” How do you make numbers? ”: Rhythm and turn-taking when coordinating ear, eye and hand

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In this paper, we examine an environment involving a young girl, an adult and a touchscreen application (TouchCounts), in which engagement with number draws on all of the audible, the visible and the tangible. We broadly frame our analysis in terms of the conversation (both verbal and non-verbal) that occurs, seeking to gain insight into the nature of number – and in particular of its ordinal aspect – in this complex assemblage. We propose that much can be learned from our analysis about the nature of counting in more traditional environments, as well as about the particular forms to which TouchCounts may give rise.

Keywords: Kindergarten, touchscreen application, audible, visible, tangible.

INTRODUCTION

Over thirty years ago, Stephen Brown observed, "One incident with one child, seen in all its richness, frequently has more to convey to us than a thousand replications of an experiment conducted with hundreds of children" (1981, p. 11). Nowhere, perhaps, is this as true as in the arena of early number. Our starting point here is with such an incident, involving a five-year old girl – for argument's sake, we'll call her Katy. But the full encounter, which lasted just over an hour, also involved an adult, Nathalie (second author), some geometry tasks with pencil and paper, and, from about half-way through, an iPad with the numerical App *TouchCounts* (Sinclair & Jackiw, 2011), the pertinent aspects of which we describe briefly in this paper (see also Sinclair & Pimm 2014). We wish to explore the potential of framing this interaction as a *conversation* about number, albeit one involving an entanglement of the audible, the visible and the tangible.

We are also interested in examining how children's number activities within this particular entanglement relate to findings from prior research on children's development of number. Elsewhere, we have described how the design of this App supports the development of subitising (Sinclair & Pimm, in press) and finger gnosis (Sinclair & Pimm, 2014), in addition to offering more expected opportunities for children to work with cardinal aspects of number (Sinclair & Heyd-Metzuyanim, 2014). In this paper, we follow the suggestion of Coles (2014), who argues for the importance of ordinality in the early development of number, based on recent neuro-science findings, as well as on the work of Caleb Gattegno (1974). [1] Ordinals convey a sense of time and sequence, of 'the next one to be named' and 'the one to be said after that'. Success with intransitive counting primarily involves being able every time to generate stably the same set of words in the same order. Transitive counting, which may be over-emphasised in early schooling (see Tahta, 1991), relies centrally upon intransitive counting and can actually be seen as a 'mere' application of it, a subordinate practice. Among other things, 'ordinality' refers to the capacity to place numbers in sequence: for example, that 4 comes before 5 and after 3 in the symbolised sequence of natural numbers, as well as in the parallel ordering of the number words. We here interpret attending to any kind of sequencing of numbers (not just counting by ones) to be attention to the ordinal.

In particular, Coles points to the need for research to explore the potential of an increased emphasis on ordinal aspects of number with children of primary school age, or younger. In current classrooms in Canada (and elsewhere), children are generally offered concrete resources and materials (such as Dienes Blocks, a move which Tahta, 1991, terms *metaphoric*). The neuro-science suggests such schoolwork on linking symbols to objects may reinforce the very way of thinking that underachieving students need to overcome in order to become successful at counting

and arithmetic. Coles hypothesises that what these students need is support to work with number words and symbols in their relationship to other number words and symbols (which Tahta terms *metonymic*). Our research focus and central question involves understanding better the particular entanglement of the audible, the visible and the tangible plays out in young students' developing ordinal sense of number.

THEORETICAL FRAMING

In Jackiw and Sinclair (2010), user interaction with *The Geometer's Sketchpad* is discussed in terms of a pedagogic conversation, one in which it makes far greater sense to frame the student as the *teacher* rather than the software acting as one. The authors rhetorically ask, "If *Sketchpad* cannot speak, in what sense can it participate in discourse?", yet go on to claim, "there is a coherent and well-defined linguistic trajectory to users' interactions with *Sketchpad*, an explicit interplay and evolution of language [...]" (p. 159). The 'language' they discuss is all written and the user issues commands by means of verbal menu selection, mouse play and/or keyboard entries.

In the excerpt we discuss here, we wish to go further and examine the 'coherent and well-defined linguistic trajectory' we see in Katy's interactions with *TouchCounts* broadly inspired by the field of Conversation Analysis (see, e.g., Sacks, 1992), specifically focusing on sequential aspects of turn-taking, the core characteristic of naturally occurring conversation. The focused conversation (in the conventional sense) between Katy and Nathalie in the first part of the encounter proves Katy to be well-accustomed to taking turns and a respecter of that: indeed, there are almost no instances of overlapping speech. But when she 'converses' with *TouchCounts* on the iPad, she takes most of her turns with her index finger, changing things significantly.

This latter 'conversation' is about the spoken sequence of number names in English, as well as the visual numerals on the discs that are generated by her finger in the varying rhythms she adopts. Unlike with the *Sketchpad* setting mentioned above, there is no written language here: the only visible symbols (which are not part of the English language) are the numerals appearing on the successively generated discs. But the associative *rhythm* – parallel structure in the number words said, repetition in her finger touches, pulse in her attention – is so evident that it becomes for us one of the main phenomena of interest in this episode. Temporality and sequentiality lie at the heart of ordinal awareness. As Tahta (1989) claims, "Time becomes manifest [...] in the experience of rhythm and repetition. The medium for language, and so eventually for counting, is at first *sound*" (p. 20). Staats (2008) convincingly argues that, "repetition creates ideas that transcend the sentence", a phenomenon she links to Roman Jakobson's poetic function of language, one where "the form of the message calls attention to itself" (pp. 26–27). [2] While 'the number poem' [3] may be used as informally to refer to the sequence of number words, we doubt users of this expression are attending to Staats' assertion "Any time a repetition causes listeners to attend to the form of the statement, or to use the form of the statement to construct meanings, the poetic function of language is in play" (p. 28).

METHODS

The encounter at the heart of this paper occurred in an elementary school in a rural part of British Columbia, where the second author worked for about an hour with each of five kindergarten children, in a one-to-one setting separate from their customary classroom and teacher, which was videoed as part of the research project. The first part of each clinical interview focused on symmetry tasks, while the second part involved the use of *TouchCounts*, which was new for each student. Because this was the beginning of Katy's work with *TouchCounts*, it gave us an opportunity to see her first encounters with counting tasks on the iPad, seeing how she made sense of the App and how that interacts with her feel for number. Katy was the first student to be interviewed, as well as the youngest (having recently turned five). Although portions of this session have been analysed in a paper for the previous CERME (Sinclair & SedaghatJou, 2013; there is also more discussion of methods there), that paper focused on cardinal aspects of number. Here we offer a more ordinal focus and closer attention to the entanglement of the audible, visible and tangible.

Brief description of TouchCounts

We briefly describe only the Enumerating World of *TouchCounts*, which starts almost blank, except for a horizontal bar representing a shelf (Figure 1a). In this world, a user taps her fingers on the screen to summon numbered objects (yellow discs). The first tap (when initially turned on or after pressing Reset) produces

a disc containing the numeral "1". Subsequent discrete taps produce sequentially numbered discs. As each tap summons a new numbered disc, *TouchCounts* audibly speaks the English word for its number. As long as the learner's finger remains in contact with the screen, it 'holds' the numbered object, but as soon as she "lets go" (by lifting her finger), the numbered object falls to and then "off" the bottom of the screen, as if captured by some virtual gravity. If the user taps and releases a numbered disc above the shelf, it falls only to the shelf, and comes to rest there, visibly and permanently on screen, rather than vanishing out of sight "below". (Thus, Figure 1b shows a situation in which there have been four taps below the shelf – these numbered objects are in the process falling – and then the "5" disc was placed above the shelf.)

Discs dropping away (under 'gravity') mirror the way spoken language fades rapidly over time, with no trace left – the impermanence of speech. Also, with discs disappearing, any sense of cardinality goes too: the disc labelled '2' is simply the second one to have been summoned (in the absence of the presence of the disc labelled '1'. So the Enumerating World with 'gravity' enabled (it is an option) is almost entirely an ordinal one. However, the shelf feature allows the user to 'store' some objects for longer. Since a new numbered object is created each time a finger is placed on the screen and then lifted, one cannot 'catch' or reposition an existing numbered object by retapping or dragging it. Depositing discs on the shelf are as if they have been written down, inscribed on the screen as one might write on paper.

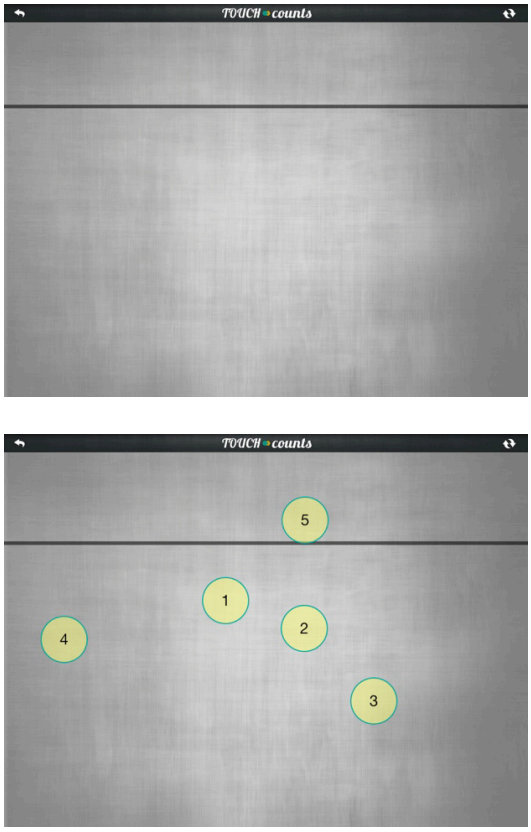

Figure 1: (a) Initial screen of TouchCounts; (b) After tapping five distinct times, but with only the last time tapped above the shelf

Fingers can be placed on the screen either one at a time or simultaneously. Thus, with five successive taps, a user sees five sequentially numbered objects appear one after another on the screen and hears these numbers announced by their English number name one by one. [4] However, if she places two fingers on the screen simultaneously, she sees two numbered objects appear simultaneously, but only hears the higher-numbered one explicitly named ("two," if these are the first two taps). Thus, repeatedly tapping two fingers on the screen produces the sequence of number names "two, four, six, eight, ...". This feature is barely drawn on in our excerpts.

Notably, *TouchCounts* 'takes care of the counting', both in terms of making sure that the sequence of numerals is given correctly on the screen and in terms of ensuring that the number names are said in the requisite order, in response to the fingered requests of the user.

DATA, ANALYSIS AND RESULTS

In engaging with the data, we looked for interaction in conversation (including the iPad as converser) as well as elements of rhythm and repetition. The ten-minute sequence from which the excerpts discussed in this paper have been taken begins:

Nathalie: Let's do some, just some numbers first, OK?
Katy: Numbers.
Nathalie: Yeah.
Katy: OK.

From strokes to pops

Without prompting, Katy's hand then approaches the screen and the index finger of her right hand touches the top of it and then slides down to the bottom (we call this a 'stroke'). A yellow disc appears under her finger with the numeral '1' on it and at the same time "one" is spoken by the iPad. Her finger moves back to the top of the screen, before touching again and slowly stroking downwards. The iPad says "two", followed by

Katy's echo. This happens repeatedly for three, four and five, while for six, seven and eight she says the number simultaneously with the device (Figure 2a).

She says nothing for nine (and it subsequently becomes clear she is not always sure nine follows eight). The appearance of the disc bearing '10' attracts her attention, perhaps because of its double digits. Katy bends over to look closely at the screen and she then says "ten" *after* the iPad and with a rising intonation (Figure 2b). She keeps her head down while continuing to make subsequent numbers at a good speed, but now only the iPad recites them: she is so quick that the iPad only gets to say the 'four-' of "fourteen" before "fifteen" comes. After "seventeen", several fingers fall on the screen at once, and then 'twenty-one' is heard. This produces a pause in the action and Katy's lips spread into a smile. All her other fingers are tucked away, as the rhythmic stroking continues along with the chorus of named numbers, which Katy begins to repeat with the iPad at "twenty-three" (only she consistently says "tenny" for "twenty"). At "twenty-seven", Katy looks up, no longer watching the screen (see Figure 2c), while she continues stroking and saying numbers.

Even in this first small episode, some transcription issues are evident, mostly concerning the coordination of ear, eye and hand. Each of the elements is a material event occurring in time in the world. Consequently, each of them occurs in time and takes a certain length of time and can occur in conjunction with the others. To transcribe them there would need to be a 'channel' (or 'register', though not in the technical, linguistic sense) for each, arranged horizontally (like a musical score for several instruments), where time is calibrated across them, but even then it would be difficult to show shifting subordination of one to the other (as occurs when Katy looks nonchalantly up while continuing to swipe). What we have had to attempt here is a narrative retelling, making observations about our linked phenomena of interest.

The *TouchCounts* timings are predictable, in that the numbered disc appears virtually instantly when the finger is lifted from the screen, while each number word takes a certain length of time to say. The words above twelve are generated syllabically, e.g. fif-teen and fif-ty, while "twenty-three" uses the same "three" as "three". There is an appreciable gap between, for instance, the "twenty" and the "seven" in the saying of "twenty-seven", a material fact that Katy makes good use of later by inserting her finger stabs to prevent the second part of each number word being said aloud.

Nathalie asks her to tap above the shelf, which she does, swiping her finger down to make 'thirty-one'. After 'thirty-two', Nathalie asks Katy to let go of the disc above the shelf (not *on* the shelf), which Katy does, noting that "it stops the number". When she taps again (above the shelf) she says "pop", and then taps several times again. At 'thirty-nine', she starts placing the discs on the shelf side by side, going from the left to the right, until she gets to 'forty-six', at which point she returns to the left edge of the line, makes 'forty-seven', looks up at Nathalie and puts her hands on her lap. Nathalie asks Katy to reset. Instead of hitting the reset button, she creates numbers in quick succession, so that the iPad says "forty-eight, forty, fifty, fifty, fifty".

Nathalie asks Katy to put "just five" on the shelf. Katy tries several times, without success, then puts her head down and taps intently on the screen below the shelf, saying the number names aloud with the iPad (one, two, three, four), then moving her finger up to place five on the shelf. Nathalie asks Katy to put "five and ten up here". On her first try, she places five below

Figure 2: (a) Katy stroking; (b) Attending to the disc; (c) Stroking while looking up

the shelf, so has to begin again. On her next try, she very quickly taps four times below the shelf and once above. She then puts 'eight' above the shelf and realises her mistake, but continues tapping quickly on the screen, so that the iPad says "twenty, twenty, twenty, twenty, thirty, thirty, thirty, thirty, thirty, thirty, thirty, thirty, thirty, thirty-nine, forty, forty, forty, forty, forty, forty, forty, forty, forty, forty, fifty, fifty, fifty, fifty, fifty, fifty-five". Katy smiles. We conjecture reassurance can derive from the regularity of repetition and rhythm.

The language of 'friends'

In the moment, Nathalie spontaneously tries to 'humanise' the mathematical task she wants Katy to attempt, namely to produce all the multiples of five alone on the shelf. She does this by saying, "Imagine five and ten are your best friends and they're the only ones you want to come over to your house (*points to the region above the line*). So you just want five and ten and not the other people in your class." The language of friends and home and the translation of what is happening on the screen into these terms, however, is precisely the sort of metaphoric shift that Tahta suggested can take attention away from the ordinal, away from links between the number words and symbols themselves. Additionally, this move transfers the 'I want' framing of the task into what 'you [Katy] want'. After a few tries, Katy succeeds in placing just five on the shelf (Nathalie: "Five is your friend."), then taps below the screen to make six.

When Katy spontaneously asks, "What kind of number is going to come after?" (there had been no talk about 'kinds of number' prior to this), we assume she is asking 'friend or not friend', but it could also signal that, at the moment at least, she is unsure that "seven" follows "six". Also, following the placing of "eight", Katy asks "Is nine going to come after?". She eventually places 5 and 10 above the shelf successfully. She stops. Then Nathalie asks her which other numbers are her friends. She mentions several (seven, one, two, "all of the numbers") and then starts tapping, making eleven, twelve, thirteen, four, fif, six, twenty, twenty, twenty, twenty-five.

From "pop" to "drop"

She starts at one again above the shelf, puts two below the shelf saying "drop", then places three above the shelf and four below (repeating "drop") and continues going over and under the shelf until she gets to seventeen above, pauses then continues until she reaches twenty-two. She then returns to the left side of the shelf, having filled the shelf with (mostly) odd numbers and continues to tap-drop, seemingly more focused on the rhythmic motion of her hand than on the specific value of the number names. She starts going very quickly, saying "drop" again so that only "forty, forty, forty, forty..." can be heard from the iPad, then "fifty, fifty, fifty...", then "sixty, sixty, sixty...". Katy says, "I'm doing a pattern", but does not go into any more detail, alas, as to which pattern she is seeing. She continues in this way into the seventies, the eighties and the nineties, until the iPad crashes. After this, Nathalie shows Katy how to use many fingers at a time to make "friends". She gets to two hundred and five, says "I don't want no friends" and presses reset while smiling. She then says she knows how many friends she wants, and makes one, two, three, four, five, six successively with her finger, then stops, saying, "That's how many friends I want."

DISCUSSION

Rhythm is the essence of counting, its heartbeat. It is there from the beginning, but changes over time. Katy's first rhythms are the slow strokings of the screen with her index finger, which she watches swim down the screen, as if each numbered disc were worthy of her attention. Here, she seems to be in conversation with the motion of the discs, more so than with the iPad's oral naming. Indeed, she notices the shift from single to double-digit numerals at ten (commenting "a one and an o"). Then tactile rhythm turns into taps, a new gesture that seems less interested in the individual number than in the succession – and this is where Katy starts chiming in with the voice of the iPad, no longer even needing to see what she is making happen. With the task of placing five on the shelf, a new rhythm develops over time, which is the four quick taps below the shelf and then a fifth above, this perhaps giving rise to the rhythmic 'above then below' alternation with which she will later play.

Rhythm is also there in the structure of the number names. It is there in Katy's large, alternating rhythmic gestures, gestures that are binary. The odd and the even, we might think: it is there in her gestures, but we hear none of it in what is said, merely in the pattern of the 'pops and drops', to use Katy's words. Were she attending to the numerals on the discs that were alternately produced above and below the shelf, she might have seen something recurring in the digits' place, attend-

ing to what changed, but changed regularly (but there would have been 'noise' here, as she occasionally places her finger on top of an already existing disc, which then does not make a new one). Had she allowed the iPad to say every number fully, she might have heard something similar: the same stem, first by itself, then followed by the number words one to nine, before the next stem changed, a decimal rhythm underlying a repeating refrain. But no, instead she edited [5] the conversation by means of her own interruptions, only allowing the iPad room to say the same thing each time: sixty, sixty, sixty, ... (ten times), "seventy" (ten times), "eighty" (ten times), then "ninety".

Gattegno (1970) claimed, "To stress and ignore *is* the power of abstraction that we as children use all the time, spontaneously" (p. 12; *italics in original*). This episode with Katy illustrates his claim consummately: she consistently *stresses* the common decade stem and consistently *ignores* the variation that follows (by editing it out of the conversation, by making in vanish, aurally) and does so across more than sixty numbers one after another. She manages to do this by complex finger movements deployed in a highly rhythmic manner. Hers is no small achievement. In relation to Staats' comment about language drawing attention to itself, we assert that Katy's dextrous manipulation of her side of the 'conversation' does precisely that (namely drawing attention to the repetitive pattern of the number words in the decades).

CONCLUSION: THE TRIPTYCH OF THE SENSES

Deleuze (1981/2003), at the end of his book on the art of Francis Bacon, offers a brief discussion of the interaction between the hand and the eye, as well as degrees of subordination of one to the other. Deleuze distinguishes four 'values of the hand', which he terms the *digital*, the *tactile*, the *manual* and the *haptic*, teased out first along the degree of subordination of the hand to the eye (*digital* more subordinate than *tactile*, where the hand is reduced to a finger). With the *manual*, the direction of subordination is reversed (Deleuze writes of "the insubordination of the hand", p. 155) and with the *haptic*, the link between eye and hand are relatively severed.

But it is not so much in the detail of these distinctions that we wish to dwell. Rather, it is that here, with *TouchCounts* present, we are looking at dynamic interactions *among* hand, eye and ear. And we are concerned with numbering not painting. But Deleuze's idea of mutual entanglement and relative subordination among senses and their organs remains. We are interested in the particular way that this specific entanglement is shaped, which is distinct from other counting environments, and we can extend Deleuze's concern with the hand and the eye to include the ear also. The lifting of Katy's eyes while still making numbers provides a clear instance of a subordination of the eye to the hand and ear, one that is easy to observe (whereas instances when the ear is or is not attending are less apparent).

Nowhere in this episode does Katy seem to be counting objects, but rather is simply counting [6]: the 'number poem' is being made by her index finger – *TouchCounts* answer to Katy's question as cited in our title. This one-to-one correspondence, in which *TouchCounts* takes care of saying the number names in the correct order, releases Katy from having to worry about *what*, if anything, is being counted, allowing her to dwell in the rhythmic succession that *is* counting. Later, the eye and the hand are both subordinated to the ear (in the same way that Hewitt, 1996, speaks of subordinating and coordinating actions and attention to achieve a central goal), as Katy achieves the (presumably desired) repetitive aural effect of the exaggerated looping back and forth tapping of her hand.

To return to Coles' work and renewed attention to ordinality, not only does number involve coordination of the audible, the tangible and visible, as illustrated in this episode, but *TouchCounts* affords the stressing and ignoring of each of these aspects in various ways. In particular, it allows the subordination of the aural to the tactile – with the IPad ceding conversational ground to her with every tactile interruption – with the possible exception of when it ends the conversation abruptly, by crashing just prior to the unspoken "ninety-three".

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ENDNOTES

1. Such ideas are also present in Walkerdine (1988) and, particularly, Tahta (1991).

2. Jakobson's poetic function relates to his metaphoric and metonymic 'axes', as drawn on in Tahta (1991) by the latter's use of these terms, as mentioned above.

3. Sometimes, 'the number poem' refers to rhymes like 'One two, buckle my shoe' or 'One, two, three, four five, once I caught a fish alive', that incorporate the number words in order as part of the text, while sometimes this expression simply refers to the number words being recited in order by themselves (see also Tahta, 1991).

4. Other language options are available with *TouchCounts*, including French and Italian.

5. For more on editing, see Hewitt (1997), although he sees it as a teacher function to affect student attention.

6. In *Symbols and meanings in school mathematics*, Pimm (1995, pp. 64–66) distinguishes between *transitive* and *intransitive* counting – the former connecting the counting of things to the fact that the verb 'to count' can take a direct object (an answer to the question 'What are you counting?'), while the latter label refers to counting (reciting the number words in order) where there is no such direct object (where the answer to the same question is "Nothing").