensors is enhancing our ability to measure complex and fuller-body physical gestures. The work of Farringdon et al (1999) and, more recently, Gibbs and Asda (2005), and Helmer (2007) clearly shows this.

hipDisk uses custom-built soft sensors to measure core-body gesture, but rather than measuring body displacement directly on the body – as in the work cited above – the custom switches developed for *hipDisk* support the measurement of a mechanical event that takes place in a physical extension of the relevant body parts. By approaching the problem in this way, it was possible to sidestep many of the more complex issues associated with the measurement of full-body gesture. In this way the resulting interface is related to Kei Kagami's Head Holder (2006), a dress that explores dynamic structures by means of rods and strings that cause exaggerated movement of the garment by the motion of the model or wearer.

An ability to understand and measure changing body dynamics seems integral to an appropriate development of interactive gesture-triggered systems if they are to reflect the complexity of the body's use, and dynamic potential. Extending and exaggerating the body and specific dynamic relationships seems to enhance our ability to read changes in dynamic, so simplify technical requirements.

There exist numerous interfaces for gestural control of sonic output. Jordà provides a detailed compendium in his PhD thesis (2005). For more recent examples, Bardos et al's Bangarama (2005) provides a suprising, albeit obvious example of a gesturally-controlled sonic interface; and Helmer's Wearable Instrument Shirt (WIS) (2007) provides an example that incorporates custom-designed soft electronic sensing. Both Bangarama and WIS manipulate guitar samples, but in the case of WIS, the same interface can also be used to manipulate other instruments – i.e. the interface is not instrument specific.

Many sonic output devices manipulate samples, mapping physical gestures to sonic gesture. An early example is Waiswiz's Hands (1985), which allow both recording and manipulation of samples for output. Zigelbaum et al's Ringalings (2006) allows individual users to map specific gestures to triggered sound samples on a case-by-case basis before performing or experimenting. Goto's BodySuit (2006) is used to control percussion robots, translating or altering the gestures algorhythmically before sending them on to the robots. Direct manipulation of artefacts can also support the mapping of physical gesture to sonic gesture. Hewitt's eMic (2003) and Singer's Sonic Banana (2003) provide clear examples.

But *hipDisk* does not map physical gesture to sonic gesture. Nor is it a manipulable artefact.

The output of *hipDisk* is clearly related to the author's previous work Ange (2004), which allows the player to trigger sound samples and control volume, so mix up to twenty-four samples in real-time, simply by manipulating their volume. In the case of Ange, sonic complexity is achieved through simple means. But this is where any similarity between the interfaces ends – though output is clearly related and Ange is worn, gestural control of Ange is limited to finger or hand pressure, provided either by the wearer or someone else. Core-body gesture of the wearer does not affect output in any way.

hipDisk allows the wearer to trigger individual tones, and so build or play simple melodies. In this way it comes closer, perhaps, to traditional acoustic instruments such as the piano or the recorder. The input/output relationship is also simple and direct, the tones triggered through core-body gesture, allowing us to make a clear correlation to physical interfaces like Dance Dance Revolution (Smith, 2004).

hipDisk

In this section the context of the creation of *hipDisk* is discussed, as well as its impact on the development of the interface. A detailed technical overview is then provided.

Context

The first prototype of *hipDisk* was conceived and developed during Reskin, ANAT and Craft Australia's wearable technologies lab, which took place over a three-week period in January and February 2007.

Intensive residential labs provide a particular framework for the creation of new work. Reskin was no exception. The first two weeks of Reskin were focussed almost entirely on skill acquisition. There was a limited amount of ideation, or development of ideas, and it was only during the third, and final, week of the lab that the focus was on the development and construction of new works. In accord with this framework, *hipDisk* was conceived and created during an intense seven-day period.

From the outset, the outcomes of Reskin were intended for public display. This requirement had a clear impact on the development of work. For example, on the final day of the lab a gala event was held for public presentation of work and on the following day, the WearNow Symposium – an international symposium focussed on wearable technologies – was held at the National Museum of Australia. The symposium included a session devoted to Reskin outcomes, including live demonstration of the created works.

Though it was clear that such a short, albeit intense, period of work, which included skill acquisition, could only result in the creation of prototypes, these prototypes had to function in highly publicised and public contexts. Small and subtle work would, necessarily, be lost in these contexts. As discussed below, the *hipDisk* developed accordingly.

Conception

The original intention that led, finally, to the creation of *hipDisk*, was to explore ways of using conductive fabrics to measure or track physical movement, or changes in the body's dynamic, so that these changes could be used to actuate digitally-mediated events.

Experiments for the input system included weaving conductive thread into three-dimensional ridges or channels that could be placed against the sides of the torso to measure bend, and the creation of small wing-shapes, that extended out from the body in a similar manner.

Both of these experiments were concerned with the body's movement along a single axis. Whilst not problematic in and of itself, such a restriction seemed inappropriate for the context in which the work would be demonstrated. The concern was

that a physically responsive system demonstrated by raising the arms and bending from side to side was not only limited, but, in this particular context, would seem somewhat ridiculous. As a result, the focus shifted to an investigation of more fundamental, dynamic and fuller-body movement.

Different parts of our bodies have varying degrees of freedom. The relationship between the hip and torso is particularly dynamic as this area of the body allows movement on its axes in an unconstrained fashion. It also provides a fundamental reflection of core strength and flexibility. For these reasons the relationship between hip and torso was identified as a more appropriate source of input for the envisioned system.

Input

In order to explore the changing dynamic between hip and torso, a pair of disks – one attached to the hip and one attached to the torso above the waist, were created. The aim was to make this dynamic relationship highly visible and so provide an input that was easy for the viewer to 'read'.

Twelve simple, soft, digital switches were then positioned at equidistant intervals around the perimeter of the disks – one part of each switch on the upper disk, the complementary part of the switch on the lower. The switches could then be activated when the corresponding parts of the upper and lower disks connected, as achieved through bending the body at the waist. (see Figure 2).

Figure 2. Wilde, triggering different switches

Construction: Soft vs Hard Electronics

'Hard' and 'soft' electronics are both used in the *hipDisk* interface.

'Hard electronics' is a name given to traditional electronic circuits and componentry. Typically constructed of hard plastics, metals, silicon, etc., the components are literally hard, in a tactile sense, rigid and angular. They are often brittle and are unsuitable for any use that requires flexibility or stretch.

Soft electronics replace wires and other conductive surfaces with conductive fabrics and threads that incorporate metal filaments into their grain or weave yet remain flexible and soft, in a tactile sense. This flexibility and softness make them ideal for use on the body in that they can be worn, rather than merely attached or placed next to the body.

Soft circuits, clearly, have different properties to traditional, hard circuits. The use of soft switches in *hipDisk* was conditioned by the need to ensure contact between two surfaces that would meet at an angle, in a system where the central, vertical axis (in the case of *hipDisk*, the spine) allowed for horizontal displacement.

It was originally envisioned that the soft switches would provide variable resistance, so provide the ability to measure velocity and express continuous musical gesture, but this was determined to be impractical from a technical standpoint. The conductive qualities of the fabrics used, combined with the nature of contact allowed by the *hipDisk* interface, did not allow a high enough resolution of electrical signal to read pressure, or amount of surface touching. The interface was, as a result (and in consideration of the development time-frame), limited to a series of twelve on-off switches.

The reduction, from variable input to a simple on-off triggering system, affected the range and quality of possible output for the *hipDisk* system, and so impacted the subsequent development of the interface.

Output

Within the larger research project any form of output could have been deemed appropriate for an interface designed to explore full-body gesture. The choice of sound was conditioned by a number of considerations.

Typically the body doesn't make sound when it moves, but sound, being an independent sensory modality, provides an ideal contrast to the highly visible, movement-based input of the *hipDisk* interface. Through the use of sound, a clear, identifiable separation between input and output – as perceived by the audience or viewer – could be achieved.

In addition, sound output can be quite simple or highly complex while still allowing for complexity of use. The development timeframe made this particularly attractive.

While the author's previous work has focussed on the creation of live performance and interface design, particularly in the field of wearable and portable costumes and interactive sculptural elements, sound was not entirely out of scope. Admittedly the final sonic output of *hipDisk* is highly simplistic, but, as mentioned above and as will be clarified below, this was not unconsidered.

Once sound was chosen as the most appropriate output modality, design of the system could then be undertaken. In order to clarify the author's thinking about *hipDisk* as a sonic interface, consultation was undertaken with a number of Reskin participants who had undergone traditional musical training. Though they didn't necessarily agree, the choice of a twelve-note interface was based on the following determinants:

- the need to place the switches evenly around a circular formation, in an easily recognisable and actionable pattern.
- the range of musical possibilities provided by a chromatic scale, as opposed to a five- or eight-note system, or any other single key or mode
- the physical precision required to bend the torso into twelve distinct positions, as opposed to eight positions, or any other number

This final point was driven by the author's desire to create a system that could be played by a novice, yet through mastery, allow greater complexity. It is the author's impression that this quality is intrinsic to many musical instruments. The example of a recorder comes to mind. Simple tunes can be played on a recorder by novices yet an entire canon of highly complex and beautiful music exists for the same instrument.

While this is conceptually sound, the final interface has a learning curve so steep that, to date, no actual tunes or songs have been learnt by the author. In addition, the precision of physical positioning, required to trigger the individual switches, is not consistent. While the centre-front, centre-back and side switches are easy, consistent identification and triggering of the other eight switches has proven to be highly problematic. It would seem that an eight-note system would perhaps be more viable, simply because it would be a little easier to learn and operate.

Design Challenges

A number of design issues needed to be addressed in order to construct the envisioned interface, particularly considering the time-frame within which a fully functioning, robust, prototype needed to be realised.

Two fundamental issues were how to keep the disks horizontal, and how to maintain an ideal distance between them. The source of the sound output also needed to be addressed as it was considered important that the system be autonomous – that the wearer of the interface be able to move around freely within a self-contained system, with no need for additional computers or amplification beyond that which was to be worn on the body.

It is perhaps useful to point out that an underlying driver in the ongoing work of the author is the need for simplicity in interface design. In reflection of this, it was considered important that all elements of the interface be functional responses to the technical and/or conceptual development of the work. The resulting interface, as a result, steers clear of decorative addition.

It should also be noted that a number of aesthetic issues are yet to be addressed. In developing the interface further, different materials would perhaps be employed, and the design, necessarily, refined and further developed.

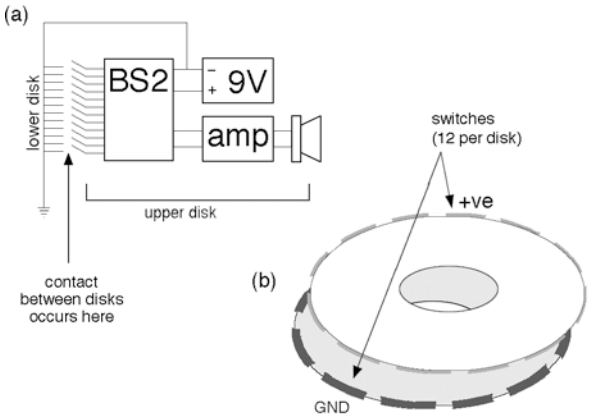

Figure 3. (a) schematic
(b) placement of switches around disks

Technical Overview

The sounds output by *hipDisk* are simple tones created digitally by the Basic Stamp 2 microcontroller, triggered by a series of twelve custom-built soft switches, amplified, then output through a simple speaker. The entire system is self-contained. (see Figure 3).

Construction

The current iteration of *hipDisk* is made of polypropylene sheets, cut and connected with rivets and reinforced with aluminium strips in order to maintain a perpendicular relationship between the waist- and hip-bands and the corresponding horizontal disks. Attached to the exterior of the waistband, on the upper disk, are two transparent plastic boxes that contain all of the electronics – the box on the right contains the Basic Stamp, that on the left a 9V battery, a small amplifier and an on-off switch (see Figure 4). All wires are held down with a combination of white electrical tape and white duct tape, except where they enter into the boxes containing the circuitry.

Lycra tubes filled with cotton braid and wadding are mounted on the interior faces of each disk, to support the soft switches (see Figure 5). The switches consist of two layers of conductive fabric sewn together with conductive thread, wrapped at

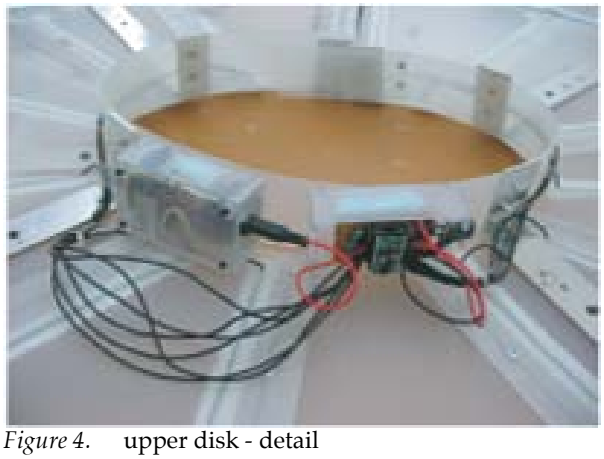

Figure 4. upper disk - detail

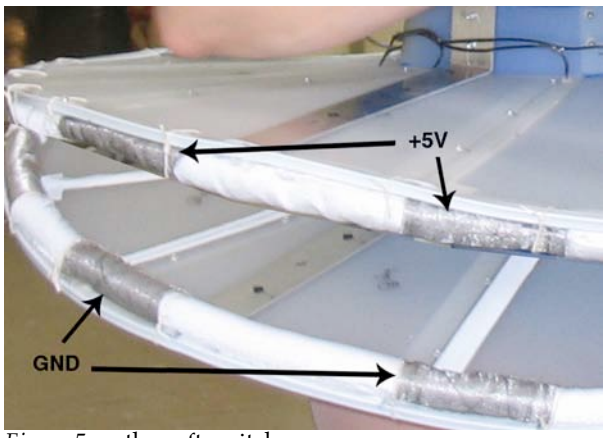

Figure 5. the soft switches

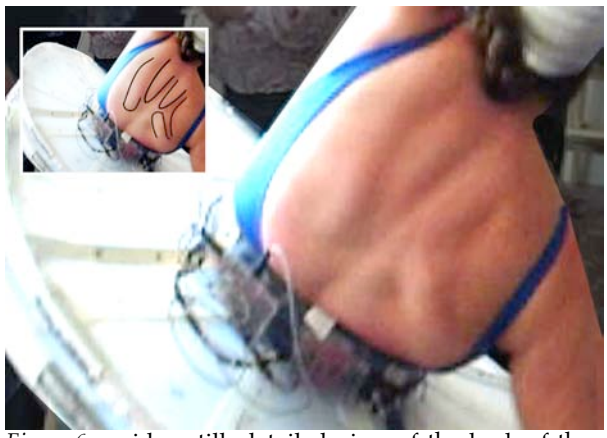

Figure 6. video still: detailed view of the back of the wearer while performing with *hipDisk*

specific points around the lycra tubing. The softness maximizes the potential for contact by providing greater surface contact under pressure.

Conductive fabrics and threads have varying amounts of resistance depending on the surface area and amount of thread in contact – the more thread in contact, the lower the resistance. While this resistance would not impact the functioning of the switches in any direct way (as the switches were binary), the impact of this additional resistance had to be taken into account in the design of the overall circuit.

Sound output is through a small speaker mounted into the bodice of the costume of the wearer. When *hipDisk* was demonstrated in the context of Reskin, it was found that the cleavage of the wearer provide a suitable amplification chamber for the speaker. As a result the sound output capabilities of the system were enhanced. It should be noted though that his aspect of the interface would necessarily vary with each performer.

Outcomes

A number of surprising outcomes have resulted from the creation of the *hipDisk*. The interface seems to embody an inherent interdependence between composition and choreography that leads the wearer to perform at the outer limits of his or her physical capabilities.

In 'reaching' for contact to be made by the two disks, the performer's body seems to be thrown almost unconsciously into a variety of positions that exist purely in order to support the necessary physical extension that will result in contact.

Rhythm of desired output is also closely linked to core strength and flexibility – the tempo of the produced melodies are limited only by the wearer's ability to move from one position to another.

Though *hipDisk* was designed specifically to inspire people to swing their hips and explore and extend the full range of movement available to them, the physical repercussions of this were not fully understood in advance. It was only after public presentation of the interface that this became apparent.

Video footage of the first demonstration of *hipDisk* (see Figure 6), clearly shows that the wearer's back muscles were highly engaged to perform the necessary dynamic movements. The following day muscle strain also indicated that a strenuous workout had been undertaken the day prior.

In light of this, it is recommended that a full physical warm-up be undertaken before use of the *hipDisk*, and additional stretching and cool-down exercises be performed after use.

Despite the fact that *hipDisk* does not appear as an exercise interface, the performer's focus on doing whatever is necessary to achieve the desired sound output seems to extend, over time, the body's capabilities to do so. Their ability to move from one position to another in a timely manner is enhanced through use. As a result, core strength and flexibility are positively affected through an extension of the outer limits of the wearer's physical capabilities. The *hipDisk* thus provides surprising, yet not undesirable health enhancing aspects for the wearer.

In addition, use of the interface seems to be highly compelling for audiences.

Audience Reception

hipDisk has been shown in four radically different contexts to date (at the time of writing). The first was a gallery opening; the second an academic-style conference; the third an informal presentation to representatives of a government funding organisation; the fourth, at Dorkbot Melbourne to a group of technically savvy arts professionals.

Each of these contexts was radically different, yet the resulting interface was found to be strangely compelling in each instance, almost without exception.

It is difficult to qualify what it is that makes *hipDisk* so compelling without conducting rigorous audience surveys. Some informal questioning and conversation has been undertaken to date with participants in each of the aforementioned fora so an attempt will be made to discuss the question despite the lack of statistical information.

The design goals, in creating *hipDisk*, were:

- to explore ways of using conductive fabrics to measure or track physical movement, or changes in the body's dynamic, so that these changes could be used to actuate digitally-mediated events
- to inspire people to swing their hips and explore and extend the full range of movement available to them
- to make a musical instrument that was at once simple, so able to be played by a novice, and sufficiently complex, so that mastery would afford musical complexity.

It is the author's belief that the first goal has not impacted on audience response as it has been driven by purely functional concerns, and the use of soft conductive substrates is not actually evident to an audience member without a detailed inspection of the interface.

The impact of the third goal can perhaps only be fully explored once a level of mastery has been achieved, though it should be noted that in presentation of the interface the suggestion of playing actual tunes with the *hipDisk* does elicit much laughter and encouragement. In performance there is currently no discussion, or clear evidence, of this aspect of the interface's potential, unless we accept that any audience member who has ever heard a piano, keyboard or recorder, could arguably extrapolate this potential from the available information. As a consequence it's difficult to argue the impact of this goal until further development has been undertaken.

The second goal, to inspire people to swing their hips and explore and extend the full range of movement available to them, seems to be that which has impacted most favourably on audience response.

To clarify: The interface seems to embody an inherent interdependence between composition and choreography that can only be demonstrated with an inordinate amount of effort. The wearer is required to perform at the outer limits of their physical capabilities for the simple result of a single audible tone. Added to this, rhythm of desired output is closely linked to core strength and flexibility – the tempo of the resulting melody is limited by the wearer's ability to move from one position to another. The physical difficulty presented by this seems to compound the imbalance in input and output energy. Finally, in 'reaching' for contact to be made by the two disks, the performer's body seems to be thrown almost unconsciously into a variety of rather strange positions that exist purely in order to support the necessary physical extension that will result in contact.

This combination of strange body positions and extreme imbalances in input and output energy seems to be both humorous and compelling.

Other unintentionally attractive aspects of the device seem to be:

- the choice of costume and persona – reminiscent of a character from a circus. Though there seems to be no clear logic behind the choice of bathing costume and cap, the original idea was conceived when the author became conscious of the pleasure experienced swinging her hips whilst swimming laps. The incongruity of this choice seems to support the strangely humorous and compelling nature of the interface as a whole.
- the ungainly manner of physical input necessary to achieve what could arguably be (and certainly sometimes is) highly pleasing and beautiful audible output
- the fact that the author, when wearing the interface, seems compelled to smile broadly, continuously, throughout her performance.
- and finally, the fact that anyone could even think of such an interface, let alone realise it and perform in it seemed to be particularly compelling.

hipDisk demands, conditions and requires total freedom of physicality on the part of the wearer. It cannot be used in a restrained manner. In fact, the effort required to use *hipDisk* effectively removes any thoughts of appearance, as well as conscious thoughts of the external realities of physical displacement at the time of use.

Activities that require total freedom from physical constraint, as a rule, seem to be outside the boundaries of most people's limits, so perhaps the desire to exist in an unconstrained manner is what is highly compelling? Is this not what leads people to undertake extreme sports and other physically demanding, extreme or dangerous activities?

Many adults, in fact, asked the author if she would be constructing *hipDisks* for children. Though it's beyond the scope of this paper it would seem that being unconstrained can be equated with freedom, the kind of freedom perhaps experienced by, or equated as being possible for, children who do not yet need to live by adults' rules.

Future Directions

Future directions include aesthetically resolving the current interface, and creating an extensible version that can fit multiple-sized wearers. The author's intention is then to work on a series of performances, beginning with the realisation of the standard tunes: "the Girl From Ipanema" and "Do You Know The Way To San Jose". The objective is to create compelling performances that explore the potential of an interlinked choreographic compositional system, as well as to explore the possibilities

made available by numerous *hipDisk*ed performers. For example, four *hipDisks* make it possible to play Jazz chords, or to provide back-up for solo singers or players, to harmonize, etc.

Within the context of the larger research framework, the author will also be exploring more subtle and embedded interfaces for the measurement of physical gesture, and the subsequent triggering and more complex control of sound output.

Conclusion

Many decisions were made during the realisation of *hipDisk* that were conditioned by the constraints of the context in which it was created. The interface is a necessarily highly simplistic input-output system. The overwhelmingly positive response to *hipDisk* has led the author to question what it might be that would give such a simplistic interface so much power to excite, enthuse, captivate. It seems clear to the author that the focus on gestural input, the body, it's dynamic and affordances have contributed in no small part to the success of the work.

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Figures and Tables

Figure 1. *hipDisk*, demonstrated by the author.
Figure 2. Wilde, triggering different switches
Figure 3. (a) schematic
(b) placement of switches around disks
Figure 4. upper disk - detail
Figure 5. the soft switches
Figure 6. video still: detailed view of the back of the wearer while performing with *hipDisk*

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