Affordances of The Digital Academic Article

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Abstract

Affordances of The Digital Academic Article

Muhammad Shahrom Ali

Academic articles in their digital form are skeuomorphic: a linear translation from paper to screen. This linear translation makes engagement with digital text awkward and also creates a boundary between the form of the article and the form of the digital reader. Attempts to solve this problem retain the PDF form and enhance it by revising either the ISO standard, or readers that can read a certain type of PDF formats with plugins.

Based on the assumption that the existing forms and tools for academic reading and publication are saturated, this research re-imagines and speculates on a *digital-first form of the academic article* that breaks the constraints imposed by PDFs. With a Research through Design (RtD) approach – iterative prototyping and design journaling, this project calls for a paradigm shift: from Article as Files to Article as Software. It re-imagines the form of the digital academic article as a digital-first artifact, and explores the design space of the digital-first academic article (DFA). Instead of setting it up for printing and archival, the goal is to establish a unique identity of the digital research article that affords enhanced reading and learning from academic text.

Prototypes can be found at https://prose.shahrom.dev. It is assumed that this thesis will be read on a computer, so you can explore the live version for yourself.

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Introduction

Digital academic articles are skeuomorphic: a linear translation from paper to screen, with page-based demarcations, fixed layouts, and interactions similar to the print form (Noyes & Garland, 2008; Sanz & Romero, 2007; Somers, 2018; Sopinka et al., 2020). This linear translation makes it harder to engage with research articles on a screen due to a conflict between the way digital media invites interaction, and the way the current digital form demands *paper-like* engagement from a screen. This dissonance creates friction between the user and the technology which often leads to readers printing papers for deep reading. Studies comparing print versus screen reading conclude preference and better efficiency of print reading (Baron, 2015; Clinton, 2019; Mangen et al., 2013; Noyes & Garland, 2008; Two Sides, 2015).

Digital text is software and software affords dynamism: it is capable of adapting to the user. Digital text is superior because it affords high-speed searching, linking, augmentation, and translation. But despite these affordances of software and digital media, digital reading as it stands today with PDFs (or in general, file-based texts) forces users into printing to read, or forcing them to work *around* these constraints and adapt an individual process; the reader has to put in work for the technology when the technology should be working for the reader. In treating digital text as files rather than software we limit the ways we can interact with it. Files are static, they afford data containerization, they afford archival properties. But we don't need our articles to be archived, they need to be read! The academic article is a distance-educational technology, it needs to be learned from!

The digital form needs to rise above these specifications (read: constraints) that were defined for paper (Bentley et al., 1929) and establish a unique identity for digital reading. Resizable windows

remove the need for fixed layouts. Scrolling removes the need for pages. Conditional rendering[1] and hyperlinks remove the need for appendices. And annotations in margins have been made obsolete by theoretically unlimited space to write.

The digital form must establish its identity separately from the print form, and through the lens of technological affordances this research grounds itself in the idea of a *Digital-First Academic Article* (or DFA for short) and its affordances. I ask: What does this academic article look like? In what ways can a reader interact with it and in what ways could it change reading and learning from academic articles? This research calls for a paradigm shift: from Articles as Files to Articles as Software. In treating digital text as software, we bring it to life, we enable it to scale and develop further. This form can now adapt the content of the article to the reader's needs, it can *enhance* the reader's learning.

A digital-first form of the academic article prioritizes digital reading over translation-to-print[2]. A digital-first form is software: scalable and responsive; adaptable to the user's needs and purpose, the content, and the discipline of study. A digital-first form should invite active reading (Tashman & Edwards, 2011a; Victor, 2011a) or *deeper* reading. It should invite thinking. Writing is imperative to learning: we don't write what we have thought, we write to think (Hayot, 2014). An article must therefore encourage writing alongside reading.

Through developing four prototypes (eight variants in total) in a collection called *Prose*, this research explores the design space of the Digital-First Academic Article. It illustrates what a future of digital academic publication could look like. A form that enables the communication of text, graphics, game builds, software, and invites *in vivo* reflection/writing, all in one place. A form that enables deeper engagement, and transforms the article into an "environment to think in"(Victor, 2011a).

Prose is a step towards interactive research communication; towards *enhanced* research communication. As the system evolved, the prototypes went from linear reading (v0)., to a 'conversation' with the article (v2.2).. At that point, is it still an article? Or have we entirely redefined research communication? At that point, does an 'article' even exist? And, if so, how do you define it?

[1] Displaying something ad-hoc

[2] PDFs and other file-based articles are not digital first because they afford digital dissemination and archival, but not engagement or reading

Perhaps then... it's just digital academic *prose*?

Background

In his Atlantic article, Somers (2018) contextualizes the academic article in time: from the 1600s when the research article was invented for the dissemination of incremental research to the public, to today when the article is unable to contain everything that needs to be communicated to the public and is starting to feel inadequate. He explains this is because back then, research results were presented in much more direct and informal ways, with much smaller datasets (they would fit on a single page), and validation of data was straight forward as all that was needed to make sense of the article was contained within the article. All that was needed to validate research *could be* contained within the article.

He further explains that today, research is backed by massive datasets and requires a range of computer programs to generate, process, and visualize data, and run statistical models. People have to "play computer in their head" (Somers, 2018) to make sense of the article and the data it contains. This results in a publication that does not paint the whole picture for the reader, and the reader has to find and use all the extra tools (and in some cases data) needed to learn from the article. The activation energy of performing the task of learning from the paper becomes too high, which may then lead to frustration and disorientation when reading in the digital form. The same issue in paper may not be as pronounced because the reader can note the learning from engaging with all the extra tools on to the print copy which makes it *their copy*, a single source of truth. The medium stays consistent as the reader makes their thoughts tangible (writing by hand on the same sheet) and maintain the context and continuous stream of data from the paper.

Scientific research of today depends on computation, but its current form is still behind and is not capable of positioning the writing within all the other data. The purpose of reading an academic article is to learn from it. But in addition to learning from the article, the reader now also has the

responsibility of figuring out *how to engage* with the digital article, in ways that will preserve the article for them.

A survey by Two Sides (2015) of 1000 people in the US and 500 in the UK shows that regardless of age, people prefer to read on paper; they find it less distracting and believe it is more informative. 81% of people preferred to read on paper and 88% believed they understood and retained information better reading from paper. Overall, consistently across all age groups (18 - over 65), over 75% of people prefer to read on paper for reasons including: print being easier to read, being more secure, better for storing and archiving, and less likely to be lost.

Noyes and Garland (2008) explore equivalence of tasks when reading from print vs computer. They perform a literature review which generally indicates paper is better for reading speeds, accuracy, and comprehension as well as a lighter cognitive load. Even though reading comprehension showed no significant difference between the two mediums, they report a significantly higher cognitive workload (measured using the NASA-Task Load Index) for computer-based reading tasks. They concluded equivalence of tasks between the two is not possible. Their conclusions and direction is based on literature from the 1980s and 90s when computers were not as ubiquitous and they reference cathode-ray tube (CRT) monitors which would have provided a much different reading experience from today. This is further validated later when they acknowledge that a study from 1991 demonstrates reader preference is shifting to computers as screen technology improves.

The idea of equivalence between paper and screen fixates on how one directly interacts with the medium and not the underlying meta-interactions. For instance, it does not take into account the portability or disposability of paper, or the minimal tactile feedback a computer provides. The entire notion of translating a paper to a computer is flawed, and as long as it goes on, it will limit innovation in digital reading and it will continue to feel restrictive. Imagine interacting with a printed paper but the paper is framed, and you read it from behind the glass.

Aharony and Bar-Ilan (2018) explore post-secondary information sciences students' preference between paper and computer. They measure three variables, namely: relative advantage (the influence of the perceived benefit of using paper over screen), learning strategies (individual differences in reader's motivation, objectives, and reading process), and comprehension. They conclude students prefer printed academic material over digital even though they all acknowledge the advantage

of the digital medium, and that relative advantage and comprehension in the digital medium are directly related to choice of medium.

Aharony and Bar-Ilan investigate *what* student preferences are without any inquiry of *why* the students feel that way. That intention/motivation dimension of student preferences is only speculated to students being more used to traditional learning materials, comfort, being less distracted on print, feeling less disoriented, or that the less interested shallow reader prefers reading in digital because they prefer to skim and scan without a thorough understanding of the text. This speculation completely disregards the medium-message dissonance of the digital-paper and is also very didactic: pushing for a set way reading must be done, and the connotation for “shallow" readers is nothing short of disrespectful.

Clinton (2019) performs a meta-analysis to reach the same conclusions that reading from print is preferable with roughly equivalent comprehension results. She concludes that "readers may be more efficient and aware of their performance when reading from paper compared to screen" (Clinton, 2019).

Studies investigating paper versus screen are one-dimensional: they only investigate the ‘what’ but not the ‘why’. To understand this disconnect, studies need to explore *why* students prefer reading on print. What about the form of the printed paper is supportive to better learning, what needs are being met, and if they are disoriented reading from screens, then *why*?

Baron (2015) surveys and discusses in depth how digital reading is better suited for fiction and non-serious works, and academic reading on screen is prone to distraction. What is the difference between fiction reading and academic reading? Fiction is meant to be read linearly and engagement with fiction involves visualizing what you read. The same is not the case for academic text since reading an academic text entails *learning* from it and engaging with academic articles involves writing as you read, highlighting information for future reference, and relating information across articles.

Academic reading is expected to be deep reading, whereas fiction is more likely to be light reading. However, readers sometimes also skim articles and do critical readings of fiction. Would the digital book support a critical, deep reading of the classics? Would it be possible for me to engage with King Lear critically in its PDF form? Well, can I do all that I need to do to the text for

this deep reading without feeling limited? Since the task is similar to what we do with academic papers, I will deduce no I can't. So then is it really the genre of the text that is better suited for each medium or is it the purpose of reading? It would seem that the medium is not incompatible with *genres* – after all, they are both essentially words on screen – but with the *purpose* of reading. The *intention* of the reader is incompatible with the form. The current digital form does not support deep reading of text, it does not support engagement with text.

Another point Baron makes is that reading on the screen is distracting, with notifications and the urges to browse the web. One would imagine the same urges and notifications would be felt with reading fiction on screen. And the same factors would be possible/present if the reader was trying to deep read a text. What is the difference here, then? How does the reader maintain attention in fiction (words on screen) but not on a research article (also words on screen)? I would argue this to be a motivation problem. Readers charge through the distraction because they want to keep doing what they are doing. Then perhaps it is time that academic papers were also written in more approachable and engaging ways? There is some inherent difficulty to a text but if the content is not well presented and is frustrating to read, it is bound to drain the reader's motivation to read.

The APA format was recommended in 1929 (American Psychological Association (APA), 2023; Bentley et al., 1929) and the majority of the recommendations were based on the limitations and cost of printing and editing. Mistakes in print are expensive whereas in the digital form the text can be revised easily. Ebook are software and not really 'books', which allows us to continuously upgrade them with changelogs. Electronic text no longer needs to follow the same processes and limitations. Research articles in digital form don't need the same guidelines from 1929 either.

Over the past three decades, there have been a range of speculations envisioning the future of the academic article (Aalbersberg et al., 2014; Khaled et al., 2024; Newe & Ganslandt, 2013; Sopinka et al., 2020; Tashman & Edwards, 2011b; Thoma et al., 2010; Victor, 2011a) or just digital reading in general; exploring ways in which the academic article can be enhanced by bringing in what we normally do with computers into the construct of the article.

The Article of the Future (AOF) (Aalbersberg et al., 2014) was an initiative by the academic publisher Elsevier that aimed to reimagine the way academic articles communicated research in the digital age by interlinking the text with the data it builds on such as 3D chemical structures

for research in chemistry. The AOF prototypes focused on linking data with papers, integrating data visualization tools like 3D protein structures or MATLAB figures built into the paper, and text mining and automatic links generation.

This initiative was started with the Article 2.0 competition, crowd sourcing designs for a new form of the academic article (Anderson, 2008, 2009). The three prototypes that won the competition, and also the article of the future itself, are nowhere to be found anymore and the whole scene is plagued with deadlinks. This was almost 15 years ago and the article of the future generated around 13 prototypes (Aalbersberg et al., 2012) but none of them seem to have developed into a general form for the academic article.

This is a problem with this approach of designing something high-fidelity at this stage, when we have not synthesized reader needs with medium affordances. If anyone had the resources and network to build a ubiquitous digital-first article it would have been a publisher like Elsevier but that hasn't happened. This is why we need to define and explore the design space of the digital article, first. We need to understand how computers (in their various form factors) can afford active reading.

Victor (2011b) recreated the small-world networks paper by Duncan Watts and Steven Strogatz (Watts & Strogatz, 1998), found on his blog[1]. This is built on his idea of "Explorable Explanations" (Victor, 2011a)[2], a project aimed at helping people see text as "an environment to think in" instead of passive absorption of content. This recreation explains the small-world networks algorithm directly with illustrations in-place instead of a textual description of an algorithm; which, while is more succinct, is much harder to visualize and hence comprehend.

The entire idea of Explorable Explanations is to give the reader the ability to interact with the text in a way that helps them comprehend it better. Paper allows this by giving the reader the space to write and think on it, alongside the text while staying in the same medium. This affordance is not provided on screens and annotation is constrained by PDFs. The reader is unable to explore the topic as they read it.

Bostock (2014) is an article that discusses sampling, shuffling, sorting, and maze traversing algorithms with visual demonstrations of all steps in the article. These are generally algorithms that

[1] Compare this with the original publication here

[2] which builds on Alan Kay's idea of Active Essays (Yamamiya et al., 2009)

a computer programmer visualizes in their head as they write an implementation in a programming language. To think through them however, programmers sometimes write steps on paper to derive general patterns of how different variables are changing. This is colloquially known as performing a 'dry-run' of an algorithm and over time becomes something programmers do entirely mentally. Bostock's article demonstrates the power of visualization by dynamically illustrating the steps of all these algorithms from start to finish and also visually contrasting different variants of the algorithms. It proves by demonstration, the value of visualization and "using vision to think'. More specifically using vision to think through *abstract* topics. These visualizations make it extremely intuitive to understand how said algorithms work, it provides a visual construct that can then mentally transfer to other similar problems.

Affording visual thinking is especially important for computer science, mathematics, physics, and engineering research. These are abstract topics that are inherently difficult to follow. Visualizations of algorithms, physical simulations, finite element analyses, and machine learning models, could significantly improve the way research in abstract disciplines is communicated and learned. Comprehending, visualizing, and learning abstract topics like these, imposes significant cognitive load without visual aids. Bret Victor calls these visualizations, "Media for thinking the unthinkable" (Victor, 2013): visual representations that help us think about problems differently, more deeply and broadly. That allow us to see more and hence do more.

And, so, these speculations force us to think: what if we were to disrupt this space of long form essays that still heavily rely on words alone, redefine the form that visually helps the reader comprehend difficult reading material?

Reflective Surfaces (Khaled et al., 2024) is one such speculation on interactive academic articles. It is a paper about materialization of tacit knowledge and the Method for Design Materialization (MDM) (Khaled & Barr, 2023; Khaled et al., 2018) in game design. As part of the playables track at the Association for Computing Machines (ACM)'s Designing Interactive Systems (DIS) 2024 conference, Reflective Surfaces converts a pictorial paper (Association of Computing Machines (ACM), 2023) into a fully interactive version as found on this web link.

The article features reflections by nine game designers on their design process and every "page" of the article is a specific game designer's desktop screen. Each screen displays the designer's tools,

reflections on their design process, and conversations between members of the research group they are all a part of. Alongside the text and pictures, there is the narrative element of the reader being a “screen invader” (Khaled et al., 2024) invading and reading through each designer’s live desktop, conversing with an entity that is guiding the reader through each page, and finding out at the end that it was design backtalk and tacit knowledge (Schön & Bennett, 1996) materializing.

Reflective Surfaces presents game design research in a playful and playable form; as "form following function" (Sullivan, 1896). It demonstrates an interactive version of a pictorial article, that would otherwise be a static, US letter size, max 12 pages (Khaled et al., 2024) PDF. This interactivity affords the authors to include a lot more material since the reader can now open and close windows on each desktop, which would not have been possible with a static PDF. It invites the reader to directly explore GitHub repositories, blog posts, and Trello boards of the authors which although possible with PDFs, becomes a second order task since PDFs invite a passive absorption of content, rather than active engagement.

For the Article of the Future initiative, the goal was to link external things into the paper, to bring in chemical models into the PDF. Newe and Ganslandt (2013) and Newe (2015) follow a similar path where they introduce 3D models into the PDF form. They explored the ways in which the article can be enhanced and be more than what it is in its print form. But at its core it was still all about PDFs and ‘plugging in’ data and interactions.

Reflective Surfaces is a web application that is supposed to be an article but its interactions are context specific to a *pictorial* article and the narrative of the playful article. What if the digital form of academic article invited interaction from the reader the way Reflective Surfaces does? What if it invited a dialogue with the content and afforded a specialized learning experience leveraging the technological affordances of digital media? These are the questions this project explores.

Methodology

This is an exploratory research project that aims to explore affordances of the digital-first article. The core research question is: What does the digital-first academic article look like? In what ways can a reader interact with it and in what ways could it change reading and learning from academic articles? What kind of behaviours would it invite, and in what ways could it change reading?

Active reading, academic reading, deep reading, and engagement with text, are used interchangeably throughout to refer to the underlying motivation that each of these fulfills. The goal of academic reading is to learn, and to learn from text the reader must engage with it beyond linear reading and passive absorption of the content.

The mechanisms and conditions framework (Davis, 2020) enables us to analyze how an artifact affords: what kinds of interactions it invites, to what degree, for whom, and under what conditions. It foregrounds the bidirectional relationship between the subject and object, and the forces they apply on each other. An artifact may *allow*, *request*, *encourage*, *demand*, *discourage*, or *refuse* some kind of behaviour or action; that is to say an artifact's affordance is on a spectrum and not a binary. These are the *mechanisms* of affordance. An artifact's affordances may be conditional to being perceived, may have a requirement for skill level, or may need legitimation from culture & institutions. These are the *conditions* of an affordance.

PDFs for example *enable* digital dissemination like mail and allow annotations and highlighting. They *refuse* mutability of structure or content and encourage linear navigation, demand fixed layouts, and refuse dynamic content. In print-form however, Paper allows free-form illustrations/annotations, and also non-linear (spatial) navigation but only if the pages are not bound. A book, for example, refuses spatial navigation since the pages are fixed together. And if it is from a library, it also discourages writing on the book.

Current trends in designing reading interfaces tend to reaffirm the features of the academic article in print form (Aalbersberg et al., 2014; Tashman & Edwards, 2011b), trying to bridge a *paper-screen gap* (Tashman & Edwards, 2011a). This research aims to re-evaluate the assumption that putting text on a screen is sufficient to invite active reading, and highlighting and annotating in margins are sufficient interactions.

I first introduce a preliminary theoretical understanding for the DFA (as seen in Chapter 4), developed through the lens of technological affordances and the mechanisms & conditions framework (Davis, 2020). In this process, I develop an understanding of what is it that people do during active reading, what are their objectives? How were these goals fulfilled in print-form? What changes when we switch mediums from physical to digital and how can this shift be made-up for, in the digital space? Readers annotate, highlight, and underline but it is important to understand *why* they do that. These interactions are a means to an end, what is the end?

With an understanding of the end goal, I analyze a) how the print form supports reader's goals and how the PDF form is unable to fulfill them, and b) speculate on how these needs and goals can be fulfilled better through a digital-first form.

Research through Design (RtD) is a research approach that utilizes design practices from a particular subfield of design to investigate a research question (Zimmerman et al., 2010). It is a method of scientific inquiry grounded in the creative practices of a particular design subfield (Godin & Zahedi, 2014). Iteration is a tool for thinking by making: it helps us articulate the purpose of the creation and how it affects users (Sharp & Macklin, 2019). Prototypes are a means to organically discover, generate, and refine designs. Prototypes are design thinking enablers and help traverse a design space (Lim et al., 2008). Through iteration and prototyping, designers refine, re-frame, and discover the possibilities in a design space.

I take a research through design approach to speculate on the affordances of a DFA. Speculative and Critical Design (SCD) (Helgason et al., 2020), RtD, and iteration and prototyping are problem-setting methods that help explore a design space to define a problem (rather than solving a problem).

Considering the ubiquity of the web, I developed four prototypes as web applications (as seen in Chapter 5), with sub-variations in each, summing up to a total of eight variants. They grew out iteratively, and over the course of the development fed input into each other, but all of them focus on

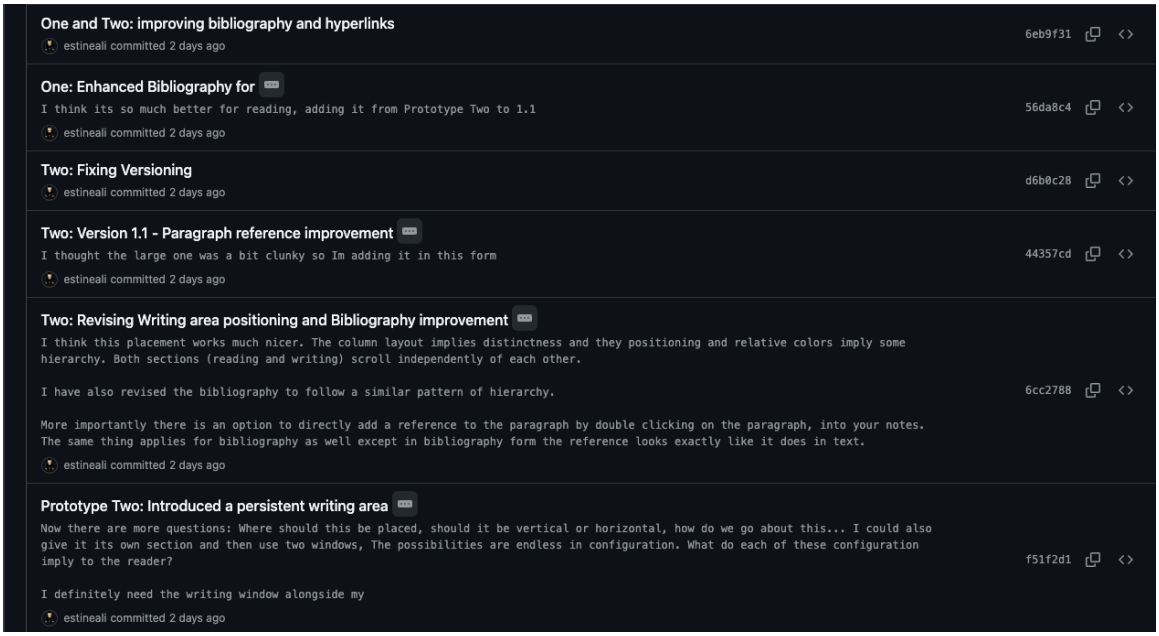

Figure 3.1: GitHub commits in Prose's repository

their own unique directions. By iteratively developing prototypes with core elements of academic reading, I explore in what ways can these artifacts manifest to afford for these purposes. These are the article's fluidity[1], reading with meta-interactions and meta-cues, writing for active reading, and embedding dynamic media in their separate directions.

Following the economical principle of prototyping [2](Lim et al., 2008), the design process did not aim to replicate the myriad ways one can engage with digital text already, but rather focused on designing specific forms of the feature set that could invoke reflection about the future of the DFA. The design process of the prototypes is discussed in depth in chapter 5.

I am also using GitHub for source code management. GitHub is a web platform that builds on top of Git: a version control system by Linus Torvalds and Junio C Hamano (2005) that enables users to track changes to files in a repository (folder) into 'commits, and only tracks things in one direction Adding code and files is adding as one commit and removing something or 'un-doing' is then a new commit. Git and GitHub afford tracking the evolution of a repository/folder (usually software source code, but can be any collection of text-based files) over time i.e. version control.

[1]This is explained further in chapters 4 & 5

[2]*"The best prototype is one that, in the simplest and the most efficient way, makes the possibilities and limitations of a design idea visible and measurable."*

The method for design materialization (MDM) is a methodical approach for capturing game design that makes use of Git's commit system to leave traces of the design decisions and thinking taking place during the game development phases. While this method was developed for video game design, it can be used for any kind of development done using the Git version control system, and so works for this project. Throughout the development, I documented the design process, rationale and speculations, through MDM (Khaled et al., 2018). It also comes to me naturally as I leave archival notes about my thinking in my commit messages[3]. An example is in figure 3.1.

Usually, reflection on designed artifacts happens in retrospect at the conclusion of the design/development phase. MDM allows for a) reflection at the time of development, b) reflection on individual design choices, serialized as Git commits, and c) reflection on the prototype & the prototyping process as a whole in a process journal, supported by individual reflections from point a. This allows for the capturing of the design process employed by the researcher. I think MDM's strongest point is capturing the reflections that happen at the time of development. This leaves permanent marks that not only can act as proof of the rationale and thinking behind the design, but also where things went wrong or what is missing. And since this process journal is also stored within the git repository, changes to the process journal will also be tracked by git.

I used (Khaled et al., 2018) as the article for these prototypes because game design research communication is a good candidate for this speculation (especially in the case of embedding media into the paper – see prototype three) for two reasons. First, it is a converging point for many disciplines in engineering, science, arts, and business, so arguments illustrated with game design research can then apply to other contexts as well. And second, specifically in the case of digital games, having the ability to see a game's design materialize over its lifetime is extremely valuable for learning from the design process – for the outsider and the designer/developer both. And part of watching this design materialize with MDM is the ability to explore game builds, or slices from game builds; if for instance, instead of screenshots there were live game/software builds embedded in the article with a corresponding git-commit history and design journal entries, it would completely change how the reader explores.

This is a research creation project and it is subjective to my world views: it will build on my

[3]Commit messages are messages that can be added to a commit and operate as metadata of the commit

understanding of digital reading and how I think it could, and should be, better. It is based on, and biased by, my experiences as a graduate student, a reader, a software developer and interaction designer, a user of technology, a minimalist; and generally an optimization and technology enthusiast. I believe technology should improve productivity, and should serve and adapt to users, not the other way around. The fact that I find myself adapting my physical and cognitive processes to the rigidity of PDFs, that I have to juggle multiple tools (Zotero, Google Docs, Obsidian, GitHub, Lucid Chart, and now Overleaf to name a few) for my academic reading process makes me question the ergonomics and efficiency of this system. And because I *can* (and want to) build software I feel more strongly about something that could make me more productive by eliminating this clutter.

The probability of being the only human with this perspective is near zero. So when I use generalizations such as reader-needs, and what is it that readers do when reading academically, I am reflecting on my own experience then removing myself and trying to generalize the underlying needs to a sample size greater than one. I think of ways for this to be something useful for more people (but still not all people). This is how I think and design.

People have their individual reading needs and reading methods which they fulfill in different ways. People do adapt to PDFs and it is possible to read perfectly well. The design and development in this project is how I wish computation was enhancing reading for me and people who may also see this problem similarly. Prose is by no means an ideal way for *all* humans to read academic text nor is it intended to be; as I expressed in chapter 2, that is premature optimization, we need to understand the design space better, and these prototypes are intended to do only that[4]. One size won't fit all, nor is it expected to, but the goal is to start thinking about the possibilities. Prose is one possible direction for academic reading so future works can explore others, and over time we will be able to build something more universal, something that is reconfigurable and allows multiple forms that could work for different people.

[4]Every single HTML based reader I have come across – ACM's, Sage, and SciA11y – have all implemented something like Prototype Zero and stopped there. I don't believe this is enough, there is more that can be done and must be explored.

The Digital-First Academic Article

What is a digital-first article (DFA)? What does 'digital-first' mean? And how is digital research communication not digital-first right now? Currently, when the term digital-first is used, it is used to imply the shift *away* from the analogue. It refers to something that is going to primarily be *disseminated* through digital channels. When book publishers announce a shift to being a digital-first company, this implies a shift *away* from paper; so its digital-first dissemination. The rationale for this transition is usually economic, environmental, and/or the ubiquity of digital devices. This results in the translation of text into strongly-coupled containers (PDF, mobi, epub, azw3, etc.) that are digital only in the sense that they are being accessed through a computer. The usage of digital-first is in reference to dissemination, but not consumption.

I would like to take this opportunity to try and prescribe a definition to digital-first's *consumption* dimension. A digital-first artifact should be something that enhances itself with computation, leveraging the affordances of digital media to be an enhanced version of its analogue self. I say enhanced because even though computers take away some affordances (flexibility and negotiation, tactile feedback, laws of physics – more on this one later, etc.), they add some which drastically improve productivity (speed, searching, simulation, etc.) and so *generally*, a digital version should be an enhanced, faster and dynamic version.

A prime example is the translation of a board game to a digital game. In the physical form, someone distributes the cards or pieces, sets the board, keeps track of events and score, if there is a dice, rolling it requires physically shaking and throwing it, etc. When this game moves to the computer, dice rolls are random number generations sometimes paired with animations, setting the board is algorithmic and automatic, event tracking happens in the background as conditions are met, etc. The game *may* require someone to do the things that were part of the board game like gestures

to shake the dice or tracking events – that can just be part of the game design, an intentional choice of the designer – but it is not *needed* and is not a standard part of the Digital Game. Physical and human elements afford negotiation and flexibility whereas computation is rigid and strongly defined. It affords determinism and precision, and can take off some menial tasks, should you want it to. Computers afford *systems* that can implement and enforce rules for predetermined, expected and intended behaviours. And the way the user is allowed to interact with these systems – controls and feedback – shapes the digital experience.

A DFA would then be a form of the article that uses the affordances of modern computers: automation, systems, user interfaces, and networking, to allow and enable the fulfillment of academic reading objectives in different and more ways than possible in the analogue form – in more productive ways than in the print form. Academic articles differ from games in their function but this digital translation in both cases leverages the technological affordances of computers to enhance themselves, to better fulfill their function.

Reading and Learning

What *are* the objectives of academic reading? What do readers do when reading an academic article? And in what ways are these objectives fulfilled with current forms? In general, people read to research, learn, critically review, to write documents, to summarize, solve problems, revise, for leisure, etc. (O'Hara, 1996). In the academic context, research, learning, critical reviewing, writing, and summarizing objectives would be of interest.

When we are reading casually, the text is the centre of attention. Reading the text is an end in itself. But when we are reading to learn, the end is the learning and the text is a means to that end. To learn we process what we have read, we reflect on the text, we put texts in conversation, and we "think tangibly": by writing, drawing mind maps/concept maps, or speaking out loud. We make our thoughts tangible to further develop them.

The purpose of the academic article is to educate. It encapsulates the writer's intention to teach, and the reader's intention to learn. Reading an article involves following the author's thought patterns, rethinking them, and connecting them with existing knowledge. In addition to reading the

text, the reader must also *write* as they think; writing is thought manifest, we write to think (Hayot, 2014). Learning from an article then *depends* on writing. We see this on paper in annotations but the general implication is that an article, in addition to being read also needs space to write.

An article to read should also be an article to write. In print form that is a consequence of what we can do to a paper with a pen, and we seem to have adapted the margins for writing. When those are not sufficient or appropriate, adding post-it notes in print form is a way to allow more space by appending space in the Z axis (like apartment buildings) for writing on the article; because paper is constrained by physical dimensions.

The same interactions translated to the digital space is a limiting element now; space is simulated in the digital world – it can scale easily and it is possible to pan the view-port. Highlighting is to guide the eyes to focus on what is important. Color coding was something people did ad-hoc; it was a way to group/cluster information. These are engagements possible with PDFs. We have translated these actions from physical to digital spaces, but not their underlying intentions.

Learning from articles demands active reading, active reading requires playing with the ideas presented in the article, and active reading is non-linear (Tashman & Edwards, 2011a). We see this function in print form through spatially shifting the paper, isolating pages of importance, removing sections that are not relevant, or skipping to other sections directly without spending attention.

Readers form mental models as they read (Glenberg et al., 1987) and I think the structure of the text is an initial point for the structure of a reader's mental models. These meta-interactions and meta-cues shape one's reading and learning experience. The article, in any medium and form must afford *active* reading.

I define any action that is not directly reading or writing in this process to be a meta interaction: actions that structure and shape the reading and writing. Metadata cues, or meta-cues for short, are the messages that the article sends the user that cue the user's perception and behaviour. An example in print form would be the thickness of the stack of papers left, which informs me of my place in the whole article.

Currently, the article imposes itself as the centre of the reading process. Its rigidity refuses manipulation and customization, it discourages working *with* the text. For academic articles, the focus should be the reader: the reader's process, reflections, ability to learn, and their learning from

the article. Reading and writing are key parts of learning independently, and for an article to afford learning it has to afford both together.

Print and Digital form

In print form readers can restructure the article, annotate, highlight, make the article their unique copy, and archive. Without losing their mental frame of reference, a reader can freely move around the article, they can shuffle the pages and change the sequence, or link different pages together, connect pages from different articles, cut and link different sections together, or only retain pages relevant to them.

The print form is dictated by material constraints and use cases of paper, and the politics surrounding it. I feel more in control over the paper in physical form because I am able to exercise my agency over all the affordances that paper has to offer as a medium. I am able to do everything to the article that I want to do to the article to engage with it fully.

Paper-like interactions with digital academic text are clunky and inadequate. They are frustrating and cognitively demanding because now it is a form familiar to the function of paper but no longer affords the same way as paper nor entirely like a computer. I can no longer exercise my agency over either the affordances of paper nor those of the computer. I can no longer do to the research paper everything I *want* to do to the research paper. Since interactive technologies are already a significant part of our everyday lives, there are expectations attached to how digital artifacts ought to behave, expectations that have developed over years of converging on UI and UX standards. And when they don't, it creates friction between the user and the artifact; a *medium-message dissonance*. This dissonance leads to frustration and results in the initial uphill struggle of having to relearn how to read within the material constraints of a *digital page*, or the path of least resistance: printing it.

Physical space is governed by laws of physics and we can directly impact it because we inhabit it, our bodies afford applying forces. The digital space is governed by encoding: representation as numbers is the only law here. The digital world affords through input devices. Input devices translate continuous, physical input to discrete, digital input; there is a translation layer with computers whereas the real world is direct.

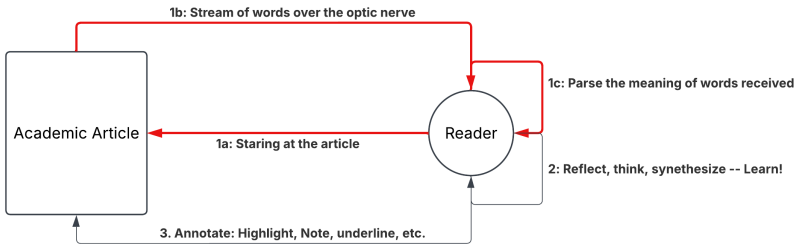

Figure 4.1: Current Article-Centric Reading Process

Anything that is needed in the digital world must be built (encoded) from scratch: numerical representation for the circuits, graphical representation for the screens, and encoded behaviours for interactions with input devices. All interactions need to be implemented, unlike the real world where they are a consequence of laws of physics, and our motor and cognitive skills.

The problem with skeuomorphic design is that when it looks similar to its physical form, the meta-cues invite similar interactions and affordances[1]. It is not possible for it to afford the same way because it is a representation, an emulation. The closer it gets to looking and feeling like the real thing, the more it invites interaction like the real thing when it might be incapable of fulfilling those. So I think skeuomorphism can only be a stepping stone towards a digital-first future. There is value to digital reading: cost, paper waste, does not occupy space, and we see people transition from print to digital. But now studies on equivalence of the two media and comparative efficiency (Baron, 2015; Clinton, 2019; Noyes & Garland, 2008) show us that despite the rational advantage, the perceived advantage is not strong enough for it to be the obvious choice. It *should be* enhanced reading but it is almost worse reading.

The digital reading process (as illustrated with figure 4.1) puts the article at the centre, and everything is *in addition* to the article. Highlighting and underlining allows tracking what information is important in a sea of words. Different coloured highlights categorize the information into arbitrary categories. For instance, when I'm reading, I highlight interesting or useful information in yellow, things I disagree with in red, and things I agree with in green. If the section headings and structure are missing, I highlight those in grey so then I can filter highlights in Zotero and traverse

[1] If it ~~walks like a duck, swims like a duck, and quacks like a duck~~ cues like a duck, then it probably is a duck.

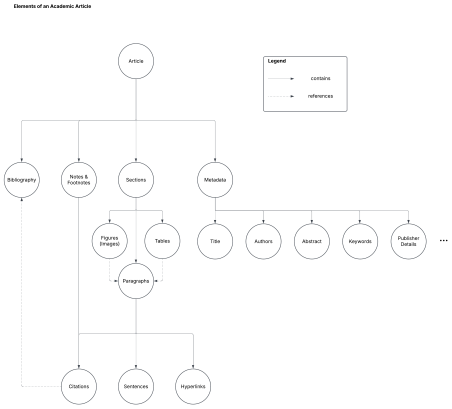

Figure 4.2: General structure of an Article

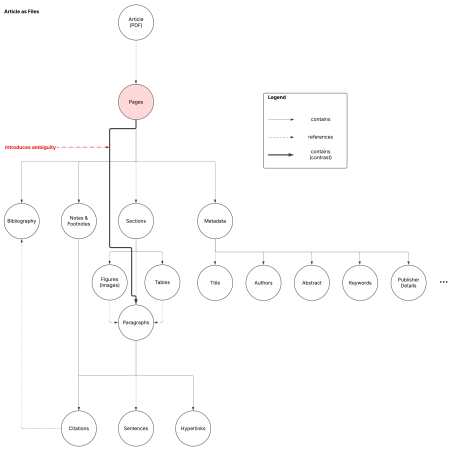

Figure 4.3: Structure of an article including pages

along the structure of the essay. Adding notes to highlights or on random sections also invites an archive of 'micro-thoughts' that cannot be developed further in conversation in the same medium.

This creates a process where the focus shifts from the reader's learning to the article, and sidelines everything else. It allows reading but does not enable engagement. This is especially inappropriate considering the fact that when I am reading something, my reflections should be the most important thing; these are what I am going to develop further later on. I may be writing to remember, so a thought does not slip my mind, but also to make it tangible so I can develop it further. Note-taking in PDFs discourages developing these thoughts, it limits us to snippets of thoughts as anchors for reference later, and essentially archives my reflections inside itself.

There is an intrinsic structure to an academic article based on its elements such as sections and paragraphs (figure 4.2). The presence of pages as a construct in digital text, introduces page numbers: a variable that is related to the print form of the article. A page becomes a container of other elements of the essay (figure 4.3). I think having two independent variables of navigation – page number and elements of the article – can make it less efficient to navigate the digital article. In the print form we have to rely on page, but in the digital form we can have direct access if we traverse along the structure of the article.

In the digital world, I think text should be raw data, it should be *fluid* and take up the form of its container. PDF's main virtue is their rigidity which serves archival purposes excellently (especially with the PDF/A standard), but for academic reading this is constraining because it does not support

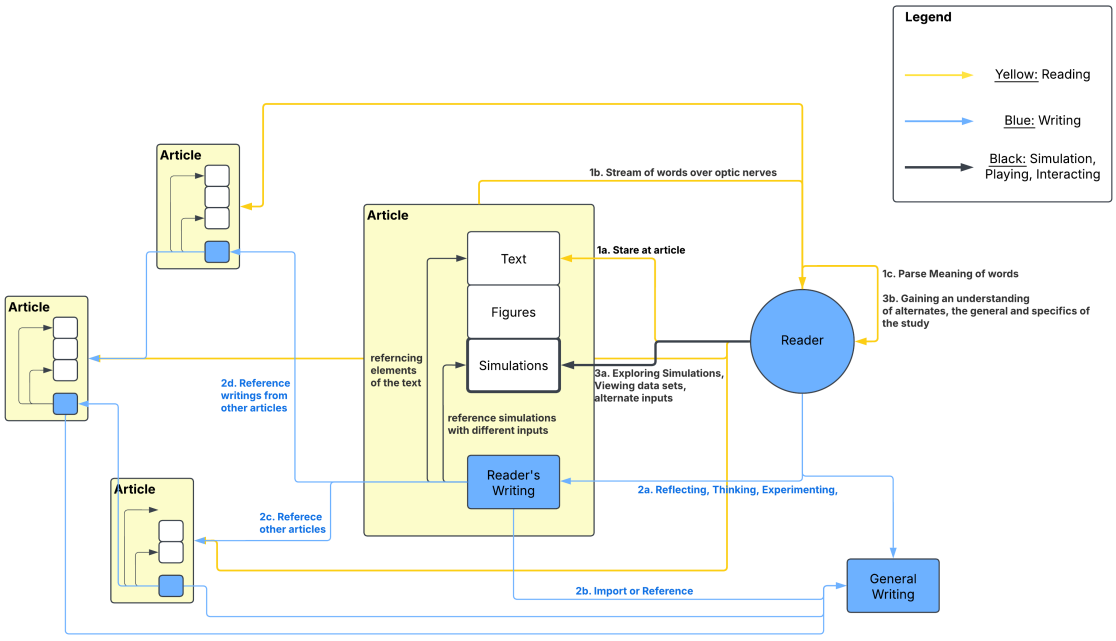

Figure 4.4: A Digital-First Reading Space

the main function of reading academic text: engagement.

The form of the article needs to support learning. The goal is for me, the reader, to develop an understanding of the material. If reading the article was the end in itself then the end would be achieved once the article was read end-to-end. But that is not the case. The reflection continues, the conversation of materials learned from one article with previous knowledge and with future articles continues. Learning from an article transcends the article, so I don't think the article can be the centre of the process.

A DFA should put the learner at the centre of reading. One such model is demonstrated in figure 4.4. Interactivity is an extension of the reading process (Vandendorpe, 2009). Interactivity between reader and article, between article and article, and ideally eventually: between readers. Interaction between all these elements of digital reading form an ecosystem that affords learning and treats reading as only one part of a bigger process. This process already exists but it is in the background. The DFA should foreground this process of learning that involves reading, writing, and thinking.

The DFA should not be bound by fixed layouts: a computer is able to dynamically change into different forms without occupying more space. The screen is a view port into a quasi-infinite

dimension that allows spatial freedom with panning, resizing, and zooming. Digital reading does not need to conform to page dimensions, fixed margins, black-on-white text colours, two column layouts, and references at the end, when these no longer need to be static properties of an article. Annotation in margins and highlighting: are these an end in themselves or a means to an end? The objective is to write and be able to think. We need to fulfill this objective differently in the digital form.

The screen feels like a barrier because the current digital form implies paper-like interactions but does not allow them. Which could be why when we read a paper on a tablet with a stylus it feel a lot more natural; it feels closer to our expectations of the medium although with its own problems. Thus far the objective of digital reading research has been to close the gap between paper and screen (PDF Association, 2020; Tashman & Edwards, 2011a, 2011b). PDFs as a form(at) are saturated, they have been developed carrying the print metaphor onto the screen but there are things that we *can't* do in print form but can in digital. Paper and screen exhibit very different materialities. A different approach is needed to redesign digital reading, to re-imagine the digital form of academic articles.

Article as Software

Much like a fluid takes the shape of the container, an article should also spread to fill the container. In print form this is part of the creation process and there is no distinction between the form of the article and the print form. Digital space is defined by the size of the screen so the article must fill this space; for example web pages morph according to the form of our digital device. We should see the article as fluid, filling a container.

I identify two problems that we need to solve. First, we need better, intuitive interfaces for digital reading, one that guides the eye, attention, mental models, and orients the reader. And, two, we need a scalable medium that is able to grow as possibilities of research and hence needs of research communication, grow. If we define an article as a file we define too strictly; if we define an article as a web app we define nothing [2]. The research of today uses more than images and text.

[2]Homage to Johan Huizinga and a reference to my blind obsession with the idea of play being free-will that has pissed off my friend Richy Srirachanikorn to no end. This footnote is entirely useless but its in the foot its ok please ignore.

It relies heavily on software for data processing, generation, collection, etc. (Somers, 2018), and for anyone to learn from an article, they should be able to interact and engage with the data and resources that it was built on top of. To do this, it must become more than a file *inside* software, it must become software itself.

This conversion can be lossy and won't translate from screen to paper as naturally. But this lossy conversion is the cost of having digital-first reading. For instance, printing digital comics or games does not make sense; it spoils the form while physical comics and board games exist separately. Translation layers are possible that can dynamically typeset an article for printing and the print form will stay, but this will establish a distinct identity for the DFA.

For an article to be fluid, the formatting should belong to the container it fills so it can be customized by the reader as needed. If we were to separate out the elements of an article from its format and layout, we get figure 4.2 as the underlying structure of an academic article. In The Elements of Style, Strunk and White (2009) recommend the paragraph should be a unit of composition: it represents the development of one idea. Words are not unique so the building block of the digital article has to be at-least a sentence. In a digital-first ecosystem, both of these constructs – the paragraph and the sentence – should be reference-able.

There is already plenty of research and creation about using computers for interactive reading or enhanced reading (Aalbersberg et al., 2014; Bostock, 2014; Kay, n.d.; Tashman & Edwards, 2011b; Victor, 2011b, 2013) and we recognize the potential of visual and interactive presentations especially for scientific research communication(Somers, 2018). But there has been no investigation into the *form* of the academic article, the *container* that this knowledge is disseminated and consumed in. There is no discussion on using affordances of modern computation (Connectivity, Responsiveness, Scalability, Dynamicism, and more). Studies that compare the digital and print reading experience (Baron, 2015; Clinton, 2019; Mangen et al., 2013; Noyes & Garland, 2008; Two Sides, 2015) present a one-dimensional investigation of whether people prefer reading in this or how efficient they are. But they don't investigate *how* the digital form is limiting, or investigate the form at all.

Research through design is concerned with creating the ideal (Godin & Zahedi, 2014) and ideal forms are shaped by intention and desire. Form may follow function (Sullivan, 1896) but function

follows intention. Form *must* therefore follow intention. What is it that we want to do? Want to be *able* to do? We must dig down to reader motivations: what is it that a reader would want and need to (be able to) do when reading digitally? I think the problem is in the form of research communication and we need to explore different forms.

PDFs are the primary form of research communication. Limitations of this container transitively limit research communication. The digital academic article should not just be paper on screen, it is software. And translating the structural metaphor of the printed paper limits what we can do with it. For an ecosystem of reading like that depicted in figure 4.4 to exist, an article needs to be more than a file. In the digital space, files invite archiving and PDF files impose a structure that may not be best suited for the reader.

The article already exists in an ecosystem comprising all the other works it cites and builds on, but it is dormant. the reference and inspection of these sources gets postponed but computers afford immediacy of information so sections and their summaries can be readily available. The DFA should be able to foreground these elements of this ecosystem that is already present in academic writing.

Digital text as software could do all that we do on paper and *more*. For instance, viewing a dataset or running a code snippet is not something you can do on paper and PDFs do not afford that dynamism either. PDF may evolve over the next years and I'm sure there are more functions that newer versions are capable of and there will be more in the future, but the notion of "digital documents" limits us. It is only once we treat the article as software can we freely extend it, make it truly interactive. The long-form will stay, that is the form of the communication of complex thought. But exploring how it is displayed and what others it is paired with, can enhance the educational value of the article.

Computers can assist readers with their speed, immediacy, and dynamism in reading and learning from articles. The way we engage with digital media, with software, is different than how we interact with physical media. Computation affords customization and also accessibility; Accessibility *is* enhanced reading and digital reading can dynamically afford mechanisms of reading for people constrained by different conditions.

There are four dimensions that I will start with. First, removing the fixed print layout offers a

continuous stream of text with elements of the article as the structure. This takes away the mental model of pages and emphasizes the structural value of sections more. This is valuable because it will allow the reader to traverse the article along its semantic structure. Creating this form is necessary to contrast with the rest of the prototypes and variants. Second, I explore meta-interactions and meta-cues for digital reading. I try to implement ways a reader can control their reading experience and the feedback the article gives to situate and guide the reader along. Third, I explore writing and reflecting alongside reading, and the way the system can be more inviting of reflection alongside writing. And finally, I explore dynamic media embedded within the article – in this case a video game – instead of being available elsewhere, and how that can change the reading experience or even the writing.

Prose: Speculating on A Digital-First Form

Prose is a container of four prototypes (a total of eight variants including sub-versions) that explores evolving forms of the digital article. I built this system with a vision for an article that is not so rigid in its structure like PDFs, one that is dynamic and responsive to the reader, one that invites the reader to write and reflect alongside reading, and one that is able to scale by including other interactive media.

I wanted to see each of these aspects be introduced gradually to simulate a kind of evolution; almost like Pokemon evolving, the article is evolving and at every stage introduces a different aspect of a DFA. To illustrate this chain of evolution, I named them as Zero, One, Two, and Three similar to Pokemon having basic, stage one, stage two, and mega evolutions.

So prototype zero represents the idea of the article being fluid, one represents the idea of meta-cues and meta-interactions that guide the reader and give them more control. Two introduces writing and reflecting alongside a meta-cue enabled reading in a fluid form, and three introduces having interactive media embedded in a reflection enabled paper.

These prototypes then also have further variations inside them, specific to that particular dimension. For instance, there are more than one ways in which a writing interface can be built around an article, so version 2.0 and 2.2 of prototype two depict two different types of writing interfaces. I wanted to be able to contrast between these different variants and use this contrast to reflect on which configurations could work well.

The goal with these prototypes is to explore the design space of the digital-first article (DFA). The exercise is not meant to demonstrate a final or ideal digital form but to imagine what the DFA *could* look like, by contrasting and reflecting on these different prototypes, and how the DFA could afford. Any degree of fidelity is only to help us visualize and imagine the ideal form better. Prose is

not a tool, but a collection of *stepping stones* to approach a DFA.

Prototype Zero: Article as Fluid

Try Prototype Zero

In PDF form, the article's structure is imposed on top of the article's content. As a result, not only is the article not customizable, window placement, window sizes, screen size, zoom levels, and other visual elements also need to be aligned with the imposed form in the PDF.

As also discussed in the previous chapter (figure 4.2), what is important for the article is its content and the primary structure should be the structure of that content; pages are a material condition of print. In print form the content is tightly coupled with the material. This is no longer needed: the article should fill in the window/screen/device in whatever way the reader needs it to; or generalized, it needs to fill its container like a *fluid* does.

V0.0

Version 0.0 strips the structure imposed by PDF and extracts it into a JSON file structure. Prototype Zero is meant to be a direct translation of the article from a PDF reader into a web app. In this form, the article is a single, continuously scrollable page. The width of the article spreads from end to end of the browser window. The section headings are in bold and centre aligned. Now instead of page-based and section-based demarcation, there is only section-based demarcation. Moreover, the section heading is also a meaningful element in the structure of the paper, and operates as an anchor for situating oneself in the article. The shades of grey, font weights, and sizes apply an information hierarchy and support scanning reading as well as guide the reader's attention to find what they want.

The continuous vertical scroll implies continuity, inviting a linear, continuous reading process and now freely subject to the interactions built into the operating system. The reader can now be focused on the article itself; it blends into the medium unlike in PDF form when it retains its form distinctly from the PDF-reader that displays it. This form has now already enhanced itself with affordances of digital media (i.e. no page length limits, no predefined layouts, etc.). It is scalable.

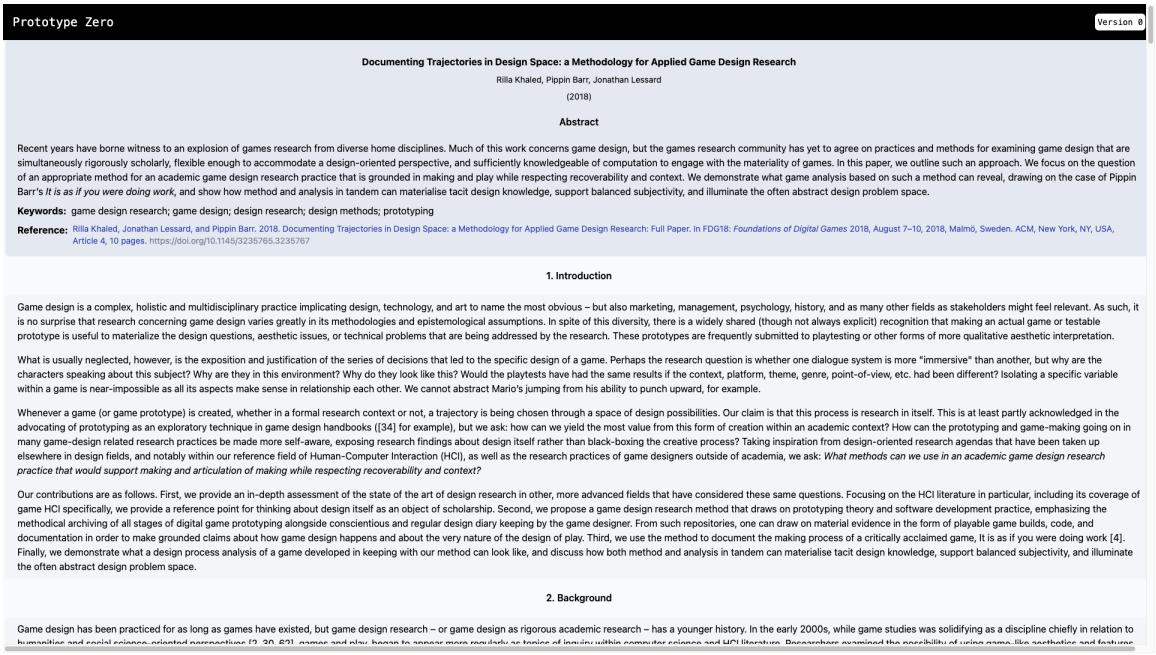

Figure 5.1: V0.0 - Article as Fluid

It is accessible from any digital platform: desktop, tablet, or mobile. And so the fact that an article is now a web application already makes it quasi-digital-first [1]: it can do anything a web application can, it can go anywhere from here.

A larger screen by default now allows continuous, *spatial* navigation across the article. This can be seen as part of figure 5.2: the article is spatially distributed and all parts can be dealt with independently while still belonging to a whole. It is resizable, reconfigurable, and allows linear and spatial navigation, simultaneously[2].

V0.0 is meant to demonstrate what the article as fluid means. Now that the web app affords fluidity and the article takes the shape of its container, we can start developing the container, visualizing what more could be done to this; what more *should* be done to this.

V0.1

After having built all the versions, I couldn't help but appreciate the raw form of prototype zero; it had a charm to its simplicity, especially as seen in figure 5.2. However the control, foregrounding,

[1] I say quasi because there is more to this, I can see it. There *has* to be MORE.
[2] A video of this demo can be found here

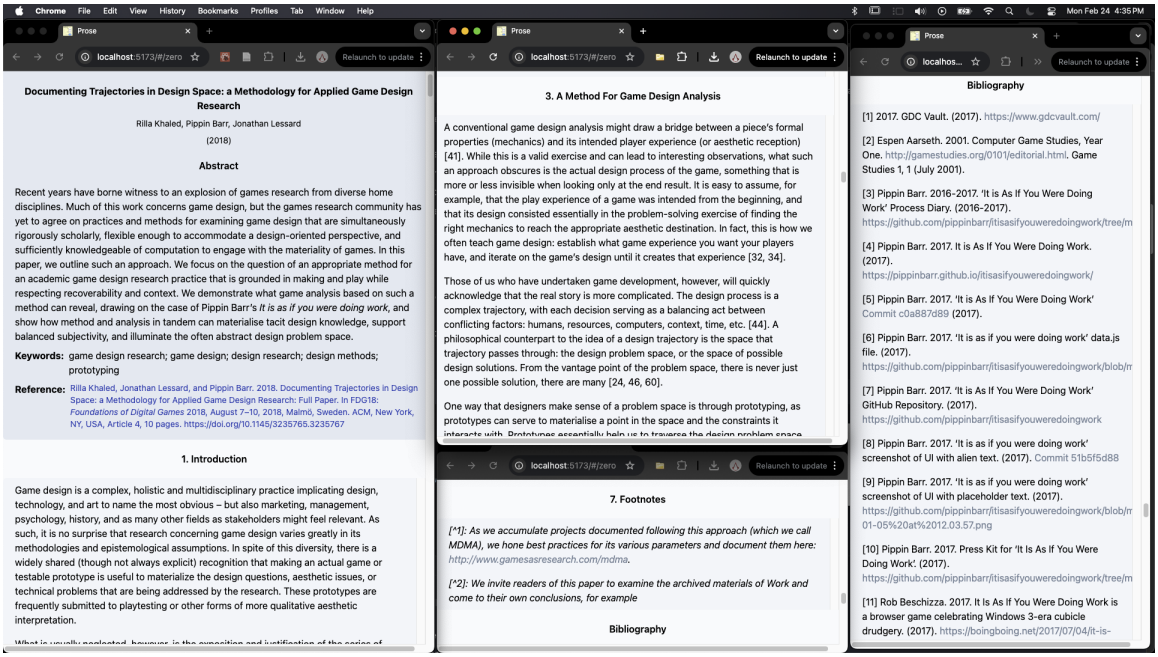

Figure 5.2: V0.0 - Multi-window setup.

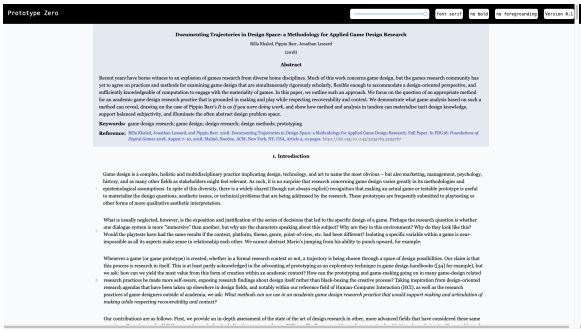

Figure 5.3: V0.1 - Margins

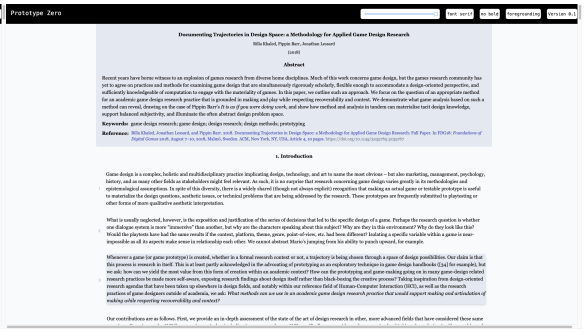

Figure 5.4: V0.1 - Hover as foregrounding

and focus the others were allowed was a significant UI difference that could enhance this version too. This is when the insight from those versions fed back into this one, and I built v0.1. Click on the top right 'version 0' button.

Prototype 0.1 retains its static, continuous form while adding the control and foregrounding as seen in other versions.

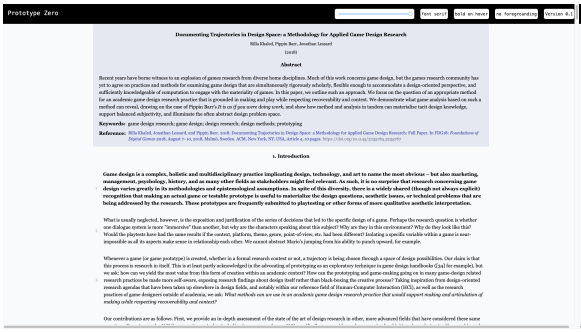

Figure 5.5: V0.1 - Bold as foregrounding

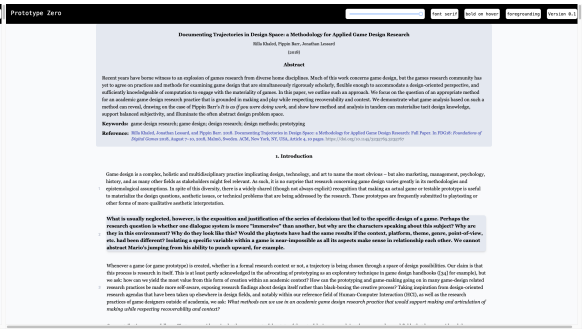

Figure 5.6: V0.1 - Bold Hover foregrounding

Prototype One: Meta-cues and Meta-Interactions

Try Prototype One

One main complaint about digital reading is of disorientation (Baron, 2015; Clinton, 2019) and additional cognitive load (Noyes & Garland, 2008). The form needs to provide the needed metadata cues (Tashman & Edwards, 2011b), or *meta-cues* for short, the way print reading does to help the reader orient themselves in the whole, and be able to refer back. Prototype One enhances Prototype Zero with 'meta-cues' to improve the reading experience.

The main interactions for reading any article are reading and writing, both of which directly assist thinking, and hence learning. Any other interaction that assists these process is a meta-interaction. Meta-interactions include scrolling, conditionally viewing, spatially navigation, linear navigation, horizontal switching, etc. And any 'message' that the DFA sends to the reader is a metacue.

Meta-cues are elements of the form that help position the reader, and guide their attention. If we contrast between print and screen, the print form gives us a range of meta-cues such as how much reading is left by thickness of pages remaining, the discrete nature of the page isolating our attention and focus on the material on one page at a time, and the ability to shift back and forth in the paper non-linearly.

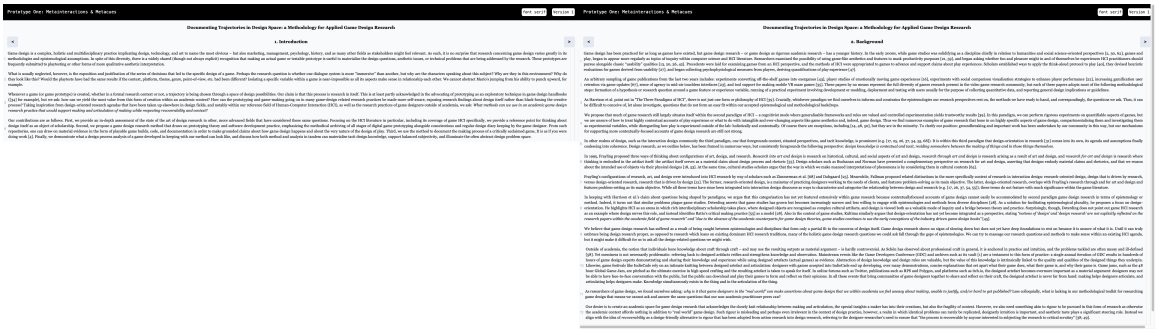

Figure 5.7: V1.0 - Section 1: Introduction

Figure 5.8: V1.0 - Section 2: Background

V1.0

Translating these needs into the digital space, I break the article down by sections. Horizontal shifting takes you from one section to the next, and isolates it on the screen – as show in the figures 5.7 and 5.8. And while on a section, continuous vertical scrolling is how the user navigates the section.

It is important for the visual structures to remain consistent so as to background the structural elements of the article. For the scrolling to be successful, the whole screen must *not* be scrollable. Instead, only the text material should scroll. The article's title stays visible at all times, as does the section title and the next and previous section buttons on its side.

Some elements of the article can be rendered on an ad-hoc basis. For instance the author names, year, keyword, abstracts, or the outline of the paper. The title of the article is a clickable entity that reveals the article's outline, abstract, authors' names, and other metadata (see figure 5.9). This is information that is usually only read once in the life-cycle of reading a paper. Also given that it is at the top and always accessible, this conditionally rendered panel can operate as a *control panel* for the configuration of the article. Initially, I was unsure about the importance of the outline section; one of my MDM logs: (Commit SHA: c0828c49) reads:

> *Another question is, does it suffice to have the switch between sections one by one, or do we need the jump-to-section thingy too? How important is that to the reading process? How does that change reading?*

But, over time, I realized without something high-level, I felt *blind* in the article. This type of

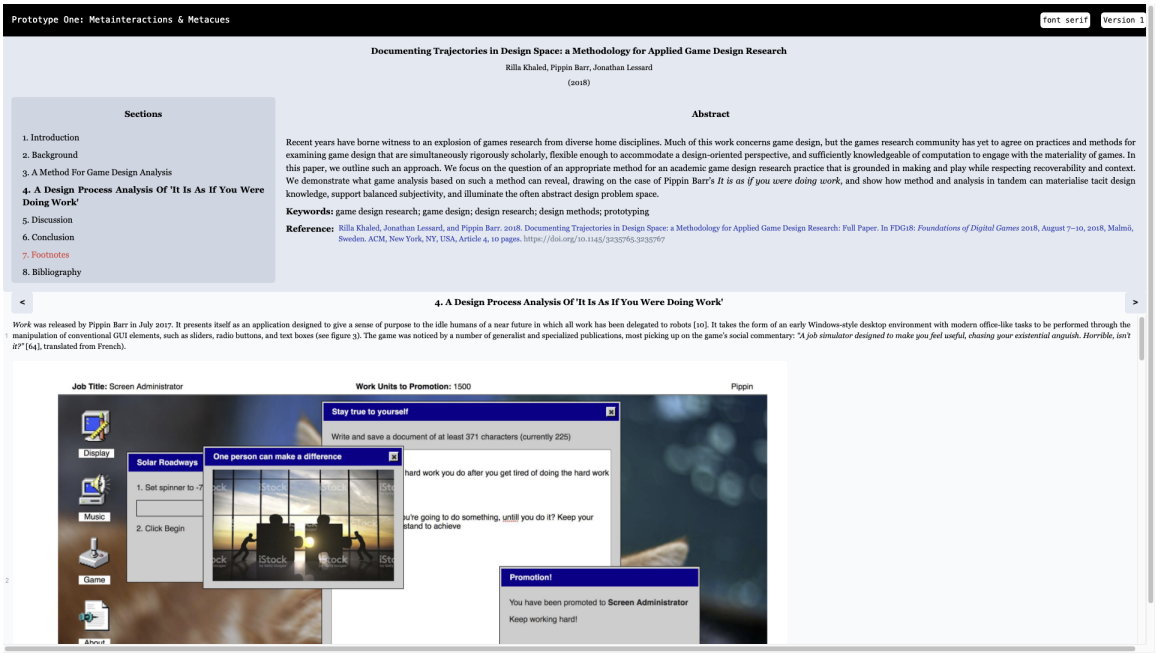

Figure 5.9: V1.0 - Conditional Rendering of non-essential information

navigation is crucial to gain a sense of the structure of the whole, so I came back at the end to add this to v1.0 after I implemented it in v2.2.

Words are not unique so the building block of the digital article has to be *at-least* a sentence. A collection of sentences forms a paragraph. A paragraph is the quanta of an essay, it represents an idea in a long form piece, and should be a 'unit of composition' (Strunk & White, 2009). Instead of page numbers, I add paragraph markers as anchors to position. These are the thin numbers on the left side of the paragraph;. In an ideal form a sentence would also be referencable and allow deep referencing across articles as part of citations, in a digital-first ecosystem. In my MDM logs (Commit SHA: 840850b37) I wrote:

> *Introducing paragraph markers. Now not only is a section referable but also a paragraph. When I go forward into writing, each paragraph number will be referable. These also give me an initial structure of the essay I want them to be visually small because they are not important to view at all times, nor should they demand too much attention. Should they be bold, or thin? Worth exploring... Thin dissolves too much, medium might be too bold. I have a history of preferring bold text, so I think I will go*

with either thin or light as font weight. Im also wondering if the font colour should be a lighter grey. Because keeping in mind, this is meant to orient the reader, it shouldn't take too much attention..."

Now we have precise locations for each paragraph and as I read, this well-defined position will be able to serve as a precise anchor for concepts, assist my reading comprehension (Glenberg et al., 1987) and meta-cognitive processes.

Altogether, this version discretizes the article and forms segments of the article along semantic structural elements, and adds the ability to traverse the article along these elements. Unlike in PDF where these elements are a part of the article, here these elements have become part of the structure.

V1.1

But we're still not quite done, this is still too jarring. Modern computer screens have a wide aspect ratio and my eyes can only focus on so much. Click on the version 1.0 button on the top right corner and that switches to V1.1.

First thing we need is to have the text in central vision. The slider that just popped up does exactly that (see figure 5.10).

To further cue the focus on a paragraph, I imagined a touch-screen based version where instead of swiping continuously, there is a gentle *flick*, a smooth transition that focuses one paragraph at a time. It is a meta-cue for the reader ("that idea was 4 flicks ago"): making a paragraph a *step*.

In the pointer and screen layout, however, a good interaction to use for foregrounding a paragraph and focusing the reader's attention is hover. You will now notice a paragraph is foregrounded with the text being bold and the background growing darker, when the cursor hovers on it (see figure 5.11.

This hover is composed of font weight increase, text background change, and a gentle transition. These three can be combined in many ways and this becomes an interesting point to think about variations in this foregrounding. Do we only make the background darker? And if so, how dark? What if we only make the text bold? If so, how bold? If the font is too bold, it occupies too much space and becomes a bit jarring. If the transitions are too quick, they add too much visual clutter. And the background change may not be enough.

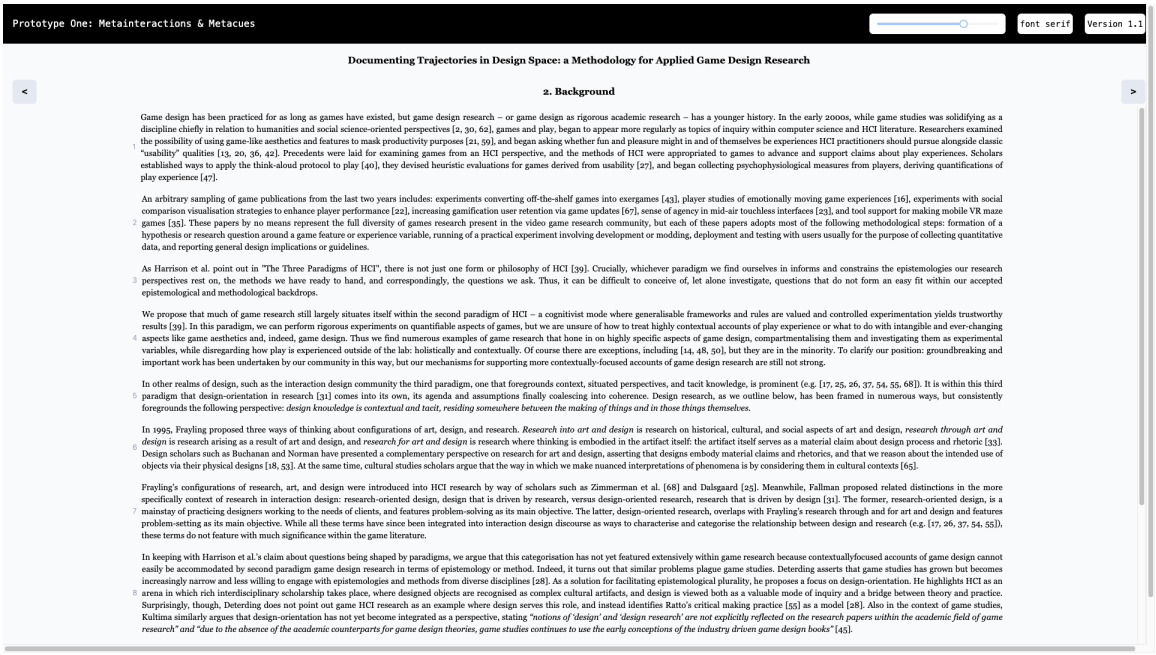

Figure 5.10: V1.1 - Customizable margins

Figure 5.11: V1.1 - Foreground paragraph on hover

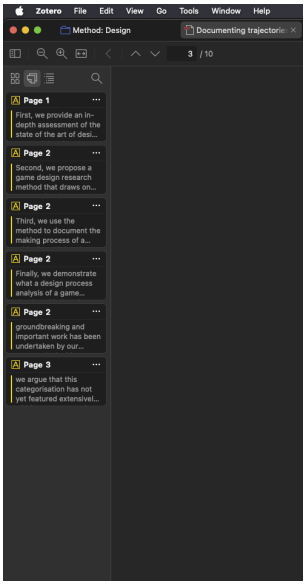

Figure 5.12: Annotations panel in Zotero

But for now, the constraint I feel is not variations in hover, but the fact that I can only passively absorb content; I want to engage and annotate, I want to write.

Prototype Two: Active Reading

Try Prototype Two

As I went through testing Prototype One, it started to feel a bit restrictive because reading an article urges me to question and reflect upon what I read. I don't think carrying the metaphor of writing in margins into the digital space is productive anymore. More importantly though, writing in snippets and on the side gives centre stage to the article. For active reading, this should not be the case. Not only should the writing interface allow expansive thinking, it should also be a main task, connected directly to reading.

To illustrate the meta-cues of digital annotations we should look at Zotero (V7). Their visual hierarchy (see figure 5.12) gives more importance to the page number and the colour of the highlight, and the text I selected is dim in the background. There is no grouping of highlights and notes by page numbers which further adds visual clutter when the same information is repeated. This is counterproductive to the purpose of highlighting i.e. revisiting an important piece quickly. The

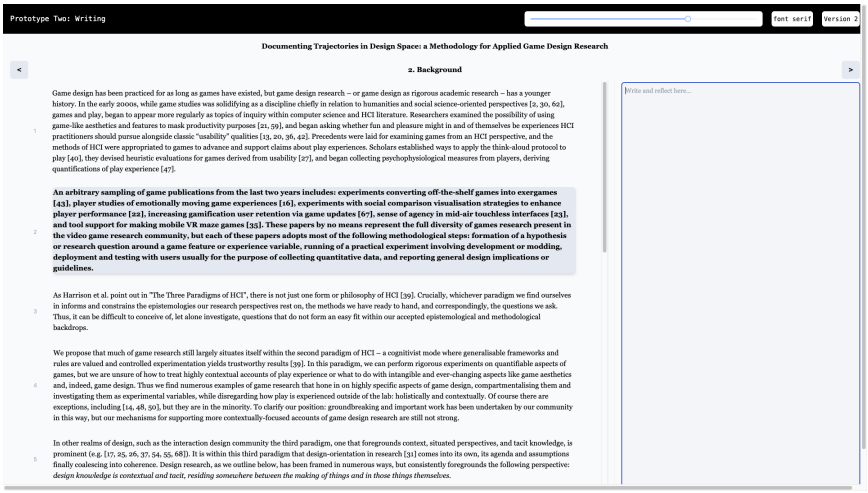

Figure 5.13: V2.0 - Writing Space

main thing should be the highlighted text, or at least a part of it, and the page number should be a secondary thing – especially since clicking it will take me to it. And lastly, the pane is in my periphery vision, inviting once again to highlight and forget.

V2.0

Like Victor (2011a), I want the article to be a space for thinking. The reader's notes, reflections and development must be available at the forefront when viewing an article because their learning is the most important thing about reading; the article without the reader's reflections is essentially useless to them. An annotated article (on paper) is more valuable to the reader than a fresh copy because the annotation is the bridge between the external (article and what it aims to teach) and internal (the reader's mental models and schema). The writing space has to take centre stage.

I add an expandable, free-writing space right next to the article (see figure 5.13). This invites writing *as* you read: writing long form as you read long form. The panel stays there persistently. Given the fact that navigation within the section does not require any clicks, the user can navigate freely while continuing to write; the text area stays focused.

Since there is the foregrounding on hover feature, I make the assumption that people are placing their cursors on the paragraph they are reading. One thing we do is we write in reference to a segment. Since we have paragraph numbers, double-clicking the paragraph adds a reference to it

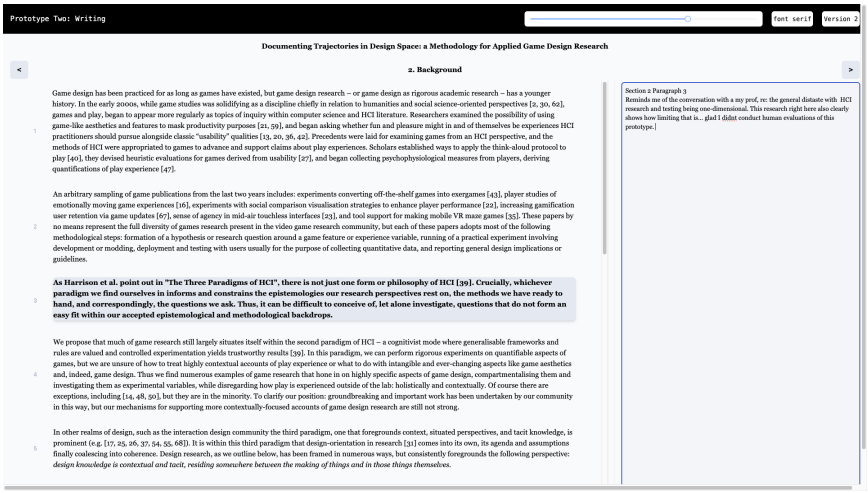

Figure 5.14: V2.0 - Referencing paragraphs in writing

in the text area, and automatically focuses it so the reader can continue writing directly (see figure 5.14). The same interaction also works for referencing elements of the bibliography in your writing, which is useful for putting references in conversation.

V2.1

If you click on the top right 'version 2' button again, you will see version 2.1.

This version was only marginally different to begin with, as I wanted to experiment with a different encoding of paragraph referencing in the article. This one is sharper and contrasts more strongly with the text that I write: it is notation instead of words. Now the references to paragraphs stand out (see figure 5.15).

In addition to the revised referencing, I also added some more control over the interaction. When I came back to the system after some time and the novelty of the hover-foregrounding wore off, the transition was a bit too fast at times if the cursor accidentally slid away. So, I added more control over the foregrounding and sometimes (especially in v2.2) it is based on how I am interacting with it, it is a lot less distracting to have regular font instead of bold.

V2.2

What if active reading was like a conversation with the text?

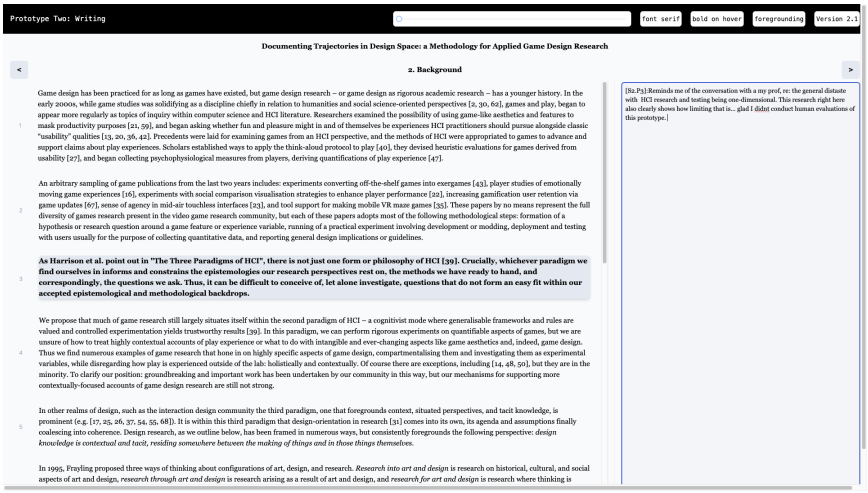

Figure 5.15: V2.1 - Revised Referencing

Literally.

Click on the version 2.1 button again.

This version introduces a chat-like interface around an article. On the side is a panel that looks like a chat history and at the bottom is a text bar. The text bar can grow larger to allow for similar writing experience as v2.1 and v2.0. The panel on the side supports markdown so the writing can now also be formatted and there is no length limit to the size of the notes. When you double click on the paragraph it adds a reference to the text bar and focuses it so you may write.

When reflecting on paper, copying snippets of text is clunky but still very useful. In v2.2 (open), highlight a piece of text, then double-click the text area. From five clicks for copy and pasting some text, plus some formatting and referencing the paragraph, it comes up to approximately an additional ten 0 key presses. This (v2.2) does it in two clicks. You press the send button and it formats the text into the chat history. In addition to that, the top left corner of the chat history has an arrow to download your 'chat history' as an MD file. How does this make you feel? What kind of engagement does this invite you to perform?

Prototype Three: Media Embeddings

Try Prototype Three

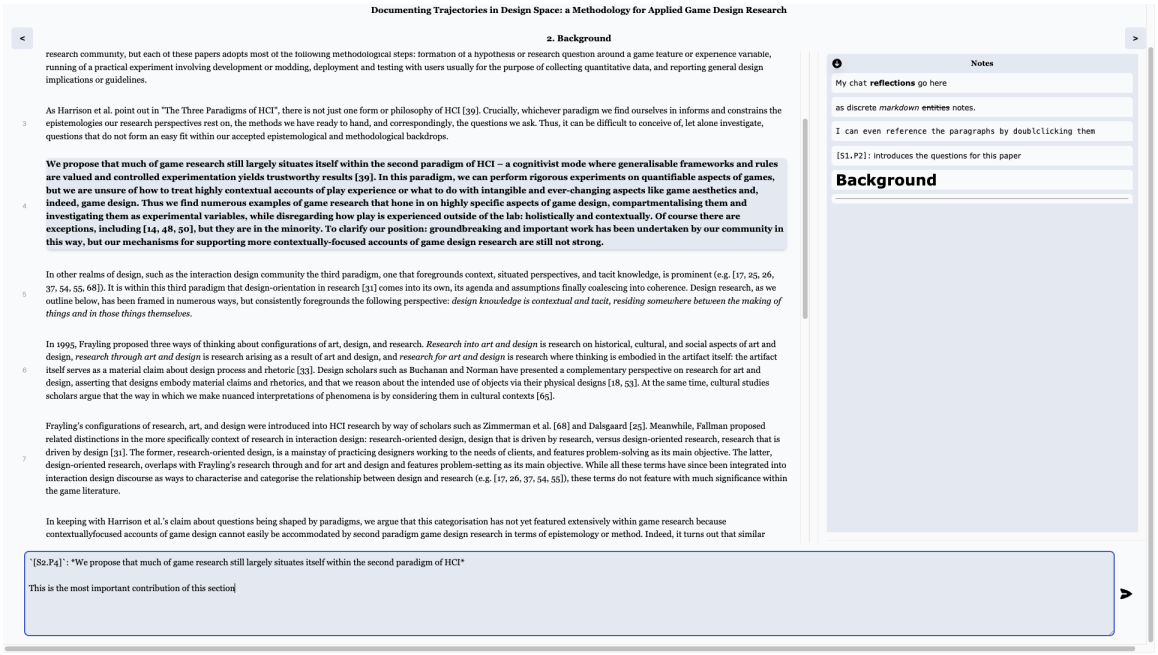

Figure 5.16: V2.2 - Like a chat with the article

V3.0

Prototype three is supposed to demonstrate the potential of live-ness and playfulness of the DFA by embedding the game that is the subject of this article, into the article alongside the text. If you click on the title of the article, and navigate to 'Section 8: Playable Build' you get to play the game from inside the article (see figure 5.17).

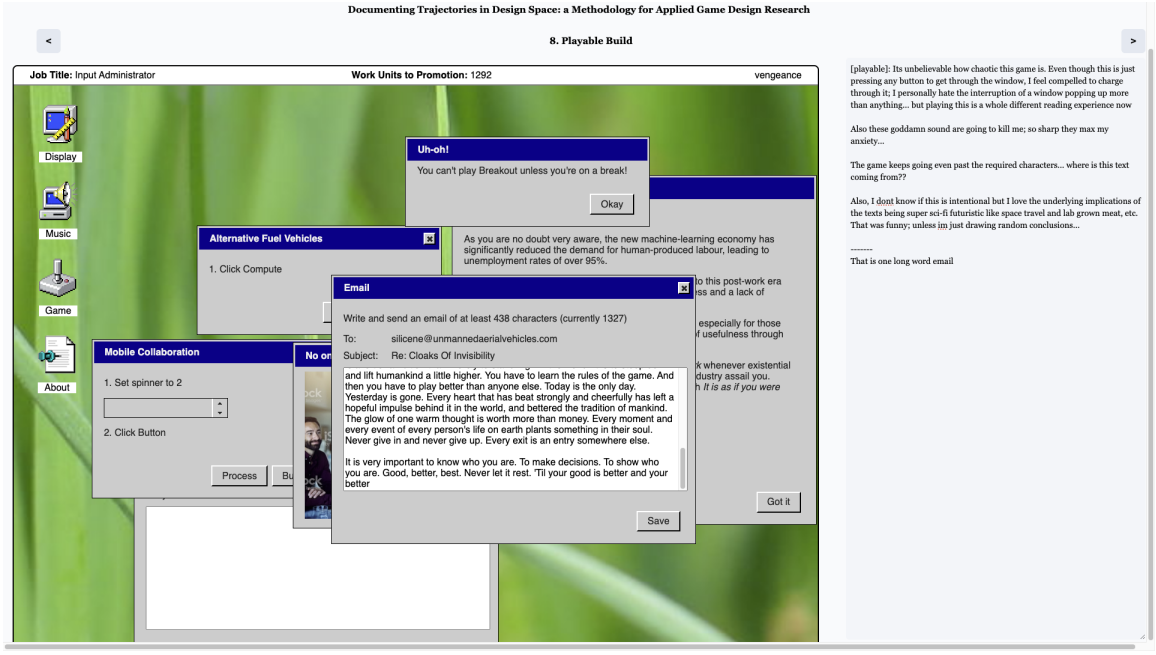

Figure 5.17: V3.0 - Playable Build

Discussion

These prototypes were intended to demonstrate the possibilities of how we could be reading through computers, and to explore innovation in active digital reading. The basis of my design decisions were reflections on my own reading experience and then expanding a relatively more general explanation that could apply to an audience of more than one.

I used the same article because this places emphasis on the changes between versions in each prototype, but the JSON structure in the appendix shows that any article that can be put into that structure, can be read this way. If a feature is possible in one prototype it is possible in another, it is possible in general, and it is possible conditionally. The way features are added or left out is intentional to draw contrast between versions, to make you want one that was just present in the other; there is no chat interface in prototype three, there is no playable build in prototype zero.

In the Linux file system, users get Read, Write, and Execute permissions for every file. From a high-level perspective, we can visualize the prototypes in these three categories. We can view prototypes zero and one being read-only versions, while prototype two is write-enabled, and prototype three is executable. From v0 to v1.0 to v1.1, the form of the article is still a linear translation. Not a linear translation from paper to screen but a linear translation of a file to a webpage. Even in its more responsive state (v0.1), we cannot imagine the article as anything more than a static artifact (it is, after all, a read-only article) until v2. The staticness, I believe, is related to the article being read-only, and can also contextualize the results of all the surveys comparing print form versus digital in chapter 2 (Baron, 2015; Clinton, 2019; Two Sides, 2015). A read-only article does not afford engagement. A printed article is read and write enabled, so naturally it is the preferred format. This becomes more pronounced when prototype two introduces reflections alongside the text. Based on that, I think is possible that the *why* element of preferring print form, has to do with the inability to

engage with the text freely.

Prototype one specifically develops on meta-needs of the reader: meta-cues and meta-interactions give the reader more agency over the infrastructure surrounding the article, give control over things beyond just reading and writing. Readers can engage with the article like it is a digital artifact, designed to be used through a mouse and keyboard, instead of finding “ways computers can feel more paper like" and closing a supposed paper-screen gap (Tashman & Edwards, 2011a). Prototype zero and one both break the requirements as were laid forward by (Bentley et al., 1929) for print articles and I think this is generally good because it backgrounds the structure of the article and foregrounds what I can do to it.

The introduction of writing alongside reading changes the reading experience. Instead of staring at an article, I am now extracting and constructing knowledge from it. This construction becomes a primary part of the reading process. When I am finished with the article I have constructed something tangible as the end product, instead of a tacit understanding in my memory. This construction is what we want for academic reading.

Comparing v2.0 and v2.1 with the kind of writing we are able do in PDFs and readers like Zotero, when we make small notes on the article it seems like the notes are part of the article. In contrast, when I introduce a free writing space next to the article it creates a third space, outside the article and outside my head for ideas and knowledge to be born and cultivated. This third space is what I want to be able to engage with text in the same medium as the text. This external space, a playground for ideas, is missing in skeuomorphic articles, they are a requirement for learning. So, yes, I think when Baron (2015) declares digital a better medium for reading fiction/casually only, she is right because reading fiction can survive in a read-only environment.

If I view these prototypes on a continuum, like dots on a number line, the kind of writing we do on PDFs seems to be in the middle of prototype one and two. Some writing is better than no writing. But notes on a file might send the message that the reader is doing something *to* the file, the reader is somehow *imbuing value into the file*. Reflections in the writing space instead imply a construction, creation of a *new* order on the meaning derived from reading *outside* the article. This is part of what I think would make the article an Explorable Explanation (Victor, 2011a): a space for the reader to do their own development.

As the last variant in prose, I ended up liking v2.2 the most. This is the one that finally feels like an article embedded in an ecosystem. The focus of the system was on my reflections and reading was purposeful: reading *to* write, to *reflect*. Downloading the reflections file as a formatted markdown integrates directly into my existing processes. When digital tools are able to adapt to the reader, they are better able to *enhance* reading.

V2.2 was something that had been in the back of my mind for a while but as I was about to wrap up, I got the strongest impulse to make this. What really came out of this was a form that now, with all its interactions, absorbed the article as a smaller part of a bigger whole. The article itself starts taking more of back stage. With the re-sizable text area, highlight and double-click to copy, and ability to download my annotations, v2.2 creates an ecosystem around my learning from an article. The system is encouraging engagement and active reading!

It is also interesting to notice the contrast between v2.2 and 2.1. Although 2.1 does not have any formatting, it is the inability to download the written text that can be disruptive or frustrating. But 2.0 and 2.1 have text that is persistent, it stays within the ecosystem (in this case the browser). Whereas with 2.2, although refreshing the page deleted the text, it is able to leave the ecosystem in a format that can integrates with your other tools. This contrast hints at the question about whether we would want a cloud-native digital reading ecosystem, or would prefer to maintain our own repositories. They are not mutually exclusive, but still a core question in shaping this future of a DFA.

I kept an intentional distance from using hyperlinks in this. Hyperlinks and hypertext has gotten a lot of attention since the beginning because high-speed switching is an affordance native only to computers. However, I think hyperlinks don't invite exploration in depth, they encourage a lateral exploration – of related topics and *others*. I think for academic reading, because sustained focus is key for engagement, hyperlinks are potentially distracting. To illustrate, this entire document is loaded with hyperlinks and they are all a stark blue. Because they *pop* so strongly, they are a bit of a distraction. In contrast, in Prose prototypes, the hyperlinks are all a dull grey. They allow but don't encourage. You may press it if you really want to, but if you don't and you're too busy with the text, it is not important .

Hyperlinks take you away from the source and my vision for the DFA, for article as software,

is for it to contain everything in one place; and v3.0 demonstrates the economic advantage of such a structure by embedding the game in the article, situated in the same visual context of the article. Its placement in the same environment has got me (cognitively) on the edge of connecting what I have read to my experience with the playable. The DFA should be able to embed live simulations, game builds, dynamic switching between software builds, recompiling software repository, visualize parametrized mathematical models, and more.

Prototype three is also similar in intention to the Article of the Future (Aalbersberg et al., 2012, 2014) and the approaches of (Newe, 2015; Newe & Ganslandt, 2013) as it links and embeds external media into the paper. Treating this as a web app instead of a file, removes any bounds on what can be embedded into the article. Something like (Victor, 2010)'s parametrized interactions and (Bostock, 2014)'s dynamic representations, this makes it possible for academic articles to be living.

Overall, this collection as a whole approaches an exploration of the two problems identified in the section 3.3[1] [2]. While V0, V0.1, V1, and V1.1 target the problem of a better interface for digital reading, all eight variants demonstrate how article as software could present and behave differently for an enhanced learning experience; for a Digital-First reading experience.

Viewing these prototypes from an Archimedean point, I see different forms that afford differently for different purposes. O'Hara (1996) has defined six different types of reading that readers adopt to fulfill their various goals (see more at the start of chapter 4): Receptive Reading, Reflective Reading, Skim Reading, Scanning, Serial/Non-Serial Reading, Single/Repeated Reading. Variants of prototype zero and one afford receptive, skim reading, and scanning, while prototype two and three are able to afford reflective reading as well. Looking at these altogether, I see that different parts and forms of each could be useful for different purposes in different configurations. I may want to be able to change the article into different forms based on my intentions at a time and a more refined version will be able to do that.

The need for a different form is evident by the number of attempts made to create an interactive research article. It was not a question about the *visual form* of the paper and its layout but also about what one can *do* with the research article. Active reading is not possible in an article that restricts

[1] We need a better interface for digital reading, one that guides the eye, attention, and mental models.
[2] Need for a scalable medium that is able to grow as possibilities of research grow

the reader from engaging with it freely. Much like watching a movie is different from watching a live play, the experience of reading digital text *should* be more than just an interaction with a static artifact. And with prose (and further development in this direction) I think we can establish digital reading as enhanced reading.

The prototypes developed in this project opened the design space of the DFA. This is transitively also applicable to digital-first reading in general. When reading and reader expectations change, writing will change. The re-imagination from the user's perspective and the medium's capabilities could revolutionize the way electronic text is created and consumed. When writing was invented, it was written to be read aloud (Vandendorpe, 2009, Pages 6-7). In the 12th Century writing evolved with the intention to be read silently. This evolution changed reading, writing, and thinking a second time[3].

The prototypes I explored isolate aspects of reading as it is and as it could be. V0 and V1 make explicit what we do implicitly when reading , while V2 and V3 bring in elements of the the reading process that are usually external, inside the article. However these prototypes are still very crude and not user ready at all. My focus was to explore the form on a higher-level: How does making it look like a chat interface change my perception? If integrated playable builds are now possible, what else can I do with it? Where else would they be relevant in the paper? What if I embed a playable over multiple stages of development? All these questions open directions and prompt further development towards a digital-first article.

[3]The first time being when writing was first invented (Vandendorpe, 2009)

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JSON File structure for Prose

This demonstrates the structure of the file; truncated to prevent the file running too long.

Return to Chapter 5 - Prototype Zero

```
const ArticleData = {
title: "Documenting Trajectories in Design Space: a Methodology for
   Applied Game Design Research",
year: 2018,
authors: [
   "Rilla Khaled",
   "Pippin Barr",
   "Jonathan Lessard",
],
abstract: "Recent years have borne witness to an explosion of...",
keywords: ["game design research", "game design", "design research",
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citation: "Rilla Khaled, Jonathan Lessard, and Pippin Barr. 2018.
   Documenting Trajectories in Design Space: a Methodology for
   Applied Game Design Research: Full Paper. In...",
sections: [
   {
      title: "Introduction",
      paragraphs: [
         "Game design is a complex, holistic and multidisciplinary
            ...",
         "Our contributions are as follows. First, we provide an ..."
      ]
```

```
},
{
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      "Game design has been practiced for as long as games have
         ...",
      "Let’s recall our primary research question: *What are the
         methods for an academic game design research practice
         that supports making and articulation of making, while
         respecting recoverability and context?*..."
   ],
},
{
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      "A conventional game design analysis might...",
      "The analysis itself was written by another author ...",
   ],
},
{
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      Doing Work’",
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      "*Work* was released by Pippin Barr in July 201...",
      "![Figure 3: It is as if you were doing work* during play](
         https://raw.githubusercontent.com/estineali/assets/refs/
         heads/main/prose/Figure3.png) **Figure 3: *It is as if
         you were doing work* during play**",
      "## **4.1 A UI Game**",
      "A key finding in looking at the design process of *Work* is
         ...",
      "In his first post, Barr was ...",
```

```
      "Eight months later, ... a player character story suddenly
         appears fully formed:",
      " ‘‘‘’the player’ is a person who ... without the actual
         productivity. [3]‘‘‘",
   ],
},
{
   title: "Discussion",
   paragraphs: [
      "## **5.1 Externalising tacit knowledge**",
      "The analysis presented above is but...",
      "## **5.4 What might have been**",
      "While these ideas may not have..."
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},
{
   title: "Conclusion",
   paragraphs: [
      "The design of games is the solving of imagined problems."
   ],
},
{
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   paragraphs: [
      "*[^1]: As we accumulate projects documented following this
         approach (which we call MDMA), we hone best practices
         for its various parameters and document them here: http
         ://www.gamesasresearch.com/mdma.*",
      "*[^2]: We invite readers of this paper to examine the
         archived materials of Work and come to their own
         conclusions, for example*",
   ]
```

```
      }
   ],
   bibliography: [
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         id: 1,
         title: "2017. GDC Vault. (2017). [https://www.gdcvault.com/](
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      },
      {
         id: 2,
         title: "Espen Aarseth. 2001. Computer Game Studies, Year One. [
            http://gamestudies.org/0101/editorial.html](http://
            gamestudies.org/0101/editorial.html). Game Studies 1, 1 (
            July 2001). "
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export default ArticleData;
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