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Hands-On Reading: An Experiment in Slow Digital Reading

Aditi Nafde <Aditi_dot_Nafde_at_Newcastle_dot_ac_dot_uk>, Newcastle University
Matt Coneys Wainwright <Matthew_dot_Coneys_at_sas_dot_ac_dot_uk>, Newcastle University
Kate Court <kate_dot_court_at_newcastle_dot_ac_dot_uk>, Newcastle University
Fiona Galston <Fiona_dot_Galston_at_newcastle_dot_ac_dot_uk>, Newcastle University
James Cummings <James_dot_Cummings_at_newcastle_dot_ac_dot_uk>, Newcastle University
Tiago Sousa Garcia <Tiago_dot_Sousa-Garcia_at_newcastle_dot_ac_dot_uk>, Newcastle University

Abstract

This paper offers a case study of the development of Hands-On Reading (https://hands-on-reading.atnu.ncl.ac.uk/login), a web app that explores the interconnections between digital reading and writing. The app was created as part of the AHRC-funded project "Manuscripts after Print c.1450-1550: Producing and Reading Books during Technological Change," which ran at Newcastle University between February 2019 and July 2020. It was initially designed to enable the project to ask two crucial questions: why does handwriting have an enduring relevance in a digital age; can a more hands-on approach to reading lead to a deeper engagement with a digital text? However, as this paper will show, the creation and testing of this app also raised a number of conceptual issues and technical challenges of broader relevance to the DH community, relating in particular to the question of whether reading and writing practices can be translated to the digital world.

Introduction: Background and Concept

The initial concept of a digital reading and handwriting app stemmed from an interest in exploring the endurance and adaptability of handwriting in response to technological change. Before the invention of the printing press, writing a text by hand was the dominant means of producing a book. The scribes employed to undertake this task copied out texts slowly and carefully and, as a result, were usually their first readers. This task gave them an intimate and detailed understanding of the text. The invention of print changed the craft of book production. The mechanical processes of the press meant that printed books did not look like handwritten manuscripts although, in a close parallel to e-readers with page-flip features, printers tried to copy the handwritten book format as closely as they could. Nonetheless, scribes were aware of the differences between manuscripts and print, caused by the mechanics of the press, as were the patrons who commissioned manuscript copies, and scribes swiftly began to incorporate features of print into their manuscripts [Nafde 2020]. By the late sixteenth century, scribes were producing manuscripts that could have been mistaken for printed books. This change in scribal practice disrupts the linear narrative of supersession that often accompanies the invention of a new technology: that the new technology at first supplements and then eventually supplants the older technology (the German abbot, Johannes Trithemius, for example, wrote of his fear that print would eventually destroy manuscripts [Trithemius 1974]). But this linear narrative does not take into account that the older technology also adapts and changes in response to the new. This is particularly the case with handwriting, which has adapted through several technological changes. The Hands-On Reading app leverages handwriting's adaptability to explore the relationship between digital reading and digital writing. 1

The digital revolution has prompted a renewed interest in handwriting and its place in a multimedia world. In addition to the popular resurgence of calligraphy, there has been substantial experimentation in digital handwriting tools: from the integration of styluses with existing touchscreen technologies to the development of dedicated hardware and software solutions (e.g. Remarkable, Kaligo, Moleskine Smart Writing, the handwriting to text conversion tools built into some 2

mobile phones and tablets). Unlike the majority of these commercial products, however, the development of Hands-On Reading was informed by a familiarity with medieval manuscript culture and, in particular, its blurring of the boundaries between scribe and reader. This allows us to better explore the relationship between writing and reading.

3 The project was also informed by an awareness of different modes of reading and the possibilities they offer. Since the late 1990s, a growing body of research has explored the varying ways in which readers approach printed and digital texts, as well as the broader impact of digital culture on the evolution of reading practices. For all their advantages, it is generally acknowledged that digital texts tend to encourage swift reading at the expense of contemplative analysis. Recent research has found that university students who access texts in digital form are less likely to take detailed notes or employ other study strategies [Schugar 2011]; they excel in identifying and recalling the information needed to answer concrete questions, yet they are outperformed by peers who read in print when it comes to abstract questions that require inferential reasoning [Kaufman and Flanagan 2016]. These findings have prompted a renewed interest in the value of "active reading," whereby readers engage in critical or evaluative thinking as they read a text, often simultaneously taking notes – a practice familiar to any medievalist who has encountered heavily annotated manuscripts or early printed books. Yet such scholars will also be familiar with another form of reading prevalent in the Middle Ages: the slow reading of scribes, who copied texts word by word from an exemplar, and were therefore constrained to read them at a measured and regular pace, with all the time this task afforded for unhurried reflection. We wanted to use the app to explore the potential value of this process of slow reading within a digital context, and to assess how it influenced readers' perceptions of and responses to the digital text.

4 Development of the app brought together a team with significantly varied expertise. The project's PI and RA shared research interests in medieval reading and handwriting practices, familiar with DH research tools though primarily from an end-user perspective. The involvement of researchers affiliated with Animating Text Newcastle University (ATNU), a collaboration between the Faculty of Humanities and Social Sciences and Newcastle University's Digital Institute, brought specific expertise in the application of DH techniques to textual editing. Engagement with the broader public and creative practitioners such as professional calligraphers was central to the project, allowing investigation of contemporary trends in reading and writing and perceptions of how reading and writing practices might change in the future. The day-to-day development of the app was accomplished by research software engineers with extensive experience of both commercial and academic software development. This combination of perspectives was crucial to the conception of Hands-On Reading.

Initial Design and Related Work

5 Digital reading has grown vastly with the introduction of platforms such as Google Books that are digitising material at such dizzying rates that "it would take a human an estimated twenty thousand years to read such a vast collection at the reasonable pace of two hundred words per minute, without interruptions for food or sleep" (Aurnhammer et al. (2019), referencing Aiden and Michel (2013), refer to Google who have scanned "over 30 million books"). One of the consequences of this growth is the tendency towards computer-aided distant reading whereby broad patterns are identified across large volumes of digitised texts by machine [Aurnhammer et al. 2019]. Our interest, on the other hand, is in exploring the possibilities offered by digital texts for critical or evaluative close reading. To better understand how users interact with digital texts and digital writing tools, we held a symposium to which we invited academics, creative practitioners (mostly professional calligraphers but also artists and designers), and digital specialists, i.e. groups of practitioners that read and write differently. Conversations with this range of users allowed us to draw more concrete conclusions about the kind of experience we hoped to provide through the app, as well as its potential value from a research perspective. One of the key outcomes of these initial discussions was the notion of slowing down digital reading to allow time for critical thinking and reflection. This notion is particularly timely given the rise in bite-sized information on social media platforms that results in increasingly fast-paced reading. One of the ways we wished to explore slowing down digital reading in designing the app was to connect reading to writing. While other DH studies explore the possibilities offered by digital texts for active reading – annotating while reading – we are interested in the possibilities offered by digital texts for using writing *as a means of* reading – reading as modelled by medieval scribes.

6 In order to encourage slow reading, we had to carefully consider the writing surface, the writing space, and the choice of

pen tool in designing our app. A number of DH projects have attempted to expand the functionality of annotation tools, bringing together the applications of the pen with the possibilities offered by digital writing. One of the earliest examinations of computer-based active reading was Schilit et al.'s XLibris "active reading machine" [Schilit et al. 1998]. XLibris used a "commercial high-resolution pen tablet display" that mimicked the "key affordances of paper" to allow readers to mark up a digital text by hand, thereby encouraging active reading. Various projects have attempted to develop this machine-based active reading further: PapierCraft experimented with hybrid machine-paper format to bring together the best of both paper and machine [Liao et al. 2008]; GatherReader sought to maintain the flow of reading while offering a range of solutions for annotation [Hinckley et al. 2012]. More recently, dedicated updates to e-reader devices explore the possibilities of active reading by replicating the look and affordances of paper (such as page flipping) while also offering additional features such as adjustable text size, quick definitions or translations, and the ability to easily share text; but annotation is often limited to underlining, highlighting, or typing notes. Commercially available e-paper tablets – such as the Remarkable and Sony's DPT-RP1 – have allowed users to annotate and edit digital text by hand, with specialist screen and stylus technologies seeking to mimic the feel and tangible nuance of physical writing. While such developments are promising, they remain in their infancy and are targeted at specific business and creative audiences rather than at readers. Studies that examine machine-aided active reading have found there to be a significant difference between reading digitally and reading on paper which limits the reader's ability to read actively [Sellen and Harper 1997] [Adler et al. 1998] [O'Hara and Sellen 1997] (these are conveniently summarised by Tashman and Edwards (2011)).

We were therefore aware that in creating an app to encourage slow reading the type of pen tool used would affect both reading and writing practices. Early research into digital writing undertaken by Microsoft found that "there is a rich set of deeply rooted behaviors that people exhibit when working with pen, paper, clippings, pages, and books" [Hinckley et al. 2010], a concept which rang true in our initial discussions with creative practitioners. In exploring the use of digital tools to mimic physical writing, Hinckley et al. separated "pen" from "touch," finding that "the pen writes, touch manipulates, and the combination of pen + touch yields new tools." Relatedly, Weibel et al. experimented with what they call "paper-digital tools" by using Livescribe digital pens to understand the practice of note taking and data collection practices, finding that the use of digital pens caused their study participants to modify their note taking practices [Weibel et al. 2012]. This influenced the choice of pen tool for our app. Users should not need a specialist stylus but should be able to use any pen tool with which they are familiar in order to avoid introducing a new element to the study of the relationship between digital writing and digital reading. They should, however, have the option to select from various pen sizes and colours, with touch-screen input using either a finger or stylus, to allow them to colour code or size their writing as they wish.

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We were also aware that writing surfaces affect the way the pen is used. Our early discussions with creative practitioners and potential end users brought to light the key differences between digital and physical surfaces. The calligraphers in particular noticed the lack of sensorial feedback when writing on a screen, a crucial difference between traditional and digital writing. Recent studies have made similar observations: that the digital writing surface has an immediate effect on the style of writing and, as a result, digital writing is "usually larger and sloppier" than its ink and paper counterpart [Agrawala and Shilman 2005]. Their solution was not to change the texture of the writing surface but to change the available writing space so DIZI (Digital Ink Zooming Interface) zooms in on the writing space to offset the inclination to increase letter size when writing digitally. Building on the idea of changing the available writing space, Yoon et al. experimented with creating extra space via their TextTearing interface, which allows the user to break up a page of text in order to annotate freely without interrupting its flow [Yoon et al. 2013]. They concluded that their participants preferred TextTearing techniques to writing in "naturally occurring space[s]" on digital pages. But such dynamic pages that permit expanding margins and creating spaces between lines interrupts the natural flow of writing and disrupts reading, as Yoon et al. themselves observed. Weibel et al. (2012) conversely noted that paper allows spatial organisation of handwritten annotations in a way which digital tools do not. It was crucial for the development of the Hands-On Reading app therefore to strike a careful balance between such dynamism and the possible disruptions to the reading process it causes. Our primary objective was to facilitate interaction with text on the virtual page in a free and uninhibited way, offering an experience as close as possible to reading and writing by hand on paper.

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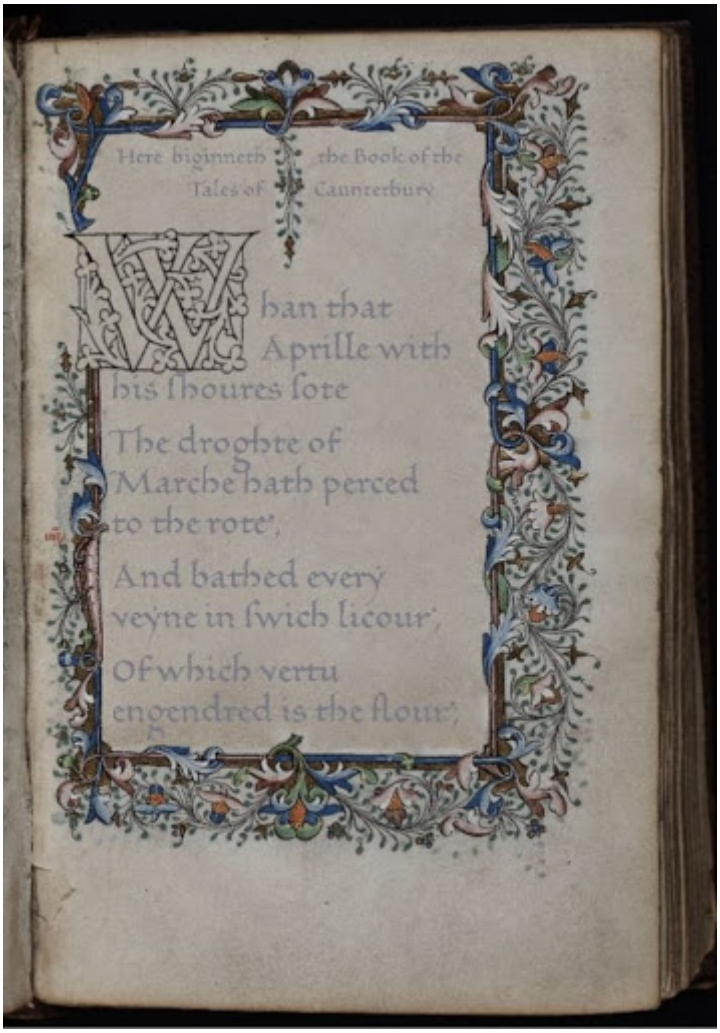

Figure 1. Initial design of the application

The medieval manuscript and early printed page are ideal models for the interaction between reading and writing. Where digital reading material such as the page-turning books available on e-readers or the articles published in e.g. *DHQ* provide little marginal space, medieval manuscripts and early printed books were often designed with large margins - and sometimes ruled with blank columns - for the very purpose of extensive annotation. To emulate the scribal process of slow reading, with pen in hand, the initial design of the app was based on a medieval manuscript page. The main page of the app displayed an image of a single vellum page that imitated a familiar non-digital writing surface. A blank vellum background was sourced from a fifteenth-century manuscript in Newcastle University Library Special Collections (Newcastle University Library, Mediaeval MS 4) onto which we provided only four lines of text alongside wide margins for annotations. To encourage interaction with the text, decorative elements such as “drop cap” initials were limited to a simple outline that could be filled in. We used a blank decorative “Humanistic White Vine (Bianchi Girari)” initial designed by Klaus-Peter Schäffel. The text was rendered semi-transparent so as to elicit tracing and, in order that the text was easily readable and yet calligraphic enough to suggest it was a template, we chose Schäffel’s 1480 Humanistica font. A modern translation of the prologue to Chaucer’s *Canterbury Tales* was selected for the text as it is unfamiliar enough to warrant annotation, yet not too unfamiliar in its language (being a modern translation) to be prohibitive or off-putting. 9

Explicit instructions were limited in order to avoid the risk of prescribing the nature of interactions, but users were given the opportunity to provide specific feedback on their experience of using the app. It was vital to find a way to gather data on user interactions that could be analysed as part of the broader Manuscripts after Print project, with the potential to pave the way for further refinement of the app through subsequent funding bids. The decision was made to ask users to register an account to facilitate data acquisition and to allow users to save their work. 10

Development

Phase 1

Hands-On Reading runs as a web application.[1] It is optimised to be used with a tablet so that users can draw with a stylus, rather than the more awkward and less familiar experience of using their computer mouse. The development of a web application, rather than native phone application,[2] but with the “feel” of a mobile app was identified as a practical goal within the timescale, and would allow compatibility with both iOS and Android. The technology stack included a client built using Angular 9 and a server built using Nest.js.[3] Angular was chosen as an open-source front end framework: as it uses Typescript,[4] it offers the security and ease of programming of a typed language. Nest.js is built on the popular Node.js server-side runtime environment, but also offers Typescript support, which made it easier for the developers to move between front and back-end programming. A benefit of using Node.js based frameworks is the volume of community support online and the wealth of open source libraries available.

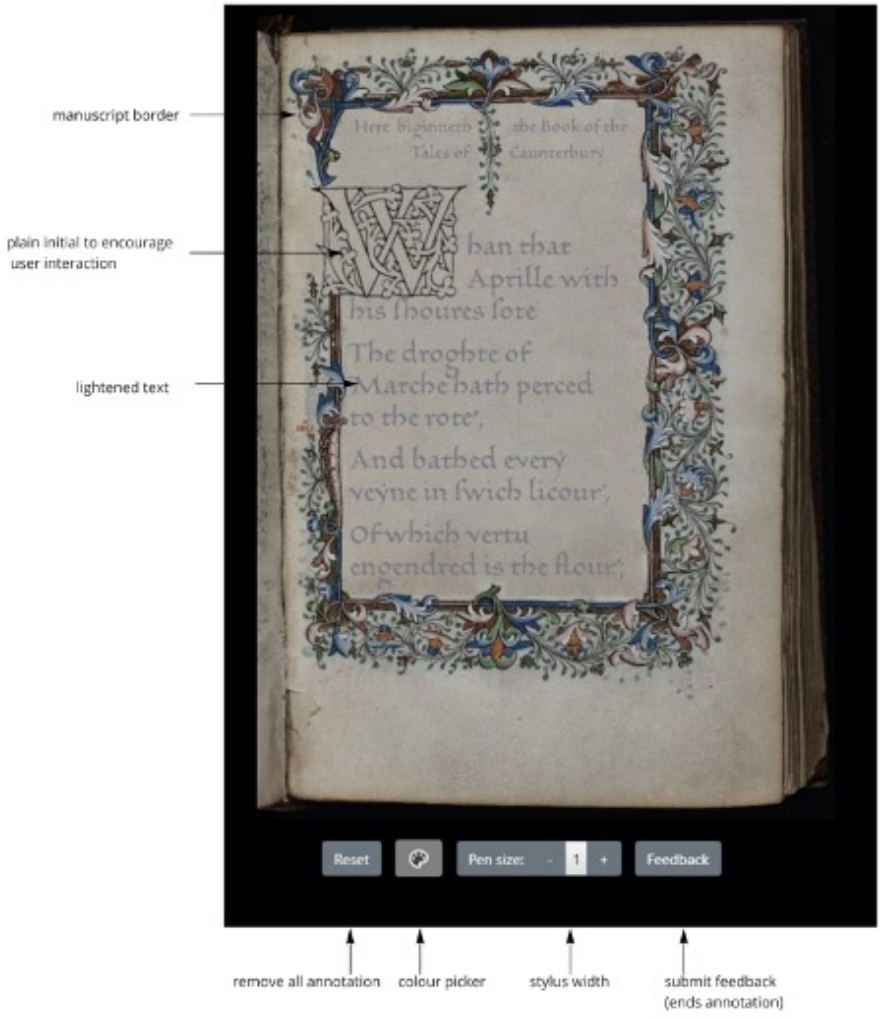

Figure 2. Screenshot from Phase 1 of the development annotated with key features.

The drawing functionality was provided by Fabric.js JavaScript framework, built upon HTML5 canvas.[5] We chose Fabric.js as it is open-source and provides a variety of drawing and shape creation functionality, enabling us to build an interactive object model on top of a HTML canvas element. A reset function allowed users to remove all annotations on the canvas. Consistent with the historical use of different inks and sizes of script in manuscript rubrication and decoration, users could also change the stylus colour and width, with these options housed within a menu at the bottom of the screen (Figure 2).

A mongoDB document-based database was used to store feedback forms at this phase of the development.[6] mongoDB is schemaless and therefore could adapt to storing additional data in future versions, rather than requiring a more static and predetermined schema.[7] This was beneficial as we anticipated that the database content would evolve in phase 2 to store more varied data. 13

Testing

Beta-testing of the app was conducted at a workshop in December 2019, twelve weeks after the initial symposium. Participants included a number of individuals who had previously collaborated with the Manuscripts after Print project, chiefly professional calligraphers and special collections librarians. The workshop was also attended by a number of academics, both with specialisms in medieval and early modern studies and from other disciplines. While participants were provided with iPads and styluses, they were also encouraged to access the app via their own devices, which included android tablets, phones and laptops, and to experiment both with and without annotation tools. 14

Following half an hour of testing, the floor was opened for general discussion. Participants were also invited to complete a feedback form, answering the following questions (which were specifically chosen to be as open-ended as possible): 15

1. Did you enjoy using the app?
2. If you could enhance or improve any aspect of the app, what would it be?
3. Did the app make you think differently about handwriting?
4. Did the app change the way you read the text?
5. Do you think the app would be of use to any specific user groups?
6. What device did you use?
7. What is your occupation?

While participants were broadly positive about the concept of the app, two main criticisms were raised: 16

1. A concern over the limited guidance offered to the user. Responses to question two included: “the task is not clear;” “a little guidance...;” “no task instructions.” While these comments were noted, they did not represent a major concern as one of the key objectives of the workshop was to see how users approached the app without instruction. Indeed, one participant noted, “[I’m] glad we didn’t get this information at the time.”
2. Frustrations regarding functionality, especially the absence of zoom and undo features. Users who accessed the app on touchscreen devices mentioned that they instinctively expected compatibility with touchscreen gestures. The lack of a zoom function was noted particularly by phone users, while there was also discussion of whether an erase function was appropriate within an app that mirrored a manuscript page; several calligraphers suggested that a "scrape to remove" function would be more in keeping with the style.

Questions three and four revealed a notable disparity between testers of different professions. The responses of calligraphers generally indicated that the app had not encouraged them to think differently about handwriting or read the text in a different way; one admitted that this might be “because I’ve been thinking about [handwriting] for a while.” The experience of using the app with pen tools rather than a pen itself stopped calligraphers from reading the text carefully, with one commenting, “I began to read the words as I traced but because that experience was frustrating I stopped reading.” However, academics and librarians stated that using the app had made them consider the relationship between the reader and the text and had encouraged them to contemplate the text's material form. One wrote that “it made me think about handwriting and decoration, material and page design as being inseparable;” another wrote that “it made me think differently about the relationship between handwriting (as a reader) [and] text;” “it made me focus more on how I read.” 17

Professional calligraphers generally did not consider the app to be a potential tool for teaching calligraphy, “unless it provided a starting point to lead someone to say ‘I want to know more’.” These responses confirmed the limitations of a generic touch screen/stylus combination for creating an experience akin to calligraphic writing with paper and pen; they 18

also confirmed that the app could be used as a tool to encourage reading the digital text *by* writing, rather than a digital writing tool per se.

Phase 2

Reflecting on these responses, it was clear that the functionality of the app limited the way the text was read. The largest barrier to reading appeared to be the gap between the expectations of users, the affordances of digital tools, and the difference between paper and digital interfaces. The app was therefore refined to address some of the issues raised by testers and to add new features that allow further reflection on the initial research questions. 19

The most pressing of these changes was the introduction of an erase button. We had initially rejected the addition of an eraser on the grounds that it would not reflect medieval annotation practices, opting instead to include a reset button which deleted all annotations. However, testers found this option frustrating and too distant from their experience of using digital tools. Part of these frustrations is that testers came to the digital interface with pre-set expectations of digital reading and writing, specifically around the features that are typically available to them on tablets. Therefore a “scrape to erase” feature, which would remove a layer of annotation and slightly damage the vellum underneath it, in keeping with medieval annotation practices, would have likewise been incompatible with how digital devices are used today. While we were conscious that the app could not directly imitate the affordances of paper and pen, the digital eraser function is both closer to its physical counterpart and a common feature on digital annotation programmes and users are therefore likely to find it more intuitive than the other options. The eraser was not a pre-existing feature of Fabric.js and was implemented as an add-on, removing any drawing or imagery existing on the canvas wherever the user “draws.” 20

At this stage we would also have liked to respond to feedback by introducing zooming, panning, and responsive sizing (automatic resizing of the app based on the user’s device). This is probably the most significant sacrifice necessitated by Fabric.js. To facilitate responsive resizing, zoom functionality, and associated panning across the screen, Fabric.js required the manuscript page to be set as a background image on the canvas. However, the implementation of the eraser meant that it removed all drawing on the canvas, not only the users' additions, and therefore the manuscript image had to be added to the background HTML in a parent `<div>` rather than as part of the resizable canvas.[8] While this was a compromise, we were also conscious of the potential disruptions to the reading process created by digital features such as zoom, as described by Yoon et al. (2013). Having observed our testers, we noted that the majority of them demonstrated familiarity with the features usually available on tablets, such as pinch to zoom gestures. Such paradigms are now entrenched enough that users expect their availability in all apps, finding their absence counterintuitive. Such gestures do not reflect the affordances of paper and it is these sorts of changing expectations that are driving the gap between physical and digital books. It will be key to a further redesign of the app to negotiate between user-expectations and the experience of focussed reading with a pen. 21

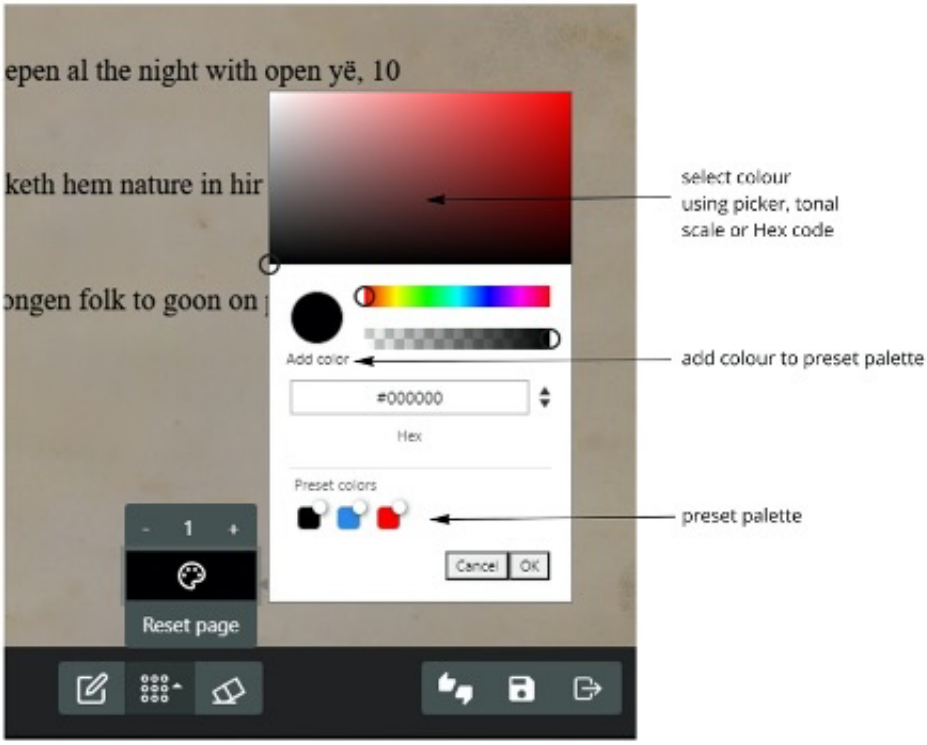

Figure 3. Colour picker introduced in Phase 1 and finalised in Phase 2.

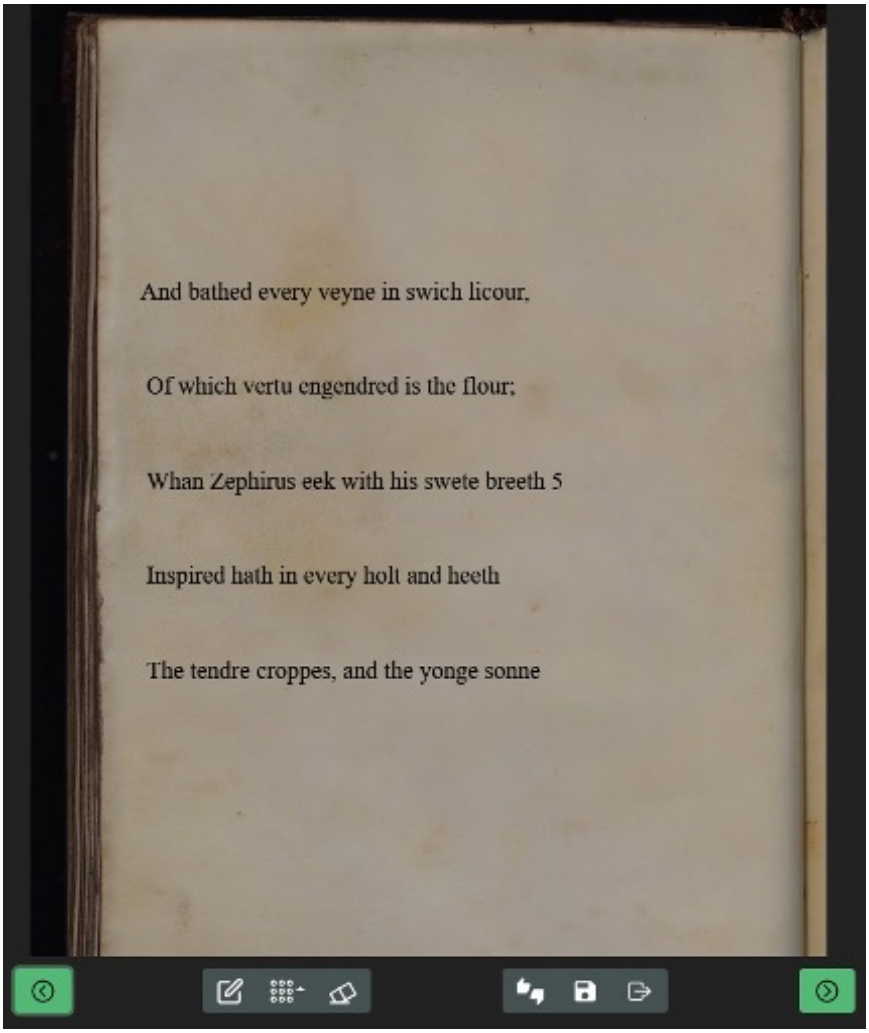

Figure 4. Left hand page

Other changes to the app were implemented to facilitate its use, thereby allowing users to operate it more intuitively and focus on reading rather than the frustrations of unexpected functionality. To simplify pen colour choice, black, red, and blue were added to the colour picker as pre-set colours, as shown in Figure 3. We also added page turn functionality to encourage users to read beyond the first page and increased the amount of text available. Given that we had to abandon responsive functionality at this stage, the font size was carefully chosen to ensure it could be clearly read while leaving enough blank marginal space around the text to encourage annotation. The number of lines displayed on the screen was limited to four, conforming with the size of a standard iPad. The text was displayed overlaid on an image of a right and left facing manuscript page, as shown in Figure 4. Users move forward and backwards in the text with buttons on each side of the manuscript.

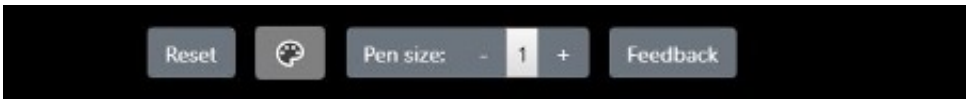

Figure 5. Phase 1 menu

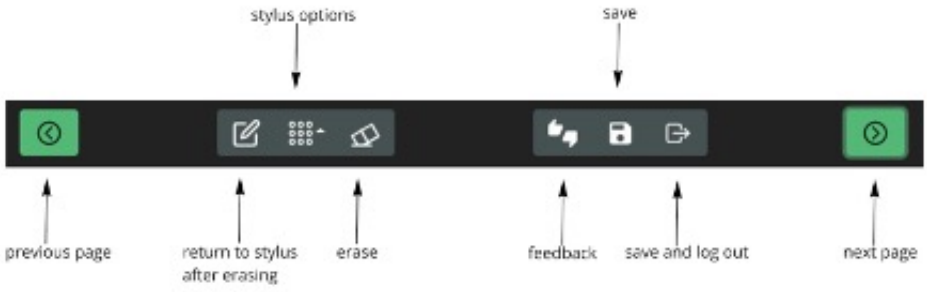

Figure 6. Phase 2 menu annotated with features

Stylistically, we refined the appearance of the app to a coherent theme giving the feel of a native application. This was achieved using Bootstrap 4, an open source css toolkit, chosen for its mobile-first styles throughout the components offered.[9] We particularly made use of the button grouping and styling and layout assistance that Bootstrap offers. Figures 5 and 6 show the evolution from the Phase 1 to Phase 2 menu with additional features. The styling makes the menu smaller, thereby ensuring that it does not encroach too heavily on the annotation space. Icons rather than text keeps button size to a minimum. So that it is not intrusive, we opted for a black background to match the black background against which most manuscript pages are photographed and introduced a green and blue colour scheme to pick up colours in the illustrated manuscript page. Finally, we included a pop-up window on opening the app which details instructions for its use. These instructions are kept to a minimum to avoid directing readers too precisely, allowing us to monitor the variety of annotations made by users. 23

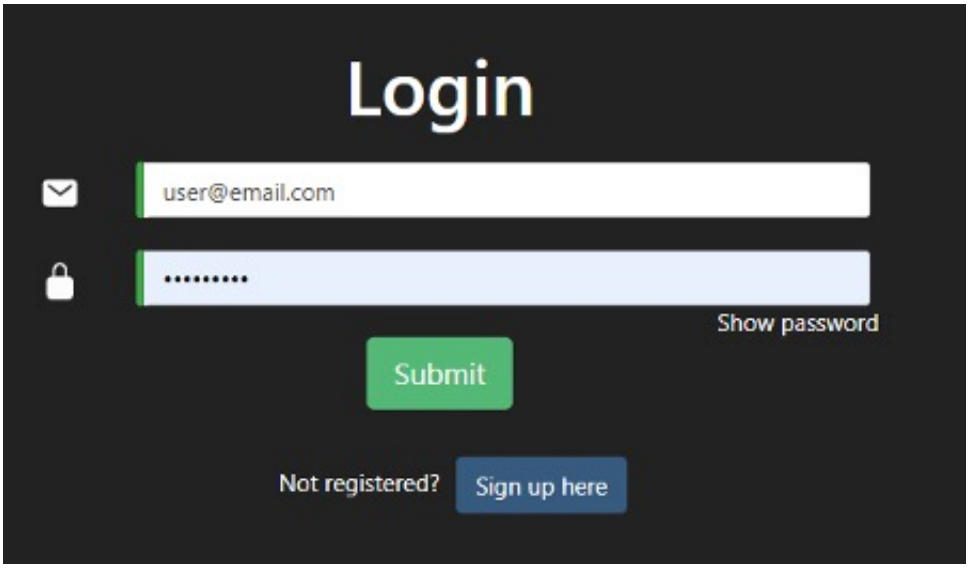

Figure 7. Login page

In order to encourage reading over a longer period of time and to enable us to gather further data on how the app is used, user accounts that allow page saving and resuming were introduced in this phase of redesign. Users are now able to register with their email and set up a password, which is saved in the database in an encrypted form using password hashing provided by bcrypt.[10] Figure 7 shows the login page, including the option to show or hide the password. On logging into the app at a later date, users are presented with their last saved page to resume reading. Fabric.js made saving images in the database straightforward through the functionality to export the canvas as an SVG string suitable to be entered into a text-based database.[11] As users make and save additional changes to a page, that page is updated in the database. To reflect the additional data now being collected by the app, admin features were added, including the ability to view a table of users, the number of pages saved with date stamp, and the number of feedback forms submitted. These data can be downloaded in csv form for ease of analysis and interoperability. Each 24

saved page can also be downloaded and viewed.

Further iterations of the app might include features which address our initial research questions more fully. For instance, a feature that captures the timings of the marks made on the page or video recordings of the page would give us a fuller understanding of the process of reading with a pen in hand. Automatic resizing for different devices would make the app more accessible to mobile phone as well as tablet users. 25

Conclusions and Future Work

While Hands-On Reading demonstrates the importance of looking at the adaptability of old technology such as medieval manuscripts and early printed books in creating tools for digital reading and writing, there are several ways in which the app might be further developed to explore the possibilities of slow reading. Despite recent advances, the gap between current digital technology and its paper counterpart remains sufficiently broad enough to prompt the question of whether digital reading can directly replace the physical book. Readers approach the digital and the physical text with different expectations; their way of processing information in digital and non-digital platforms also differs. Thus, if medieval practices of reading with pen in hand cannot be translated directly from physical paper formats to current digital formats, then a broader question arises: can digital interfaces offer new ways of reading which surpass the possibilities of physical books? 26

Early twenty-first century predictions of the demise of print publishing have proven to be unfounded, with a strong revival in sales of printed books over the last decade. Some categories of books – such as genre fiction and academic publications – have flourished in the new medium, yet many others remain firmly rooted in the print market. That audiences prefer to access different kinds of books in specific formats does not lack historical precedent. Moreover, as the recent decline in e-reader sales indicates, many readers prefer to access digital texts via computers, smartphones and tablets rather than seeking new devices for reading. Though future technological developments may well allow us to shrink the gap between print and digital media, it seems entirely likely that the two modes of textual consumption will continue to coexist, albeit with the emergence of new forms of interaction between them. 27

However, one area where there seems to be considerable potential for permeability between paper and digital technologies is that of writing. The stylus is held and moved in the same way as a normal pen; even in its most basic form it affords a familiar experience, while advanced hardware and software tools are capable of emulating (if not fully replicating) the tactility and precision of writing with a pen on paper. Current touch screen and stylus technologies are not yet sufficiently advanced to teach practical calligraphy at anything more than a basic level, but the growing number of mass-market and specialist software solutions that facilitate “inking” indicates the potential for digital writing to complement and enhance existing digital tools and modes of consumption. 28

With readers increasingly accessing digital texts with a stylus in hand, this is an opportune moment to explore the possibilities offered by slow reading within a digital context. Rather than imitating paper and pens to encourage active reading in digital formats, the gap between paper, pens, and the current affordances of digital technology could itself be leveraged to offer new ways of reading. While physical books are not designed to allow a reader to copy over a text while reading, digital texts can easily be manipulated to explore this functionality, encouraging the interaction of text and pen for example by tracing words. Doing so permits the reader to engage with the text in an entirely new way: reading *by* writing. 29

Slowing the process of reading, and thereby allowing time for evaluative and critical thinking, means that the app could be adapted to a variety of audiences. The development process brought the question of the app’s target audience into sharper focus. The initial concept of the app emerged from a set of broad research questions rather than an attempt to fill a gap in the market, and throughout the design and trial phases we sought to explore potential applications in an open and non-prescriptive way. Feedback from testing workshops confirmed our assumptions about the limited value of Hands-On Reading as a tool for teaching calligraphy, but also raised various possible ways in which it might be adapted for other educational uses. The most promising of these suggestions – and the most consistent with our research goals – is further development of the app as a tool to explore and enhance reading by writing in primary, secondary, and higher education. The growing body of work on the impact of digital reading in this setting [Cull 2011] [Schugar 2011] 30

[Chen et al. 2013] [Kaufman and Flanagan 2016] is only the most recent phase of a longstanding tradition of scholarship on how students can and should read, stretching back to the twelfth-century *Metalogicon* of John of Salisbury. More recent research indicates that the use of handwriting apps with a tablet and stylus not only improves children's ability to write with pen and paper but also aids in their general development, academic success, and emotional wellbeing (these studies are conveniently summarised in Klein et al. (2021)). Existing apps intended for both school and home use – such as Kaligo, iTrace and Handwriting Without Tears – teach letter and number formation through a similar process of tracing and are designed to complement national curricula. But while several DH projects have studied the benefits of annotation on memory and understanding at primary and secondary level [Butler et al. 2019] [Bonneton-Botté et al. 2020] [Araújo et al. 2021] and university-level study [Marshall 1997] [Wolfe 2000] [Hong et al. 2012], only relatively limited attention has been paid to the role that writing plays in facilitating the comprehension and interrogation of the digital text (on this subject see Fitzpatrick (2013)). Hands-On Reading's unique digital medieval format could be leveraged to further aid the process of annotation and so information retention, and offer the opportunity to more deeply examine the concept of slow reading with pen in hand.

Finally, the development of Hands-On Reading has allowed us to reflect on our initial research questions: why does handwriting have an enduring relevance in a digital age, and can a more hands-on approach to reading lead to a deeper engagement with the text? Though it is clear that numerous factors have contributed to handwriting's longevity, development and testing of the app has shed particular light on the role of handwriting in facilitating the critical and inferential evaluation of textual sources, whether in printed or digital form. As the digital revolution continues to profoundly change the way we consume texts – and broader social trends highlight the fundamental importance of interpretative analysis – there is a pressing need to equip contemporary readers with the tools to approach the digital text on a deeper, more reflective level. There is nothing new about the use of handwriting to promote more active forms of reading, but digitally replicating much older forms of reading while writing can allow us to make the most of these technological advances while simultaneously taking a slower approach to reading, with all the critical and evaluative benefits this brings.

Notes

[1] An application running on a server rather than installed on each user's machine.

[2] i.e. apps available through app stores, usually on mobile devices, specific to either Apple iOS or Android.

[3] The "client" is the front-end visual appearance and behaviour of a website, whereas the "server" is the back-end of the application which handles user log in and communication with the database. Generally, the terms "client" and "front-end" are used interchangeably, as are "server" and "back-end." Angular 9 is a web application framework that helps to build the client. Nest.js is a back-end framework that does a similar role for the server.

[4] Typescript is a programming language that builds on the language JavaScript.

[5] Fabric.js is a library of code available for programmers to integrate into their programs that offers drawing functionality. HTML5 is a text formatting mark-up language which dictates the arrangement of content on the webpage

[6] mongoDB is a type of database used to store text-based data.

[7] Some databases store data in tables with pre-determined fields and relationships between fields, e.g. a user will have an email and a related password. In contrast, in a schemaless database fields are not pre-determined and the database does not follow a strict schema, e.g. fields can be changed during development to add a username.

[8] A `<div>` is a block of content within the site.

[9] CSS is a language used to write descriptions for formatting HTML content. Bootstrap 4 is a library of code that can be integrated into a program that provides pre-set styling for common elements such as buttons.

[10] A hashed password is a scrambled version of the original password that can be unscrambled using a secret key known only to the website. This means that if the scrambled version of the password is ever intercepted or accessed in the database by an unauthorized source it cannot

be unscrambled. bcrypt is a library of code that offers this functionality.

[11] An SVG (scalable vector graphic) is an image type where information can be stored as text characters using the XML markup language.

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