RETHINKING GESTURE WITH NEW MULTITOUCH DIGITAL TECHNOLOGY

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This paper is about re-thinking gesture in order to reckon with its material and haptic nature, especially in the current multitouch technology environment. This re-thinking of gesture returns to the principle of indexicality found in Peirce's material semiotics, and develops this principle through the work of Gilles Deleuze around hand-eye relationships. Drawing on the work of Jürgen Streek, we propose and discuss the notion of the tangible gesture, in the context of mathematical explorations of young children with a multitouch iPad environment designed to promote counting on and with the fingers.

INTRODUCTION

In the context of education research, vast amounts of video studies focus on student and teacher use of gesture in classrooms, but this work tends to code and sort gestures insofar as they are *representations* of thinking. These studies tend to divorce the motoric hand from the feeling swipes and swishes of fingers. Material semiotic approaches to the study of interaction, on the other hand, consider gesture less as representations and more in terms of the material effects they achieve (Roth, 2001). Our goal in this paper is to take up this approach to study the gestures used in new digital media, and to unpack the implications for understanding mathematics learning in relation to new media. We begin by locating our work in relation to current semiotic ways of conceiving of gestures, as used in the field of gesture studies and adopted in mathematics education research. We then point to different ways of conceiving the role of gestures that have emerged principally from the work of the philosophers Gilles Deleuze, pointing to new forms of tangible gesturing that may operate in fundamentally new ways. Thus we aim to expand the definition of gesture formulated by Kendon (2004) so as to address the changing ways in which hand and media interact.

We argue that new media offers—and will always offer—new ways to rethink the relationship between body and gesture. By focusing on a burgeoning new technology, we can show how our understanding of gesture depends on our bodily configurations and, as Rotman (2008) and others have suggested, on our current technological prosthetic extensions. If inventive gestures are always at the threshold, then taxonomies of gestures are limited by their assumptions about where the body ends. What we find in the literature on mathematics and gesture is a concerted effort to code these gestures without adequate attention to how new gesturing habits emerge *as the body itself is reconfigured*. In other words, we cannot take for granted what a body can do. As new media emerge, so do new gestures, and these together actualize the contours of a newly assembled body and a newly assembled set of concepts. Thus we examine the ways in which new media gestures demand a reconsideration of how the capacities of sense organs—eyes, hands, ears—are coordinated *provisionally* and in response to material interfaces. In order to illustrate how these new media gestures operate, we draw on research involving the use of a multitouch application *TouchCounts*.

THE INDEXICAL GESTURE AND INSCRIPTION

Researchers such as McNeill (1992) have identified different categories of gestures (icon, metaphoric, deictic and beat) so as to distinguish different relationships between gesture and speech. McNeill has drawn on Peirce's semiotics in which signs (icons, indices and symbols) differ in terms of the nature of the relationships between the signifying sign and the signified. According to Peirce, icons operate according to likeness or resemblance between the signifier and the signified, like the image of a man or woman on a bathroom door. Iconic *gestures* are also described in terms of their *resemblance* with events or objects. If iconic signs become conventional codes within particular cultures, they may become *symbols*, which have an arbitrary relationship with that to which they refer. The third category, indices, emphasizes the material link between signifier and signified. Unlike icons and symbols, indexical signs are bound to the context in important ways—they "show something about things, on account of their being physically connected with them" (Peirce, 1894/1998, p. 5). As in the case of smoke billowing from a chimney indicating that the fireplace is in use, the smoke *indexes* the fire. In other words, smoke is *produced by and contiguous with* the fire.

What is distinctive about the index is that it is a sign that is materially linked or coupled to "its object". According to Peirce (1932), an index "refers to its object not so much because of any similarity or analogy with it, (…) as because it is in dynamical (including spatial) connection both with the individual object, on the one hand, and with the senses or memory of the person for whom it serves as a sign, on the other" (2.305). For Peirce, the pointing aspect of indexical signs was only a consequence of their essential material link or connection to their object. Visual indexical signs, for instance, like the smoke example above, capture this far better, as they entail a visual trace or mark that evokes or refers to that which formed the trace or mark. This latter indexical dimension is usually not emphasized in the semiotic study of mathematical activity, since we tend to focus on the completed trace and dislocate it from the labour that produced it. Such habits of focus have resulted in our neglect of how the activity of the body and various other material encounters factor in mathematical activity.

Pierce's diagrammatic approach to signs—and his focus on the visual—has been superseded in the research literature by an emphasis on gesture as part of "the human capacity for language" and the study of gesture as "language in action" (Rossini, 2012). However, research that codes gesture only in terms of linguistic potential tends to overlook the physicality of the hand movement of gesture, except insofar as such movement contributes to or obscures linguistic meaning. As Streeck (2009) indicates, "it is common to treat gesture as a medium of expression, which meets both informational and pragmatic or social-interactional needs, but whose "manuality" is accidental and irrelevant" (p. 39). He defines gesture:

> … not as a code or symbolic system or (part of) language, but as a constantly evolving set of largely improvised, heterogeneous, partly conventional, partly idiosyncratic, and partly culture-specific, partly universal practices of using the hands to produce situated understandings. (p.5)

Thus he studies gesture for how it is "communicative action of the hands" with emphasis on the term *action* (p.4). This focus on action allows Streeck to study gesture for how it couples with and intervenes in the material world in non-representational ways. Researchers often distinguish between hand movements *in the air* and hand movements *that make graphic marks*, where the former is deemed a gesture and the latter an act of inscription. However, such distinctions become fuzzy when we follow Streeck and study the movement of the hand across and through media, where 'media' can be more or less receptive of trace or mark. In

other words, all hand movements traverse and incorporate media. We see a trace in certain media, and not in others, but since the logic of new media is to break with current conventions of perception, this distinction is provisional. As gesture recognition technology evolves, hand movements in the air become productive of various kinds of traces.

In the case study we discuss below, the hand actually operates very close to the surface of a screen: pointing to objects on the screen by tapping them; sliding objects along on the screen so as to leave visual and aural traces of the finger's path; pinching objects together in order to make new ones. These gestures of pinching and flicking and pointing both communicate meaning and inscribe marks. In this paper, we discuss an application in which the gesture plays an even more central role in the mathematical activity. Briefly, there are two worlds: enumerating and operating. The former features an ordinal model of numbers and the latter a cardinal model of numbers. In the Enumerating World, each finger tap produces a yellow disc. Tapping the screen four times consecutively will produce three discs, each numbered 1, 2, 3, 4, respectively, and three sounds "one", "two", "three", "four". The discs fall off the bottom of the screen unless gravity is turned off, in which case they remain on the screen, or unless the finger tap is made above the horizontal line, which acts as a 'shelf' on which the discs rest (figure 1b) (video: http://tinyurl.com/q8lpzrc). In the Operating World, tapping the screen with four fingers simultaneously produces a 'herd' with the numeral 4 on it, as well as four smaller discs (see figure 1c). Multiple herds can be combined by using a pinching gesture (4 and 1 are being combined in figure 1c). The resulting herd will be labelled with the sum, and this sum is said aloud. A herd can be partitioned into two herds by using a splitting gesture (video: http://tinyurl.com/omancvf).

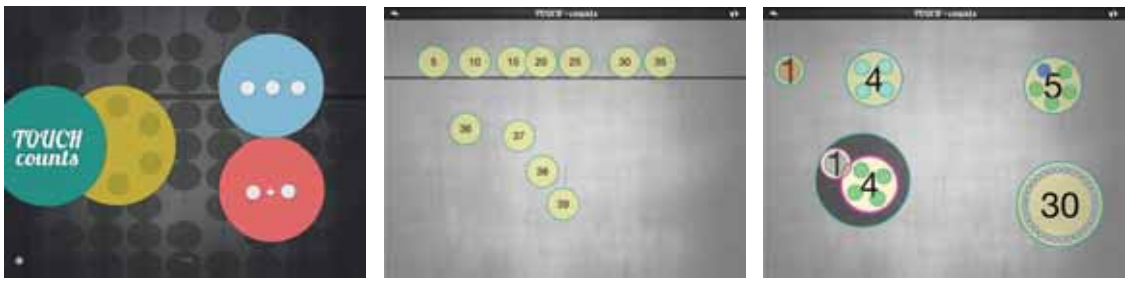

Figure 1a: The enumerating world (•••) and the operating world (•+•); (b) Ordinal numbers falling off the shelf; (c) Herds of different cardinalities.

Rather than study gestures as iconic or symbolic representations of some concept, we examine gestures for how they function as indexical, material actions. By focusing on the indexical, we can study gestures as materially coupled, generative devices, rather than only as forms of representation.

RETHINKING THE RELATIONSHIP BETWEEN HAND AND EYE

The philosopher Gilles Deleuze (2003) points to the complex and changing relationship between hand and eye, directing our attention to how particular senses outrank others in particular situations. He examines how the eye and the hand compete for control of meaning, where confusion or even contradiction is resolved when one sense dominates the other. He identifies four *relationships* between hand and eye, and he names them: the digital, manual, tactile and haptic. The first term designates situations where the eye dominates the hand, while the next two terms track an increasingly more dominant hand in relation to the eye, and

the last term a more ‘equal’ contribution of the two.

The tapping of the finger on a surface or screen corresponds to the *digital* aspect because the eye is dominant as it determines where and when the tapping should occur. The hand is subordinated to the eye: “the hand is reduced to the finger, that is, it intervenes only in order to choose the units that correspond to pure visual forms” (p. 124). But screen gestures also include various dynamic gestures, such as sweeping. Through these, the hand becomes *tactile*. The space is not entirely depleted of dynamic potential, and it is these potential dynamic dimensions that are enlisted. The flicking gesture might provide a good example here of the tactile category in that there is a virtual referent of speed involved because flicking must begin by touching an object and then quickly swooshing it higher or lower, where the quickness of the swoosh determines the speed at which the object changes.

Deleuze suggests that the hand can revolt against this optic regime in acts of creative art. He refers to *manual* relationships as ones in which the hand takes charge, where there is “movement without rest, which the eye can barely follow and which dismantles the optical” (p. 124). In the manual relationship, the eye may not be able to direct the hand, being somehow refused access to what the hand now controls. Maybe the eyes are closed, or maybe the action performed by the hand takes precedent over the visual aspects of the objects on which it is performed. The eye and hand are still somewhat individuated as organs. It is in the *haptic* relationship that it becomes difficult to distinguish the eye from the hand: “there is no longer a strict subordination in either direction, but when sight discovers in itself a specific function of touch that is uniquely its own, distinct from its optical function” (p. 125). In a haptic relationship, the eye begins to see with its hand.

TWO CASE STUDIES

In the next section, we discuss a case study of children working with *TouchCounts*. We examine two excerpts, each focusing on an encounter between a child, a teacher and an iPad.

Indexical Gestures and Rhythm

In this example, a five-year-old girl named Katy is interacting with *TouchCounts* for the first time. Without prompting, Katy’s hand approaches the screen, and her finger touches the top of it and slides down to the bottom. A yellow disc appears under her finger with the numeral ‘1’ on it and the sound ‘one’ is made. The index finger moves back to the top of the screen, slowly swimming downwards. A chorus of ‘two’ comes both from her mouth and the iPad. This happens repeatedly, although sometimes only the iPad can be heard announcing the new numbered disc while Katy’s lips move in synchrony (Figure 2a). The appearance of ‘10’ on the tenth yellow disc attracts attention, perhaps because of its double digits, and Katy bends over to look closely. Now only the iPad counts the numbers (Figure 2b).

Figure 2(a) Katy swiping; (b) Following the yellow disc; (c) Tapping while looking up.

After ‘seventeen’, several fingers fall on the screen at once, and then ‘twenty-one’ is heard. This produces a pause, and Katy’s lips spread into a smile. All but the index finger are tucked away, as the rhythmic tapping continues along with the chorus of named numbers. At ‘twenty-seven’ Katy looks up, no longer watching the screen (see Figure 2c), and continues swiping and saying numbers. This continues until a finger accidentally lands on Reset.

Grasping with Multiple Fingers and Subitising

As seen above when multiple fingers alighting on the screen resulted in the jump from “seventeen” to “twenty-one”, there can be a significant difference between one-finger and multi-finger interactions. Indeed, in *TouchCounts*, there is a possibility of asking children to produce a given number “all-at-once”, which involves them placing a required number of fingers on the screen simultaneously, rather than sequentially tapping a finger.

Figure 3: (a) Using fingers to counting up to seven; (b) Making seven on the fingers.

In this example, Cameron (four years old) was asked to make seven all-at-once. We want to draw attention to how the hand and eye, as well as the ear, work together in what happens. He first takes his hand out, unfurls his fingers one by one as he counts them softly to himself (see Figure 3a). Then he looks at what his fingers have formed, palms up, and then turns his hands over to place the outstretched fingers on the screen. But he accidentally touches the screen in more then seven spots so that *TouchCounts* says “eight”. When asked if he wants to do it again, he nods and his hands immediately take on the same seven-finger gesture he had made before (without first having to count out the fingers nor look at them to validate), and he carefully places his fingers on the screen (Figure 3b), thus producing “seven”.

DISCUSSION

Fingers can serve as both a physical extension of what Rotman (1987) calls the ‘one-who-counts’ (p. 27) as well as the thing-to-be-counted: fingers are thus simultaneously subject and object, both of the person and of the world (Alibali & diRosso, 1999). This is what makes the finger actions of Katy and Cameron so interesting; the act of counting with *TouchCounts* fuses this duality and in so doing changes the relationship between hand and eye (and ear).

Katy’s hand actions change over the course of the episode, not only in the particular muscular form they take, first sliding down the screen as if lingering on the yellow discs to produce or partake in their falling off the screen, and then tapping impetuously so that each new touching of the screen follows the end of the sounds of the voiced numerical. The swiping gesture seems more exploratory while the tapping gesture seems to concatenate into a unit the touch-see-hear bundle of sensations involved in making a new disc-numeral-name. As Streeck

writes, tapping is also "characteristic of ritualized behavior" (p. 76), which suggests that Katy has moved from exploration to practice. In both the swiping and the tapping, the finger can be seen as making an indexical gesture, with the trace being both visible and audible, not to mention tangible for Katy. Although the initial movement and touch of her finger is what produces the disc, it is the disc that determines the swiping movement of her finger. Indeed, both her finger and her eyes *follow* the yellow disc as it heads down the screen. In shepherding the numbered disc off the screen, Katy is able to see when it's time to lift her finger and start making a new disc. But with the tapping, the eyes attend to the numerical sign on the disc—indeed, when "10" appears, Katy notices the change from the previous one-digit numerals. In this sense, the eye and the finger do very similar things when swiping; the visible trace is followed closely by Katy's eyes as the swiping takes place, so that the hand is subordinated to the watchful eye in Deleuze's *digital* sense. With the tapping, the hand seems less subordinated, as the eye is only interested when a novel situation comes up, like a double digit. When Katy looks up, the hand is no longer subordinate at all and the relationship is a *manual* one. Her fingers do the seeing and touching as they are repetitively summoned on the screen.

But of course, there is more than the eye and hand involved in this situation. The ear and voice feature importantly as well. Indeed, while the voice is subordinate to the touch (it only speaks while Katy taps), Katy's hand is also subordinate to the ear in that the ear judges the moment of the next tap. And the ear is disrupted by the hand, when several fingers touch the screen at once, causing the voice to jump from "seventeen" to "twenty-one." The eye, which was about to drift off, must return to survey the situation; the hand returns to its single digit tapping. The importance of the aural and the vocal is interesting in terms of the counting activity at play. Indeed, the ritual origins of counting are oral in nature, and counting with young children is often undertaken as the learning of a song that one memorizes and chants. The involvement of the hand in this otherwise oral event provides a visual and tangible trace of the count, while also associating each counted number with a single swipe or tap.

One might question whether Katy's actions on the screen, which we might think of as touch-pointing, can really be thought of as gestures. In discussing the importance of the pointing gesture in enabling people "to make discriminations, and highlight, emphasize, and interpret the present world and orient each other to it" (p. 59), Streeck argues that such gestures (and indeed all gestures) emerge from the touching and handling of things—the tracing (or other "data-gathering devices" such as caressing, probing, cupping) of objects that allows one to discover its texture and temperature. When the hand has done its exploring, which fulfills an epistemic function in gathering information, it may then be lifted off the object and inclined to repeat the same movements 'in the air': "the hands' data-gathering methods are used as the basis for gestural communication" (p. 69). Streeck identifies such gestures as being communicative. In this sense, Katy's touch-pointing becomes a gesture once she lifts her hand from the screen to do her tapping.

Distinguishing hand movements that explore from ones that communicate is problematic though. As Streeck writes, exploratory actions can become communicative when they are made visible to others, who may join in the action or infer tactile properties. If we look at Katy's swiping and tapping gestures, we might say that they are both exploratory, with the swiping gestures involving prolonged tactile contact that enables her to discover what would happen when her finger touches the glass—that a yellow disc would appear, with a numeral on it; that the disc would move down the screen; that the iPad would speak the number's name aloud, and that this could all be repeated as often as she wished. But Katy's swiping

and, later, her tapping, are also communicative inasmuch as they tell *TouchCounts* what to do and say. The same might be said for clicks of the mouse or key presses of the keyboard, with the difference that the touchscreen is acted upon by direct hand motions. Instead of disentangling the tracing from the pointing (the exploration from the communication), we suggest that re-assembling them into an indexical enables us to see how Katy's hand movements can tap into the potentiality of the body by reconfiguring the relationships between sensations of touch, sight and sound that are at play. This potentiality mobilizes new mathematical meanings as Katy uses her fingers to count on, to count with and to count out one by one and indefinitely. Streeck recognizes that hand-gestures "enable translations between the senses" (p. 70) as tactile discoveries provide visual information for interlocutors. With Katy though, the tactile discoveries provide visual and auditory information to herself. She is her own interlocutor.

In the case of Cameron, multiple fingers engage with the screen. Whereas the first gesture in Figure 3a is *digital* because the hand is subordinated to the eye, which carefully tracks the number of fingers being raised, the final gesture in 3b has become *haptic* in the sense that neither the eye nor the hand is subordinate—the eye is seeing the "seven-ness" in its multiplicity, which the simultaneous touch has actualized. While the eye had condoned the initial gesture, the ear announced that its trace on the screen was unexpected. It was not the right sound, but it was just one word, rather than a succession of one, two, three, four, five, six, seven, eight. The eye accepted the gesture and the ear prompted Cameron to revise the precision of his hand's action so that in the next attempt the hand is placed more carefully on the screen to prevent any other parts of the hand from touching—or being touched by—it. Here it seems to be the hand's responsibility to mould itself in a particular shape so that only fingertips touch. The eye watches but the hand is in charge. Throughout, the relevant trace is the aural one, as Cameron does not stop to count the number of discs on the screen.

The gesture of seven-fingers-lifted that Cameron makes immediately becomes a communicative version of an exploratory act: first it successfully tells *TouchCounts* how to say "seven" without saying the preceding numbers—the gesture annotates the act of having lifted seven fingers up one by one; it also enables Cameron to see/produce the cardinal seven so that seven becomes a reified version of the sequential counting out of the fingers. As with Katy, Cameron becomes his own interlocutor and his hands, eyes and ears are reassembled into a new configuration through which counting becomes count—that is, through which the slow, ordered sequence of finger lifting becomes a sudden flash of the hand. Finally, Cameron's gesture communicates to the children around him, who now only need to mimic his flash of the hand in order to make their own sevens—and, later, their own sixes and eights and most happily, tens. For them, the gestures may initially act as signs, but once they place their fingers on the screen, those gestures become indexical in simultaneously pointing and tracing. Again, as with Katy, we cannot say that the epistemic hand-action has merely culminated in a communicative gesture, in part because the hands have been coupled with a certain spatial arrangement of yellow discs as well as a singular announcing of the count.

CONCLUSION

In tracing the evolution of the hand and its role in human development, Streeck shows how the hand's actions in the world, which enable fundamental actions such as eating and making, become communicative. He argues that hand-gestures cannot be taken only as components of a language system, which are cast apart from the material world, and used only to communicate about the world. Rather, they are *of* the world, and part of how we *feel* the

world around us. This perspective requires us to see the moving hand as "environmentally coupled" (Goodwin, 2007), that is, as inextricable from the things it touches and engages with. But while Streeck implies a vector from the exploratory hand action to the communicative hand-gesture, our case studies reveal how the exploratory hand frees itself from the optic regime and invents meaning as much as it communicates it. This new kind of gesture is possible in large part because of the feedback mechanism of digital technologies, which can talk, push and show back. With the touchscreen interface, and particularly the multitouch actions, the hand is involved in a process of communicating that is also a process of inventing and interacting.

In both of the examples we presented, we have tried to show that the gestures made by the children in *TouchCounts* had a significant indexical nature in part because they not only involved some kind of pointing (with one finger or more) but they left a trace that is both visible and audible. The trace is important in drawing attention to the material engagement of the children's gestures. They obviously arise out of movements of the hand, but they also result in material reconfigurations that can *give rise to* new movements of the hand. In discussing the effect of new digital technologies in disciplines such as mathematics, Rotman has written about the future cultural neoteny in which speech would "become reconfigured (as it was once before when transformed by alphabetic writing), re-mediated and transfigured into a more mobile, expressive, and affective apparatus by nascent gesturo-haptic recourses emerging from the technologies of motion capture" (2008, p. 49). In other words, the word and perhaps even the strictly communicative gesture cedes the way to the gesture-haptic so that even pre-school children can count 'on their hands' to 100.

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