The role of touch in preschool children's learning using iPad versus paper interaction

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ABSTRACT

Touch-based interaction is increasingly a key feature of digital learning environments, yet we know little about the specific ways in which digitally mediated touch reshapes interaction for very young children. This paper examines how finger painting processes, a common activity in early years learning environments, might change in digital (iPad) versus physical (paper) learning environments. It draws on the observations of nursery school participants, from one and half to three years old, finger painting on paper and on the iPad, using similar digital painting/drawing activities. The analytical approach draws on multimodal methods of description and builds on multimodal procedures for working with video. In particular, the analysis focuses on different forms of touch-based interaction, to explore whether digital environments engender different kinds of touch and re-shape the character of the physical painting process. Findings indicate both quantitative and qualitative differences in types of touch across these two environments; and suggest that individual children demonstrate different repertoires of interaction, which may be linked to family practices and familiarity with technologies, such as touch screen and handheld devices. Findings are discussed in terms of the implications for learning and children's mark making development, future research directions, and methodological implications for multimodal research approaches.

Introduction

Touch is a primary form of interaction for very young children, and forms part of our multimodal sensory systems (Smith & Gasser, 2005), which provide an interrelated experience of vision, hearing, touch, and action (Titzer, Thelen & Smith, 2003). This multimodal interaction contributes to our understanding and perception of the world, and has been shown to be important for child development (e.g. Piaget, 1972; Smith & Gasser, 2005). In general, touch has been argued to be important in extending children's understanding and knowledge of the world through its specific sensory functions, for example, experiencing texture, shape, weight as well as contributing to learners' classification skills (Berk, 2012). Furthermore, touch through finger drawing is linked with the processes of young children learning conventional writing skills (e.g. Kress, 1997).

Research examining the role of multitouch technologies in educational contexts is beginning to flourish. In particular, studies have explored the value of iPads as a teaching and learning tool in higher education contexts (e.g. Oldfield & Herrington, 2012); drawing on theoretical perspectives to inform the potential affordances and limitations of iPads and identify key research directions (e.g. Melhuish & Falloon, 2010); and examining adoption, and related challenges, in primary and secondary schools (e.g. Pegrum, Oakley & Faulkner, 2013). A recent report, based on a literature review seeking evidence for ways in which iPads support learning, highlights that they are 'easy to use, have a positive impact on students' engagement, increasing motivation, enthusiasm, interest, independence and self-regulation, creativity and improved productivity' (Clarke & Luckin, 2013, p. 4).

While these studies contribute to ongoing debates on the role of technology (and iPads specifically) in education, they primarily consider its role in school and higher education contexts. Other studies have explored young children's use of technology in general in the home, and suggest that technology is important in

fostering communication and creativity, and extending children's skill sets (e.g. McPake, Plowman & Stephen, 2013). However, little work to date has examined the use of iPads for very young children in nursery education settings, or how touch-based digital technologies might reshape current interaction and learning, and touch based experiences. Given the digital landscape of today it is critical to understand the potentials and constraints of such touch-based devices, and the losses and gains of their use to inform effective use in early learning environments.

Background

This section provides a brief background on touch in the context of finger-painting activities, and research on multitouch in digital environments in pre-school contexts, with a primary focus on the multimodal approach that informed the research design and analysis.

At around 8 to 10 months of age, most infants demonstrate the ability to engage in canonical pointing and use their forefingers to draw, scribble, and make marks on surfaces that produce some type of image. Infant finger drawing is linked with the process of young children learning conventional writing skills and other skills relevant in digital contexts, for example, touch screens (Kress, 1997). A review of infant and young children's (0–42 months) mark making, scribbling and drawing (Dunst & Gorman, 2009a) shows that there are distinct changes in development, the feedback from children's mark making being instrumental. For example, drawing contexts with images on them (e.g. animals or faces) elicited more mark making than blank pages, and opportunities that enabled canonical pointing to produce observable effects facilitated finger drawing. Furthermore, computer screens were found to be engaging in enabling children to see their marks appear on screens (Dunst & Gorman, 2009b). Digital technology devices are increasingly embracing direct touch techniques of interaction on screens. For very young children this form of interaction is more intuitive than traditional desktop computers that rely on mouse and keyboard interaction, since it exploits their natural exploration strategies that rely on a wider range of sensory-motor forms of interaction. While research is beginning to examine touch-based interaction more extensively, the work that has been done is somewhat disparate in terms of focus, and disciplinary perspective. Some focus on hand manipulation, basic computer switch skills and developmental age and the ability to understand cause and effect relationships (Glickman, Deitz, Anson & Stewart, 1996), others on age effects of using mouse versus touchpad interaction (Hertzum & Hornbaek, 2010), and others on examining children's ability or competence to interact with touch screen technology (e.g. Idriasani, De Angelis & De Brujin, 2008). Few studies have specifically explored different forms of touch engendered by touch screens, and even less with pre-school children.

This paper takes a multimodal approach to touch (Kress, 2010; Jewitt, 2013). Multimodal approaches provide concepts, methods and a framework for the collection and analysis of visual, aural, embodied, and spatial aspects of interaction and environments, and the relationships between these. While other modes of communication such as gesture have been recognised and studied extensively, multimodality investigates the interaction between a variety of communicational means, and challenges the prior predominance of spoken and written language in research. It provides resources to support a complex fine-grained analysis to get at the details of artefacts and interactions in which meaning is understood as being realised in the iterative connection between the meaning potential of a material semiotic 'artefact' in this case an iPad and paint-paper, and the meaning potential of the social and cultural context it is encountered in, and the resources, intentions, and knowledge that people bring to that encounter. Changes to these resources and how they are configured are therefore understood as significant for thinking about meaning making. Digital technologies are a site of particular interest for multimodality because it is a key place for investigating such re-configurations and their influence on representation and interaction.

Multimodality has considerable potential for researching digital representation and interaction, for example in relation to: (1) The systematic description of modes and their semiotic resources in ways that can support understanding meaning making in digitally mediated environments and can contribute to the evaluation and design of multimodal digital artefacts, interactions and experiences; (2) Multimodal investigation of interaction with specific digital environments, how digital resources are used in specific contexts in order to understand how semiotic resources are used to articulate discourses and practices across a variety of contexts; (3) Identification and development of new digital semiotic resources and new uses of existing resources in digital environments; and (4) Contribution to research methods for the collection and analysis of digital data and environments which attend to the ways interaction is realised through the interaction of a range of modes unfolding over time. These four areas show the potential of multimodality to better understand how technologies are used in context and inform

the evaluation of technology design and use. This paper hones in on touch and primarily speaks to points (1), (2) and (3).

Much has been written on gesture but there is limited research on the semiotics of touch. This paper attempts to sketch out touch from a multimodal perspective. Multimodality talks of modes rather than senses – for example it focuses on the visual, sound, and gesture rather than seeing, hearing, and the haptic. From this perspective however a mode is a set of socially and culturally shaped resources for making meaning, and mode classifies a 'channel' of representation or communication (Kress & van Leeuwen, 2001). While touch is usually thought of in terms of perception or what might be called the sensory side of communication and interaction, there are communities and contexts in which touch is a fully developed mode of communication. Tactile signing, a form of communication used within deaf-blind communities, is one example of this. It may involve either tactile fingerspelling, braille signing (using six spots on the palm to represent the braille forms), or 'hands-on signing' in which the receiver's hands are placed on the back of the hands of the signer to convey signs through touch and movement. Touch has become a shared semiotic resource among other communities, for example, among surgeons and masseurs, and other professions where a sense of touch has become a diagnostic resource.

Touch has become of interest to sensory anthropologists and ethnographers (e.g. Howes, 2013; Pink, 2009) who explore the 'multisensorality of experience, perception, knowing and practice' (Pink, 2009, p. 1). Touch has previously been talked about only as a sense – sight, smell, hearing, and touch. However, touch is increasingly foregrounded and designed within technology and human computer interaction research as an interactional mode. Is it now possible to talk of touch as both a sense and a mode? That is, are the material properties of touch being culturally and socially shaped into a set resources for meaning making – are we seeing the extension of senses into modal resources? Is the digital environment's developing use of touch as an increasingly complex form of interaction blurring the boundary between the skin and technology, refining touch itself into a (sensory) modal resource? If a mode is a set of semiotic resources organised by a 'grammar' can we talk about touch as evolving into a mode or a 'mode-like' material resource? This paper engages with the notion that interactional forms with technologies are changing, and highlights the need to explore how touch features in the digital environment. In this paper we focus on the iPad, and ask if and how touch differs in digital and paper environments.

Study design/method

Participants:

Participants were seven children aged between 27 and 37 months from a London nursery school. The staff at the centre selected the children from those whose parents had given informed consent, and included 2 boys and 5 girls.

Materials:

A pilot study, with four children, informed the specific use of materials for the iPad (e.g. particular apps were rejected to avoid advertisements that appeared during interaction) and the research design. Pilot data is not used in this paper; data is only reported from the seven participants in the main study.

Materials for the iPad environment: we selected three existing applications for use in the study:

- Doodle Buddy app: blank screen with a paint palette
- Coloring Zoo: Finger painting using a picture of a cat
- Fingerpaint Magic: blank screen when touched spreads paint in feathered patterns

Materials for the paper environment: These consisted of:

- A plain sheet of white paper
- A white sheet of paper with an outline picture of a cat, which could be coloured in
- A paint palette with 5 fingerpaint colours.

The Doodle Buddy app and the finger painting with a blank piece of paper both enabled painting on a plain white surface. Coloring Zoo and the paper with a picture of a Cat printed to scale from the Colouring Zoo app provided the child with the same outline image to colour. Both environments used a restricted range of colours; and both offered touch-based interaction. Fingerpaint Magic provided a different environment in which the app created effects on the screen and thus was connected to the paper condition only through the process of touch and colour.

A questionnaire was given to parents to provide relevant background information about their children, including age, experience with technology and specifically with iPads.

Study design and procedure

A pilot study with 4 children was undertaken to finalise the design and data collection methods prior to the main study. Since familiarisation with such young participants is critical, the researchers involved also

spent 2 days in the nursery with the participants before starting data collection.

Two researchers collected data during the school schedule over a five-day period. In one corner of the classroom, the first researcher carried out the study with the participant, while the second researcher set out the iPad and the other material for each new session, and monitored the video recording. Each child performed 5 individual activities; exploring the three applications on the iPad, and finger-painting on a blank sheet of paper and the sheet with a pre-drawn image. Each session lasted an average of 5 minutes. The session was considered over when the child spent 10 seconds without touching the screen or the paper sheet. A reverse order design was used (3 children started with iPad activities and 4 children with activities on paper), to reduce the effect of order of activity on iPad or physical paper.

Data collection methods

Data was collected using video capture from a number of different perspectives, generating a total of 7 video streams (detailed in this section). Video streams 1–4: A purpose-built iPad cover was developed to embed the four micro cameras. This comprised a polystyrene shaped rectangular frame surrounding the iPad, with 4 holes the size of micro-cameras placed at the centre of each side. This frame was covered with soft thick fabric. Video stream 5: was made of the iPad screen or paper, to record the sequence of actions and interactions with the mobile and physical devices. Video stream 6: on the iPad itself recorded the movement of the hands and the touch on the screen. Video stream 7: recorded bodily position and movement with a fixed wide shot of the activity as a whole.

The software used in the study was Reflector, which is compatible with iOS devices. Once installed, Reflector wirelessly mirrors the display of one or more mobile devices (in this case one iPad) on the computer desktop. Once Reflector was playing, other software was required to capture the computer screen and to enable the recording of everything that happens on the iPad – in this case QuickTime Player 10.0 was used.

Conceptualising and coding touch

FinalCut Pro was used for organising the data. This enabled synchronisation of the videos as well as creation of a new screenshot with three different points of view (the iPad screen or paper, the child's face, and a view of the child + environment). The character of touch was explored through the team's repeated viewing of the video data. A set of codes for describing touch was developed through this discursive viewing and drawing on the multimodal concept of semiotic resource – the actions, materials and artefacts we use for communicative purposes (van Leeuwen, 2005). These codes moved away from categories of touch embedded in the technology of the iPad and other touch-interfaces (e.g. gesture-works) that are linked to functionality, towards descriptive categories of touch relevant to both environments that could support comparative analysis of touch. This process identified four dimensions of touch pertinent to this paper: (1) whether the whole hand(s) were used, and which and how many fingers were used; (2) the type of touch used; (3) the character and quality of touch; and (4) the sequencing and configuration of touches. The codes devised to capture the range of resources used across these dimensions of touch are outlined below.

Hand/fingers used
Hand: None/ note if used – one hand or two
Finger: single – note if NOT index: multiple – how many

Type of touch
Tap: A short touch of the surface
Press: A firm push on the surface, a longer tap
Straight stroke: When a finger is held on and moved across the surface to make a line mark
Circular stroke: When a finger is held on and moved in a circular fashion across the surface
Scratch: Use of nail or tip of finger to make a scratching movement

Quality of touch
Direction: top to bottom/bottom to top/ left to right/ right to left/
'Scale/size': tiny (size tip finger)/small (2–4 cm)/ large over 4 cm
Speed of touch: noted if SLOW or FAST
Duration: short, long
Pressure: hard, soft

Sequencing/configuration
Amount: once, repeated x *n*
Continuous Touch sequence: more than one touch linked together with another in a sequence of movements in which the finger/hand stays on the paper/ screen; noted if continuous touch involved making marks that got bigger/ smaller

The codes were used/trialled independently by three researchers on an exemplar video, discussed and refined. One researcher independently coded each episode of video data using the qualitative analysis software, InqScribe and another checked the coding – any

discrepancies were discussed and resolved. Introductory notes to each video included researcher name, child's name, the surface for the interaction (iPad or paper), and the focus/site of interaction (on paper, on the paint palette, on iPad or on the iPad colour palette). The video data was coded specifically to examine different kinds of touch in the two conditions. This paper reports data on type of touch and sequencing/configuration (data on hands/fingers used and quality of touch is reported elsewhere).

Results

Before presenting the findings, it is important to clarify what aspects are being compared, since the paint palette-paper relationship that is inherent in the 'paper' environment fundamentally differs from that of the iPad environment. These environments differ in part as they provide children with different points and surfaces for interaction. In particular, finger painting on paper requires interaction with two physically separate 'sites' – the paper and the paint palette. In contrast the iPad combines the notion of 'paper' and 'paint palette' into one surface. Thus, on a basic level the children's touch-based interaction is distributed and shaped in specific ways in the paper-paint based versus the digital environment. Throughout this article we make direct comparisons of the paper and iPad screen as sites of interaction that are comparable in their place in the activity of finger painting (i.e. excluding the 'palette' interaction). However, the paint palette was an important 'site' in the children's touch-based interaction in the paint-paper environment, and is therefore included in the reported results and discussion.

Comparison of types of touch across environments

This section reports the data for each type of touch, focusing the total number of each type of touch and comparing their use across the two environments. Each environment has two parts: the palette (iPad palette or paint palette) and the painting part (iPad screen or paper). These comparisons are also shown in Figure 1 below.

Tapping: Tapping touches were used most with the iPad. The children made a total of 947 tap touches: 45% (425/947) with the iPad, 39% (367/947) with the paper, 11% (102/947) with the paint palette, and 5% (53/947) with iPad palette. Around a half (4/7) of the children used tapping more in the screen environment than the paper environment. However, a comparison of total taps with the paper and the iPad screen shows that tapping accounted for a larger percentage of the children's touches with the paper: 51% (367/719) with the paper compared to 43% (425/985) with the screen.

Straight stroke: Straight strokes were more common in the children's touch repertoires in the iPad environment, with nearly a third of touches in the iPad being straight strokes. A total of 469 strokes were made during the interaction across both the environments. The children used a straight stroke most often with the iPad screen which accounted for 60% (283/469) of all straight strokes, followed by the paper 36% (167/469) of strokes, the paint palette 3% (14/469), and the iPad palette 1% (5/469). While straight strokes were a feature of all of the children's touch-repertoire in both environments, two children used this form almost exclusively with the iPad screen.

Circular strokes: The children used a circular stroke most often with the iPad screen which accounted for 58% (242/418) of all straight strokes, followed by the paper 32% (132/418) of strokes, the paint palette 10% (43/418), and the iPad palette ¼% (1/418). It is worth noting that for 3 of the children circular strokes were exclusively used in the iPad environment, and were a restricted feature (i.e. only used once or twice) of one of the children's touch repertoires.

Pressing: The press touch featured most often in the paint-paper environment, the children pressed most on the paint palette (55/144 presses): 38% of all presses were in the paint palette, and 37% (53/144) of all presses on the paper. Presses occurred on the iPad screen only 22% (32/144), and rarely with the iPad palette 3% (4/144).

Repeated and continuous sequences of touch

Repetition of forms of touch was a common feature of all of the children's interaction while finger painting: 12% (238/1981) of all of the touches made by the children during all episodes of interaction were repeated. Repetition of touch was a feature across all of the environments: 109 with the iPad screen; 89 with the paper; 31 with the paint palette; and 9 with the iPad palette. Repetition of touch was more common in the iPad environment, with 50% more repeated touches with the iPad: 9% (89/965) of touches repeated with the iPad, 6% (42/677) with the paper[1]. This emphasis on repetition with the iPad was a feature of most (5/7) of the children's interaction.

1 Data reported on repetition and continuous touch is for 6 children, as one child (SH) is removed as they made an unusually high number of repeated and continuous touches in the paint-paper environment (repetitions: 47 on the paper, 17 on the palette; continuous 29 on the paper, 13 on the palette).

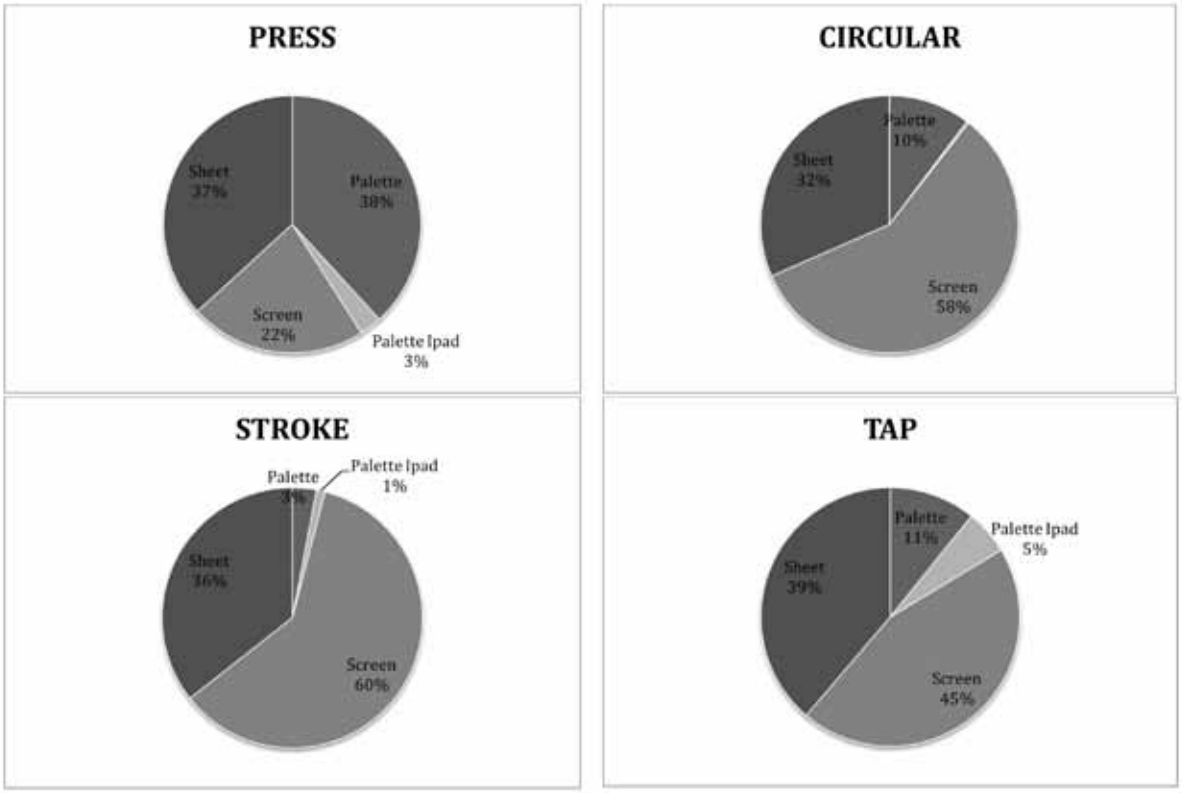

Figure 1. Comparison of touch type by environment

Sequences of continuous touch, when more than one touch linked with another in a sequence of movements in which the finger/hand stayed on the paper/screen, were a feature of all of the children's interaction with the paint-paper and the iPad. A total of 139 sequences of continuous touch across the different environments were observed, however one child was responsible for 44% (61/139) of these, while the remaining 6 children's use of continuous touch was more evenly spread. Looking at these children's activities gives a more general picture – a total of 78 sequences of continuous touch across the different environments: 62% (48/78) with the screen, 29% (23/78) with the paper, 9% (7/78) with the paint-palette and none with the iPad colour palette.

Comparison of the iPad screen and the paper shows that the iPad supported over twice the number of sequences of continuous touch: 62% compared with 29%. At an individual level, each of the children were observed to make around twice as many sequences of continuous touch in the iPad environment. The continuous sequences of touch were also longer with the iPad than the paper. The maximum length of a continuous sequence of touch in the iPad was 27 seconds, compared to 18 seconds with the paper. The total amount of time the children spent engaged with continuous touch was 6:20 minutes with the iPad as compared to 4:24 with the paper.

Touch repertoires

This study draws on a small sample limiting the capacity to reliably assess the influence of age, exposure or parent's opinion about technology. However, it does provide a basis to inform the development of hypotheses and research questions for future research and with this in mind we now turn to the 'touch repertoires' of the children in the study. Each of the children configured the features of the four dimensions of touch discussed above differently. These features and dimensions can, this paper argues, be combined to produce a 'touch repertoire' for each child, and to compare how these features played out across the iPad and the paint-paper environments. Table 1 summarises the touch repertoires of each child: it shows the extent to which each dimension of touch featured in each environment, noting if this was absent or restricted, attributed primarily to either iPad or Paper, or used 'equally' across both iPad and paint-paper.

Some children's touch repertoires were more restricted than others in relation to type of touch, quality of touch and sequencing. Several of the children made restricted use of some forms of touch and sequencing, with 3 children showing particularly restricted repertoires. One of these children, whilst having a restricted repertoire, nonetheless makes equal use of the touches that she does have within her repertoire across both environments: the other two children with restricted

Table 1. The touch repertoires of the children

	Type of touch				Sequencing	
Child	Press	Stroke	Circular	Tap	repeat	CT
AA	Equal	iPad	iPad	iPad	Equal	iPad
AM	Equal	Equal	Equal	iPad	iPad	iPad
PR	Paper	iPad	iPad	iPad	iPad	Restricted
PY	Restricted	Equal	Equal	Equal	Equal	Equal
SA	Paper	Equal	Restricted	iPad	iPad	Equal
SH	Equal	Equal	Equal	Equal	Equal	Equal
ZA	Restricted	Equal	iPad	Equal	iPad	iPad

repertoires do not. This child has access to technology (including a laptop, tablet, smart phone, portable game console) on a daily basis (5–15 minutes) and her parent considers this access to be essential.

Only one child (of the seven) made use of all the features and dimensions of touch focused on in this study. She/he has the most access to digital technologies at home, including a simple cell phone, smart phone, mp3 player, video games, portable game console, for the longest amount of time (30–60 minutes a day). This child's parent reported some discomfort with the use of technology but strongly disagreed that it was addictive. Two other children had significant access to technology, and their parents presented a positive opinion of technology. This raises a question for further investigation: do children with wider access to technologies have more expanded touch repertoires? As noted above, some children's touch repertoires did not differ markedly between the environments. This suggests that either their touch repertoire is not being strongly shaped by changes in technology, or that the touch based repertoires can be extended through the use of touch-based technologies and used across different environments. This is an area for further investigation.

Some children's touch repertoires were markedly different across environments: they appeared to make touch-based distinctions between the paper and iPad environments. For instance, one child used Press exclusively with the paint-paper and straight stroke, circular stroke and tap almost exclusively with the iPad; while another used Press almost exclusively with the paper, and Tap almost exclusively with the iPad. These children's touch repertoires appear to be strongly shaped by the affordances of the technology environment. These particular children had no access to technology in the home. This suggests that their touch repertoire has evolved in non-digital ways and raises questions about how children develop their touch repertoires and transfer them across environments.

Discussion

Drawing on the findings reported above this section explores the losses and gains of touch in the two environments studied and their implications for early years learning, and the issues raised for multimodal studies on young children's digital interaction.

Gains and losses for early years

The children clearly made use of touch types to different extents in each environment. This can be interpreted as the children's response to, or their emerging understanding of, the material and technological affordances of each environment, or in other words: the different environments 'brought forth' differently configured touch repertoires. Differences in the children's use of touch in the digital context of the iPad and the paper relate to the volume of touch, the rhythm and duration of touch as part of a multimodal sequence, the variation of touch types, the repetition, and the sequencing and continuity of touches. Drawing on Kress's notion of 'gains and losses' (Kress, 2010) we explore what these differences might mean for meaning making in early year settings.

The findings suggest that the iPad has the potential to support:

- The use of a wider range of types of touch
- More touches in a period of time – 'faster'
- More continuous touch sequences
- Longer sequences of continuous touch
- More complex sequences/repertoires of touch

When combined, the above **'gains'** have the potential to support concentrated engagement with the screen, due to the sequence of actions and longer sequences of continuous touch. They also create the potential for continuous touch sequences that are limitless in length since the iPad enables continuous marking in contrast to the paper, where the need to return to the paint-palette to collect paint may 'interrupt' the 'flow' of interaction and decrease concentration. Furthermore, this feature offers the capacity to vary size more dynamically on the screen in one movement. This highlights the affordance of visual feedback shown to be important in the development of children's mark making in the generating of higher quantity and quality of pre-drawing behaviour (Dunst & Gorman, 2009a). The findings also suggest that the iPad may promote more and a wider variety of touch-based interaction. It was shown to support 'canonical pointing' to produce observable effects which facilitate finger drawing (Dunst & Gorman, 2009a), but also provides young children with opportunities to use stroking forms of touch and continuous touch sequences that may be pre-requisite actions for developing drag and drop techniques. Thus, the iPad

can be seen to contribute to 'digit' skill development and the extending of touch repertoires for digital interaction more generally.

The findings also suggest that the iPad brings with it particular **'losses'** that need to be considered when they are used in early years' settings, in particular:

- The quantity and range of fingers used is restricted
- The range of qualities of touch used (i.e. differences in pressure) is limited
- Several sensory features of touch are lost, in particular, the haptic and tactile, textural experience of paint, which has been identified as an important aspect of infant development.
- Potential periods of reflection are reduced by removing the rhythm of movement from the paper to the paint-palette that create moments of distance and objectification

These losses can be seen to influence one another. For example, touch in the iPad environment loses the sensation of touching paint as a medium, the messiness of finger-painting, and the moments of physical 'distance' and 'removal' produced in the rhythmic move from the paper as a site of interaction afforded by the need to constantly 're-apply' paint to the fingers. This provides moments that create the potential for reflection and objectification of the painting and engagement with the process (e.g. looking at the fingers, or playing with the paint on the hands).

These losses and gains are useful in considering when and how to make use of iPads or paper in early years education contexts. For example, in an early years context, a structured painting activity focused on precision and the appropriate use of colour may be better supported by the affordances of the iPad environment, whereas a more open painting activity may be better supported by the affordances of paint-paper.

Implications for multimodal research in early years research

This paper has honed in on young children's touch towards building a systematic description of its features and semiotic resources and it has investigated their touch-based interaction within an iPad digital environment and paper-paint environment, and compared touch across these two environments in order to understand the use of touch-resources in specific contexts and how they afford and support the use of semiotic resources in different ways. This has provided a basis from which to ask how touch in these environments is used to articulate different types of practices and from which to begin to explore discourses for learning and development.

It has contributed to the multimodal work of understanding how digital environments shape and develop touch as a semiotic resource. The study findings show how the properties of environments shape the children's selection of the type of touch that they use. In this way we can talk of touch as a situated modal resource that children select in response to the material and social environment. The question of whether the children go on to develop emergent understanding of the different place of pressure in touch-based digital contexts, where touch needs to be more 'pressure-neutral' and controlled, is one for further study. The study has started to explore the features of touch as a semiotic resource and its uses in digital environments and suggests that it is now possible to talk of touch as a mode with material properties of touch being culturally and socially shaped into a set of resources for meaning making. That is, touch is being extended from the domain of sense into a modal resource: this raises the question of whether there are new forms of sensory modal resources. This study raises questions about how young children's use of touch types and qualities is socially and culturally shaped by their previous experience of technologies in the home and parental opinions on digital technology. It also raises questions about how the use of technologies in the home and school is embedded in discourses of interaction, attention, as well as larger debates on learning, creativity and social inclusion: debates that shape the social and cultural use of iPads, paint and paper in early years settings.

This study has made a contribution to research methods for the collection and analysis of multimodal environments. It has demonstrated the power of combining dynamic screen capture software with video data from different perspectives, but also raised challenges for syncing multiple sources of video data. It has raised several methodological challenges for multimodal research on touch: the difficulty of observing the quality of touch in interaction – it was difficult to 'observe' pressure of touch, except when the children were pressing for a long time or moved their bodies in a way to indicate more pressure; and consistent nuances in the character of a touch were difficult to observe – is the pressure used in a 'tap' in the paper environment the same as a 'tap' in the iPad environment.

The study has brought multimodality into conversation with a quantitative approach to coding video data. This has supported systematic sampling of events for focus in the analysis. It has enabled robust comparison of micro-interaction across the data that in turn has enabled a picture of touch to be developed across the participating children and the different environments. This combination has supported the investigation of patterns of touch to be investigated across the children,

and led to the development of the idea of 'touch repertoires'. The study provides a solid empirical basis from which to further explore and develop 'touch repertoires' in future studies and to systematically sample episodes for further multimodal analysis of the data through fine-grained analysis. This work can usefully be developed to understand and compare how touch and gesture interact, the role of gaze and body posture in moments of interaction within and across digital and paper environments.

Conclusion

This paper has explored the role of physical action with particular attention to forms of touch-based interaction in young children's learning, and the role that touch screen technologies and digital tools (iPads) might have in re-shaping these. Drawing on a study that compares children's finger painting in a physical paper environment with a similar activity with a digital iPad, the paper has exposed ways in which digital technology shapes young children's touch-based interaction: in particular, it engenders broader use of a wider range of types of touch, which include more complex and longer sequences of continuous touch interactions, fostering more elaborate touch repertoires. However, the paper precluded the range of sensory experiences enabled through physical paints. In so doing it has raised some preliminary implications for technology use in preschool contexts and directions for future research. One question raised by this study is whether or not there are significant qualitative differences in the drawing outcomes in each environment and the implications of this for children's mark making and development both in terms of early writing, multimodal literacy and digital skills. The study also suggests avenues of investigation for the design and use of apps in early years settings. Finally, this paper argues that there is the need to better conceptualise touch as a mode and form of interaction and the formulation of ways of describing and analysing touch as an interactional resource.

Acknowledgement

This study has been implemented in the framework of the MODE research project, 'Multimodal methodologies for researching digital Data and environments' Funded by ESRC (RES-576-25-0027).

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