Wii Remotes as Tangible Exertion Interfaces for Exploring Action-Representation Relationships

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ABSTRACT
Sensor technologies and exertion interfaces offer new opportunities for interaction with digital data. Technologies such as Wii Remotes can be embedded into tools that can be used to employ active sensorimotor interactions. This is an interesting concept in the field of learning, where such technologies may support exploration and understanding of real world physical phenomena (such as forces, motion and acceleration) through embodied interaction with these concepts. This paper presents initial studies that used a Wii Remote controller to investigate these relationships. Findings suggest that the action itself is central to making the meaning mapping between action-representation links.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies, Interaction styles, Evaluation/methodology*; K.3 [**Computers and Education**]: Computer Uses in Education – *collaborative learning, computer-assisted instruction*; J.2 [**Computer Applications**]: *Physics*; J.5 [**Computer Applications**] Arts and Humanities – *Performing arts*.

General Terms
Design, Economics, Experimentation, Human Factors, Theory

Keywords
Tangibles, action, representation, embodied cognition, embodied interaction, performance art measures, kinesthetic interaction, granularity, choreography, movement

1. INTRODUCTION
The development of sensor technologies and exertion interfaces brings new potential for supporting physical interaction with digital information. Recent theoretical interest on the role of embodiment in cognition [10] suggests that physical interaction with the real world plays a central role in cognition. However, further work is needed that explores the relationship between embodiment and learning. One way to explore this relationship is to investigate the action/inference relationship that occurs in linking action/object with digital effect. Drawing on Price et al.'s [5] framework, this paper explores the action-representation relationships offered through tangible environments, particularly seeking to understand the value of engaging children in physical activity involving concepts of motion and acceleration, that are directly mapped to digital representations of the phenomena.

Price et al.'s [5] framework describes a representational approach to conceptualizing tangible learning environments. As part of this framework the concept of 'action' broadens Gibson's theory of affordance [1] to include representations that employ active sensorimotor explorations. This highlights the relationship between action, external representation and cognition, as well as the importance of understanding this relationship (currently under researched) in terms of interaction and cognition.

Our research is beginning to explore how action-representation relationships with tangible interfaces aid the understanding of basic science concepts. Previous studies suggest that acceleration is a difficult concept to grasp even for university level students and teachers [6-8; 2] Acceleration refers to a change in *motion* (velocity). Velocity requires a force acting on an object and any change in velocity is called *acceleration* (e.g. speeding up, slowing down or a change in direction of motion). The concept of acceleration is often confused with the concept of speed. However, acceleration implies direction, whereas speed does not. Our interest is in how tangible exertion interfaces can aid comprehension of the concept of acceleration.

An exertion interface [3] is an interface that requires intense physical effort from a participant, such as jumping up and down, waving arms around the air, or swinging an object around the body [6; 7]. Exertion interfaces usually cause participants to sweat and whilst they can have a relatively 'low entry fee' [9], they can take a long time to master. However, a plethora of innovative interfaces have recently been introduced to the consumer, such as the Nintendo Wii Remote (Wiimote), which we believe offer apt interfaces for exploring action-representation relationships. Many exertion interfaces focus on remote interfacing and competitive games [3; 4], but few studies exist which examine the role of exertion interfaces in aiding comprehension through active exploration.

Based on the tangibles framework [5], this paper explores the action-representation relationships that emerge using a Wiimote as an exertion interface to promote understanding of basic science concepts, such as acceleration. We describe our initial set up, mapping the action-representation framework to the proposed study, discuss our observations and conclude with a description of future work.

2. STUDY

We conducted a study with 21 students (aged 11-12 years), both boys and girls from two different schools. Participants worked in groups of 3 on two different activities with the investigator for approximately 30 minutes.

2.1 Technical set up

Two Wiimotes were connected via Bluetooth to MacBook Pro. In the first activity, two versions of Darwiin Remote [sourceforge.net] ran simultaneously and in the second activity Osculator [osculator.net] was connected to Processing [processing.org]. In both cases, results were projected onto a large screen at the front of the room.

2.2 Design

Our interest is in understanding the relationship between action, external representation and cognition - not only with movement, but also in understanding how different representations are interpreted in relation to particular kinds of actions. We are therefore exploring notions of *action correspondence* [see 5] which here refers to active sensorimotor exploration – the meaning-making and non-verbal expression that unfolds through action.

In terms of *manipulation*, in our study, participants **grasp and grip** the Wiimote in their hand, and then **gesture in 3D space**. *Movement* in our study is **continuous** – data is continuously transmitted between Wiimotes and the application in realtime so that movement in the real world is continuously updated in the digital world. *Flow, regularity and directionality* in our study are dependent on how participants interpret action. How the participants hold the Wiimote is key to obtaining the desired outcome - manipulation and movement are key factors in conceptual understanding of acceleration, particularly *directionality*.

To explore meaning making through action, two children were given one Wiimote each and asked to stand in front of a large screen, which displayed visual representations corresponding to physical action (using a **discrete** design, in that input and output were located separately [5]). The other students sat in a semi circle behind so that they could see participants' action and the digital representation.

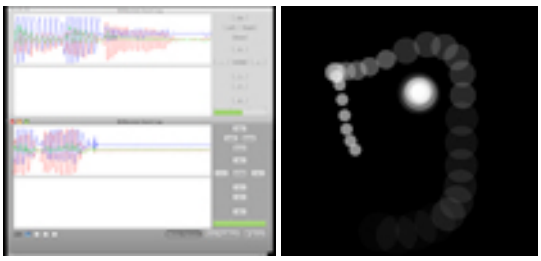

Figure 2a. DarwiinRemote showing acceleration data from two Wiimotes (left). Figure 2b. X/Y axis of each Wiimote is mapped to a dot with a fading effect (right).

Motion in the digital world was directly linked to motion in the real world, i.e. moving the Wiimote in physical space caused the digital graphics on the screen to change. In the first activity we used a **graphical** representation to map acceleration from each Wiimote axis to different colour where height and direction of the wave indicated velocity (see Figure 2a). In our second activity, X/Y acceleration from each Wiimote was mapped to an **abstract** visualisation – a large white dot, which had a fading effect (Figure 2b). Movement in one axis caused the dot to move left/right and in the other to move up/down.

The room was configured so that all of the children could see changes in visual data on the screen in real time. The intention of our study was to get participants to understand **intentional** interaction – how movement in the real world produced expected effects, although often participants' interaction produced unexpected effects.

The degree to which the physical properties of the objects are closely mapped to the learning concepts is referred to as *physical correspondence* [5]. A Wiimote is inherently **symbolic** in that like a mouse, it has little or no characteristics of the entity it represents. In other words, Wiimotes and their digital output can metaphorically represent anything. Although a Wiimote has symbolic icons on its surface we did not add any labels to indicate to the participants how to hold/manipulate it or which one controlled which digital effect.

The power of the Wiimote for learning about acceleration is in understanding its tactile modality. Our study hones in on its **kinaesthetic** possibilities – its action correspondence causes participants to turn, rotate and spin the Wiimote in their hands to explore directionality.

2.3 Activities

The aim of the activities was to explore the relationship between action and cognition, by exploiting action and familiarity with action to support reasoning about motion, speed, and acceleration concepts. Almost all participants were familiar with Wiimotes, and began by exploring what happened when they moved it figuring out which controller was their controller. Three different activities using the two different visualisations were then undertaken.

2.3.1 Exploratory interaction and mental mapping activity

This task aimed to explore the links children made between their own movements and the different graphical effects on the screen. Each colour on the graph represented one axis so that holding the Wiimote in a particular way caused one colour to move in the vertical plane more than the other colours (Figure 3). This shows that acceleration is not just about motion but also about *direction*.

We observed whether participants were able to understand how to the limit their movements to separate the different axes from one another, by asking e.g. can you make a green line rise to the top with blue and red line underneath? Participants were asked to repeat this activity several times.

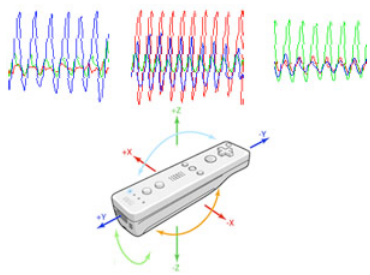

Figure 3. Holding and shaking a Wiimote in a different direction produces different colours.

2.3.2 Kinaesthetic and really physical activity

Once the participants had successfully mapped how to hold the Wiimote, the next task required them to compare, identify and interpret the differences in graph patterns generated when they performed different motions with the Wiimote. Participants were asked to perform sports activities and chose contrasting activities that generated extreme differences in the graphical output (e.g. swimming activities - how do you do front crawl? Back stroke? Butterfly?) In the first instance, students performed the same activity at the same time. In the second instance, students performed different activities at the same time.

2.3.3 Reflection activity

In the final activity, we were interested in whether attributing an object identity to the Wiimote enabled them to gain insight into concepts of motion and acceleration, by providing the opportunity for them to exploit familiar real world concepts and map to the digital representation. Students imagined their Wiimote as different objects, moving them accordingly, reflecting on what they were doing and explaining what was happening to those who had not used the Wiimote. (Let's try imagining we're cooking. Pretend that the Wiimote is a spoon and try stirring something in a pot? Can you explain why the graph looks the way it does? One of you try to stir a pot and the other try shaking a salt shaker. Why are the graphs different?)

3. Findings and Discussion

Activities were recorded on video and investigators wrote post-study observations before reviewing and analysing the video. Several interesting issues emerged from our study:

3.1 General interaction

All participants initially manipulated the Wiimote in the same way: first they put their hand through the wrist strap, grasped the Wiimote, pointed it at the screen and finally, gestured around the interface in 3D space. Each participant seemed to find his or her own **comfort level** for interacting with the Wiimote. Whilst some swung it wildly around their body in every direction, others seemed more comfortable making small movements, usually the shyer participants. Interestingly, most participants did not seem phased by swinging the it around wildly in space in front of their peers, although, two students were reluctant to take part, one eventually engaged in the activity after much prompting.

The controllers being connected wirelessly did not require participants to point the Wiimote at the screen. However, it was clear that participants' familiarity with Wiimotes, as well as the presence of a screen immediately compelled students to point the controller directly at the screen. When they turned their back to the screen observers were surprised that changes on the screen still occurred without facing the screen. Clearly their knowledge about the Infrared nature of the Wiimote was (in this case falsely) affecting their interpretation.

3.2 Role of action in cognition

This study suggested that onlookers could say where different actions mapped to the different colours, but could not translate this to their own actions. In other words they needed to try it out for themselves to secure the mappings. This suggests that the action itself is central to making the meaning mapping between action-representation links.

The link between action and comprehension must also include a consideration of skill acquisition [8]. How participants begin to understand concepts through movement will be in the way in which they transition to performers. This requires an understanding of wittingness (awareness of the performance frame); technical ability (acquiring and execute simple routines); and, interpretive ability (the ability to develop a method of making the performative activity uniquely their own – an embodiment of their own skill) [6, 8].

3.2.1 Point of reference/ orientation in space

With interfaces and controllers that require action in 3D space, orientation and positioning in real space must be a consideration as well as orientation in the digital space. The use of Wiimotes combined gesture, grip and grasp and the **controller moves with and around the body [7]**, rather than remaining static. It was clear that before our study, participants understood how to move a Wiimote but not which aspects of movement caused different effects.

Like the continuous nature of the data flow, participants continuously moved their bodies and the Wiimote around the space. However, because participants were able to move the controller in 3D space without any physical boundaries, there was no **point of reference** from which they could **orient** and **position** themselves or the controller.

All of the participants initially held the Wiimote in their hand with the IR sensor facing forward and swung their arms up and down. Different participants have different views of what up/down or left/right is. When prompted with questions like, "try holding the Wiimote upright", they didn't know which end was up or down. However, when they were asked to imagine the Wiimote as a particular object, this constrained their actions, providing a point of reference for position and movement, enabling easier links to be made between action and effect. Furthermore, when the Wiimote was used for familiar actions (such as swimming, running, golfing) it was successful in getting the students to see different patterns in the data. This helped even more when participants simultaneously tried different activities.

Figure 4. Children exploring how different movements change the pattern of acceleration.

Participants would often get the correct colour moving in the correct way but initially would not associate that movement with how they were holding the controller. They only began to **fine-tune** their movements when they were given a specific task. When the participants were asked to make different colors, they first seemed to shake the Wiimote in every which way but then began more concentrated movements, e.g. shaking the Wiimote a lot to move the waves up/down wildly and shaking the Wiimote a little to move the waves up/down slightly. Only then did they see that there were many new ways of creating different patterns. If they did produce the desired effect, when they tried to do something else, they forgot how to repeat the action. It was only through **repetition** that participants gained consistent mapping.

3.2.2 Granularity

Another key concept is **granularity** - how much or how little participants needed to fine-tune their movements in order to interpret patterns in data. Many participants initially had difficulty understanding the concept of acceleration but gained some comprehension. However, whilst they expressed a desire to know what was happening, they often had a difficult time reflecting on what was happening. Participants knew how to make different patterns, but they found it hard to conceptualize these patterns without moving with the Wiimote themselves. For example, all of the participants understood that making big movements produced big spikes and little movements produced little spikes and by the end of study, most of the participants understood how to isolate colours by holding/moving the Wiimote in a particular way. However, when the investigator asked the participants what they expected the graph to look like before they performed a particular movement their predictions were inaccurate.

3.2.3 Choreographed movements

Choreographed movements became most prevalent during collaborative activities and often caused **transitions from observer to participant interaction** [6]. On several occasions someone observing the participants started to direct the participants - a person sitting down would shout out commands and the participants would move according to these suggestions. This collaborative joining in allowed more people to be engaged in the activity and prompted performative interactions: participants often began role playing; imitating each other; and performing collaborative and playful activities. Children often collaborated through "following the leader" – one outgoing participant would be in the middle of the room swinging the Wiimote and the second participant would copy them.

Having participants explain to each other how to perform the activities worked really well. They were keen to show each other what they learned and seemed to enjoy sharing their knowledge. Although their explanations were not 'scientific' **they explained how things worked in reference to their movements** (i.e. if you hold it this way it is green, and this way it is blue).

4. Conclusion

The tangible framework [5] describes a system and intended interaction, but better guidelines need to be integrated for understanding participant action and its relationship to comprehension and cognition more generally. For example, methods for understanding how meaning-making derives from action, as well as how participants are initially **enticed** into the activity, begin to **engage** in the activity and how engagement is **sustained** are required. It was through **repetition**; **contrasting patterns**; and, **choreographed movement** that they began to correctly answer the questions.

Wiimotes are excellent interfaces for exploring action-representation relationships and comprehension. In our study, we uncovered that better comprehension of the concept of acceleration is needed. To break from the issue of familiarity, we intend to build 3D objects which look different from the Wiimote, together with 3D graphics, which better relate to movement in 3D space and we will be experimenting with sound as an additional modality.

5. ACKNOWLEDGMENTS

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