Style Blink: Exploring Digital Inking of Structured Information via Handcrafted Styling as a First-Class Object

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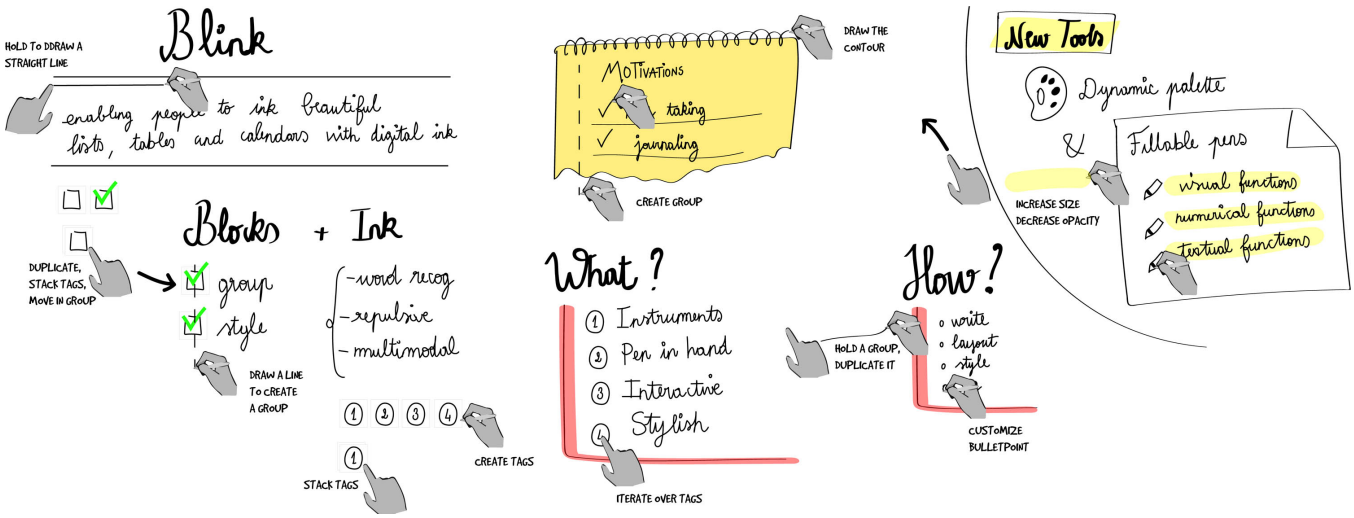

Figure 1: Visual abstract summarizing the paper motivations and contributions created using *Style Blink*.

ABSTRACT

Structured note-taking forms such as sketchnoting, self-tracking journals, and bullet journaling go beyond immediate capture of information scraps. Instead, hand-drawn pride-in-craftmanship increases perceived value for sharing and display. But hand-crafting lists, tables, and calendars is tedious and repetitive. To support these practices digitally, Style Blink ("Style-Blocks+Ink") explores handcrafted styling as a first-class object. Style-blocks encapsulate digital ink, enabling people to craft, modify, and reuse embellishments and decorations for larger structures, and apply custom layouts. For example, we provide interaction instruments that style ink for personal expression, inking palettes that afford creative experimentation, fillable pens that can be "loaded" with commands and actions to replace menu selections, techniques to customize inked structures post-creation by modifying the underlying handcrafted style-blocks and to re-layout the overall structure to match users' preferred template. In effect, any ink stroke, notation, or sketch can be encapsulated as a style-object and re-purposed as a tool. Feedback from 13 users show the potential of style adaptation and re-use in individual sketching practices.

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CCS CONCEPTS

• **Human-centered computing** → *Human computer interaction (HCI).*

KEYWORDS

note-taking, bullet journaling, pen+touch

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1 INTRODUCTION

Visual notetaking is an essential component of work and personal life [6, 11, 53]. But despite many advances in digital notetaking technologies [12, 18, 26, 35, 46, 48, 56, 57], many issues still inhibit the adoption of digital notetaking tools [1, 5, 44, 49]. In part this is due to the loss of affordances of analog pen and paper [44] – the tangibility, low-cost, high availability and reliability of pen

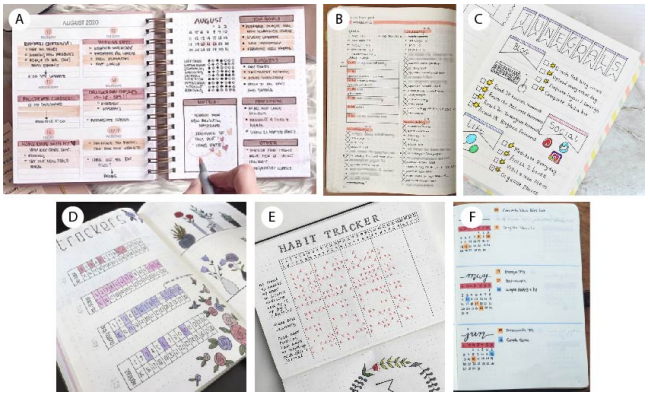


Figure 2: Bullet journaling entries composed of lists, tables and calendars, and featuring distinct visual styles.

and paper is difficult to match [5]. Another reason contributing to the limited adoption of digital inking is that notetaking and sketching go beyond the simple collection of information scraps, and that direct support of embellishments and styling for rich personal expression – while easy in the analog medium – is missing when moving to the digital [44]. As studied in many other contexts [10, 36], pride-in-craftsmanship of the custom, self-created artefact increases perceived value for sharing and display – and can similarly apply to the digital, such as with curated collections in the cloud [37]. Such attention to detail in crafting visual artefacts is at the core of many modern notetaking practices, such as sketchnoting [16] and bullet journaling [6].

The problem is that to support a digital equivalent of bullet journaling, handwritten self-tracking, or sketchnoting on pen+touch devices, we need techniques to preserve freeform expression, creative embellishments and custom layouts without requiring tedious and repetitive actions of the user. Furthermore, in its digital form, such modern expressions of notetaking afford edits and style changes that are impossible on analog paper. Towards this goal of expressive digital inking capabilities, we propose a set of novel interaction concepts tailored to the freeform creation, modification and styling of semi-structured information. Most importantly, we explore *handcrafted styling* as a first-class object throughout our techniques, with strategies to minimize disruptions [7, 44] from the notetaking process caused by selection and UI navigation while offering pen and touch interactions for a more direct crafting and manipulation of ink content.

We implemented these interaction concepts in a prototype called ***Style Blink*** (Style Blocks+Ink), which allows crafting of structures key to bullet journaling: lists, text blocks, tables, diagrams, and calendars. Three small building blocks – Blocks that allows grouping elements spatially, Dividers that help structuring handwritten notes, and Tags to make specific elements salient – form the basis of our techniques, and together encapsulate digital ink, enabling the crafting, modification, and reuse of embellishments and decorations for larger structures.

The techniques preserve the hand-crafted look&feel of personal notes, while at the same time incorporating manipulations to creatively engage with layout and styling through direct manipulation and instruments [8, 9, 23].

Our ***dynamic inking palette*** affords creative experimentation with styling of strokes by changing stroke properties like thickness, color, and opacity – and in doing so, creates a personal collection of strokes-as-tools in any desired shape or form, that can be re-used and re-sampled as naturally accrued custom commands – much like the left-over dabs of mixed paint on a traditional artist's palette.

Style Blink's ***fillable pens*** act as instruments [8] that can be "loaded" with commands and actions to replace menu selections (e.g., keyword search or common arithmetical operations in tables) as content-aware pens. Alternatively, pens can hold patterns and other composite strokes for expressive inking of patterns and compound stroke-styles along paths.

Marks laid down as normal ink, such as lines separating paragraphs, can function as ***layout instruments***, through ink that has physical collision properties [3] affecting other elements. We also include techniques to customize inked structures – including embellishments and decorations – post-creation by modifying the underlying handcrafted style-blocks. Fundamentally, across our techniques, any ink stroke, notation, or sketch can be encapsulated as a ***style-object*** and re-purposed as a tool.

Finally, to gather feedback on these concepts and better understand their potential fit into current notetaking practices, we conducted an interview study with 13 users – 4 experienced bullet journalers, 4 digital notetakers, and 5 users interested in journaling and owning a pen and touch device . Insights from this study reveal current barriers to the adoption of digital ink, and articulate the value styling offers in both creative journaling and notetaking activities. The feedback we gathered also shows similarity and critical differences between these activities, suggesting design implications for future tools aimed at styled notetaking. Participants' comments allowed us to identify successful principles such as crafting and reusing small building blocks, and modifying existing ink through post-hoc interactions, but also pointed to open problems such as the discoverability, learnability and predictability of interface components.

In summary, our research contributes:

- A set of interaction concepts that consider styling as a first-class object, providing tool instruments that allow crafting, styling, composing, and manipulating structures in digital ink for richer creative expression.
- An instantiation of these concepts in the ***Style Blink*** prototype for hand-crafting structures such as lists, tables and calendars, where we illustrate the techniques of styling palettes, refillable pens, collision ink, and post-hoc changes of styling.
- Insights from users about the potential of these techniques, such as the value of styling (as an organizational tool all the way to bringing joy and emotional support); a desire for aesthetically pleasing uniformity; and the importance of preserving a handcrafted look-and-feel in digital tools.

Together, these contributions articulate the potential of styling hand-crafted, semi-structured notations without disrupting creators from their work-flow. Our work also illustrates promising

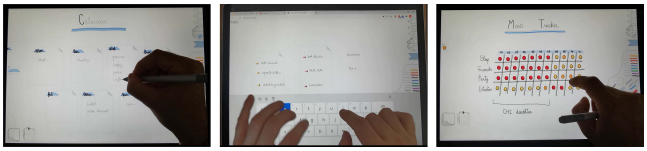


Figure 3: Overview of StyleBlink' Web-based interface, running on a tablet with support for pen+touch. (a) Users filling a calendar with to do notes (b) Users using keyboard to input ink as text into a list and keeping the list formatting (c) Users creating a mood tracker using tags

techniques to enable notetakers to produce hand-drawn notes that exhibit personally meaningful pride-in-craftmanship.

2 RELATED WORK

People lay information on paper in many scenarios. They may annotate a document in active reading [44], capture fleeting thoughts to act as reminders such as to-dos [11], externalize thinking by writing down numbers to sum them up later [25], or craft more elaborate calendars, to-do lists, or visuals for self-tracking when the subject matter or event is of personal significance [6]. We overview this research, identify high-level differences between the types of notes taken, and delve deeper into state-of-the-art techniques supporting stylistic inking of semi-structured information such as lists, personal glyphs, and tables that contain (or consist of) free-form notations.

2.1 Annotations and Notetaking

Annotations and the active reading process in particular have been extensively studied [20, 30, 31, 48, 50]. Early active reading systems such as XLibris [42] paved the way for more recent innovations such as LiquidText [52] for rich free-form notes and annotations. Systems such as RichReview [57] illustrate multi-media annotation with ink, spoken audio, and gestures. ActiveInk further extends the concept of annotations to repurpose ink as implicit commands that can perform advanced operations on the underlying content [46].

In contrast to annotations, which have a figure-ground relationship with underlying content, notetaking is commonly captured on a blank canvas. Notetaking is the process of capturing information, either in real time while capturing the key content of a meeting or a lecture, or as the product of externalizing one's thought-processes during ideation or journaling. Considerable research focuses on notetaking output and processes, such as the spontaneous spatial organization of handwritten notes [17], but also emphasizes the difficulty of organizing notes at the time of capture. Hence a need to defer organization, with re-structuring of notes post-hoc [29], to avoid disrupting the activity itself. The cognitive processes involved in notetaking are demanding [41], thus calling for interfaces that minimize disruption.

Research also suggests that the ability to capture free-form and personal notes plays a crucial role in making sense of information [20]. Such notetaking practices are greatly facilitated by the use of a pen, whether analog or digital, to input information. Research thus stresses the importance of ink primitives that enable flexible representations [51] while maintaining free-form notetaking [12].

Two contemporary forms of visual notetaking have recently attracted attention: *sketchnoting* [16], for capturing live presentations, and *bullet journaling* [6], for capturing thoughts and tracking personal data. These practices interweave textual and visual content, **structuring information** into lists, tables, calendars, and diagrams. These forms also emphasize **styling** for memorability and social display: making structures stand out with visual embellishments and ornate strokes. This practice results in crafted pieces that are often shared with others. While there is not much research yet on the benefits of such formats for capturing and understanding information, their popularity [1] (and almost exclusive existence in analog form) suggests a gap in what digital ink notetaking interfaces can currently support [2]. Our goal is to devise styling abstractions, interface elements, and interaction techniques that readily afford such practices in digital notetaking tools.

2.2 Inking Structured Information

Few current sketching and notetaking tools[2] explicitly support the creation of structured information in a blank canvas. Instead they offer *templates* for turning an entire page into specific, non-editable structures (e.g. Google Keep, GoodNotes, Linc [29]). For lists, several interfaces require insertion of a specific *UI element* to be filled with ink (e.g. Whiteboard), or require selecting ink strokes before turning them into a list item (e.g.Nebo).

Table creation. We identified a number of strategies minimizing interactions with menus, to directly craft tables in a canvas with inki: Whiteboard's *ink table structure recognition* feature, and WritLarge's [56] semantic axis navigation. Both enable the user to identify a set of strokes as a table structure, enabling easy addition of rows and columns or, in the case of WritLarge, even more complex table operations such as merging two cells. While seemingly less disruptive than other techniques, the successful use of these strategies depends on the accuracy of the automatic recognition. Recognition errors can lead to a series of erase/redraw actions which may be frustrating – in addition to being disruptive. Further, even if recognition is correct, it remains difficult to alter the table structure after content is laid down.

Ink selection. Some techniques provide support for selection and manipulation of ink-based structures. Harpoon Selection [27], a technique optimized for large whiteboards, uses crossing to select among a large number of unstructured digital ink strokes. Tivoli implemented strokes as atomic objects [38] and Flatland [34] automatically groups of ink strokes based on timing and spatial proximity. Both allow facile manipulation of the resulting groups. Perceptual Grouping [28] refines this approach by using a larger number of features (e.g., Gestalt Theory) as features for the clustering algorithm. However, grouping remains challenging when dealing with ink strokes, because of the structural hierarchy of text [47]: for example, a list is composed of items, which each have words and letters, and may individually consist of single or multiple strokes.

[1] e.g. over 6 millions posts #bulletjournal on Instagram as of August 2020
[2] We surveyed the top 12 app for digital notetaking on the Google, Apple, and Microsoft platform: Whiteboard, Nebo, Notes Plus, Pen&Paper, OneNote, Notability, GoodNotes, NotePlus and Inkredible, Squid, Google Keep, Apple Notes, Evernote

These groups may also overlap, such as strokes forming a cell, part of row and a column in a table. Later automated grouping techniques [39, 40] tried to address this by adding manual operations for merging or breaking up clusters, facilitating list selection in hand-written tables on large displays. But certain operations, such as inserting a new row in a previously sketched table, still can require multiple difficult selections. Tableur's [59] hand-drawn spreadsheets facilitates such operations with tables, but it still requires the user to convert ink selections into active objects (either tables and freeform cells). Similarly, Xia et al. [54] navigate group hierarchies, but require users to create groups first. We explore a compromise in this paper, offering a one-level grouping model coupled with styling (Style-Blocks).

Other infographics systems have been designed to ease the creation process of structured information from a data perspective. Such systems [24] focus on the relation with data to populate the canvas, and advanced interaction techniques to manipulate instances of an element at the same time, to ease the fine-tuning and the customization process. A similar approach has been investigated in DataInk [55] using pen and touch which consists of binding data to visual elements to be able to populate items based on quantitative data and automatically associate any visual variables to data properties.

2.3 Styling Notes

Pride-in-craftsmanship of custom, self-created artefacts – sometimes known as the "IKEA effect" [36] – can increase the perceived value objects for sharing and display [10, 36]. This can similarly apply to the digital, such as with curated collections in the cloud [37]. Such attention to detail in crafting and styling visual artefacts is at the core of many modern notetaking practices, such as sketchnoting [16] and bullet journaling [6].

Styling notes has two major components: the visual properties of the content and its layout in space.

Visual style. Mainstream apps all enable users to control visual properties of ink by selecting a type of pen. They often can customize ink style via adjusting stroke properties such as thickness, color, or opacity in menus and toolbars. A couple apps (e.g. Squid) enable changing properties of ink already in the canvas by selecting them. The apps we reviewed that provide support for structured information (e.g. lists in Whiteboard) did not offer capabilities for styling them when using digital ink (e.g. customizing list bullets).

Layout. Related to styling, earlier research addressed the specific issues of layout objects in space, revisiting the concepts of rulers and guidelines to snap and align graphical objects [14, 18, 19, 43, 58]. For example, Raisamo [43] proposed a ruler that pushes objects, similar to the ruler-based alignment tools later used in Lineogrammer [58]. Somewhat later, Frisch et al. [19] applied this to multi-touch object alignment, including techniques of colliding objects sticking to the changing shape of the ruler. Beyond ruler manipulation, more advanced alignment structures have been applied to object alignment, from multi-touch grid and guides [18], parametric multi-layered alignment shapes [14], all the way to declarative layout structures [32]. While these techniques allow the layout manipulation of diverse content types – text blocks, geometric shapes, images – none of them addresses the specific requirements of layout manipulations for ink-based input.

3 INKING HAND-CRAFTED LISTS & TABLES

In this section, we present insights we get from the literature and related work by presenting design principles and main components necessary to compose rich and expressive notes. Note that user feedback pertaining to the barriers of digital ink adoption for journaling and notetaking gathered during our study (and presented in Section 6) support the four design goals below.

3.1 Design Principles

We followed four driving principles to enable a wide note-taking audience to handcraft styled notes while considering the constraints imposed by this cognitively challenging task.

(D1) Hand-crafted styling as a first-class object. A key goal of this research is to offer tools that will enable people to connect to their handcrafted notes. Making notes personal by preserving their unique handwriting and controlling ink strokes' look and feel, enabling people to define their own encodings such as a specific set of symbols or colors – as well as construct their own layout of information – is critical. To this end, we explore interactions centered on styling both during and after taking notes, and with approaches that afford hand-drawn digital ink that can still exhibit pride in craftmanship.

(D2) Efficient creation of hand-crafted designs. Crafting visually rich and expressive notes on paper requires substantial time and effort. Creating lists, tables and calendars as illustrated in Figure 2 can rapidly then become a tedious and repetitive process if one is not extremely dedicated to such journaling practices. We seek to offer strategies and instruments that enable people to readily craft unique and personal designs. Providing efficient ways to style notes and reuse personal designs can help notetakers appropriate their notes without frustrating, complex, or repetitive actions.

(D3) Minimizing disruptions of the notetaking process. As the notetaking process is a cognitively demanding task [41], we aim to minimize disruptions. Our goal is to avoid expensive round-trips such as navigating menus and switching applications. The interface should enable people to keep the pen in hand while taking notes, and with affordances for doing so with flair and in style.

(D4) Expanding interaction with inked content. It is notoriously difficult to organize and categorize information at the time is captured [29]. Therefore, it is critical to allow notetakers to defer and revisit the decisions implicit in organization, re-structuring, or styling until after their notes are taken. Direct manipulation methods for layout leveraging pen and touch afford minimal disruption while keeping the pen in hand. Enabling users to craft and reuse personal tagging and robust indexing mechanisms during and after taking notes is also essential for visually parsing notes and retrieving important information. In addition, we seek to leverage the computational power available in the digital world to facilitate parallel activities occurring during notetaking. For example, providing simple arithmetical functions that sum a series of numbers when

jotting down a budget can save cognitive resources, time, and the divided attention required to switch applications.

Concepts. In the remainder of this section, we articulate four ideas addressing one or more of the goals above. While dedicated bullet-journaling software exists today — containing rich sets of templates, embellishments to help their users craft expressive digital bullet journaling entries — they often fail to address some of the critical notetaking needs (e.g. (D2, D3). By proposing a set of interface components or interaction techniques that could be easily integrated into existing free-form notetaking software, we hope to bring styling capability to the more general notetaking audience.

3.2 Create, Style & Reuse Small Building Blocks

We collected online examples from bullet journaling (Figure 2) from which we derived several categories, from the most simple ones (containing only few colors and simple architecture such as tables or calendar (D, F)) to more complicated ones (containing more colors and complex architecture with entangled visualizations (A, B, C)). By comparing differences and similarities between examples, we derived 3 common building blocks with which users can build most of the examples we took inspiration from: Dividers, Blocks, and Tags . Those building blocks are part of most of the visualizations, and any journal can be be decomposed using those primitives. Our model support most of the examples that we have collected, however more complicated examples, such as journal that encompass entangled geometrical shapes can be hard to achieve in a fully automatic manner.

Blocks are a spontaneous spatial organization of handwritten notes. The content of these blocks may vary from a paragraph of text to a bulleted list or a diagram [53]. Blocks are naturally separated by white space. In bullet journaling, blocks are often aligned with each other, their size adjusted to fill the entire page and create a sense of symmetry.

In addition, blocks are often associated with a visual style and repeated in a page. For example, a single block encapsulates multiple lists (Figure 2A) or multiple months or days in a calendar (Figure 2G).

Perhaps a key difference between bullet journaling and more traditional notetaking is the attention given to the location of future content. Users of bullet journals often spend time preparing the structure of their notes *a priori*. In other forms of notetaking, blocks of information organically emerge on the page [12, 17, 33], often presenting a less symmetrical and space-filling organization. This strongly suggest offering the ability to users to adjust the layout of these blocks at any point during the process.

We propose to consider blocks as a **grouping and styling** mechanism. In contrast to other interface paradigms, enabling users (or automatically computing) hierarchies of groups, in this paper, we explore the viability of a single level of grouping. Thus strokes laid out on the page either exist in a block or as ink on the page.

Dividers are another key component structuring handwritten notes [53]. Dividers are ink strokes acting as visual separator of blocks of information. Vertical lines in a table (Figure 2E) and horizontal line in a calendar (Figure 2F) are both examples of dividers.

As opposed to blocks, acting as a grouping mechanism to keep strokes together, the semantic of dividers is to visually separate blocks of information from each other. We propose to consider dividers as **interactive layout aids**, enabling the user to push aside strokes to make space for new content.

Tags are recurrent visual elements in notes, often associated with a particular meaning for the note-taker. In traditional bullet journaling systems (Figure 2B), tags evolve to mark the status of a task from an arrow, to a cross, when completed for example. Tags may also be elements composing visual mood or habit trackers (Figure 2E) added gradually over periods of time as one fills it out.

Tags may also serve as salient elements aiding visual search. These elements may be headers, highlighted words or keywords, or visual symbols. For example, headers in lists (Figure 2A) and calendars (Figure 2G) enable a quick parsing of the information and guide search for revising notes on a specific topics or day.

We propose to leverage tags as an **interactive visual indexing** mechanism for categorizing and searching notes.

4 INTERFACE DESIGN TO BUILD BULLET JOURNALING

From the design principles mentioned above, we derived several interface components to build a delightful bullet journaling experience.

4.1 Direct manipulation & interactive layout

Interacting with ink is fundamental when taking note digitally. Yet, moving ink in the page usually requires performing explicit (and disruptive) selections *(D3)*. Implemented interaction techniques are a combination of touch and pan gestures, with the pen or the finger to easily integrate them in the process of notetaking.

Direct manipulation of ink. Ink recognition's quality and accuracy drastically improved in recent years, especially for recognizing handwritten alphanumerical characters in English [4]. However, reliably recognizing higher-level structures (beyond letters and words) such as sentences, paragraphs, lists or diagram is still an active research area. The context of free-form notetaking poses an additional challenge for recognition as people often interweave characters with shapes and other drawings [53].

We propose to leverage the more robust recognition methods, such as groupings of strokes by proximity and spacing, to identify basic units such as ***words*** and compact shapes  . Such recognition enables moving these units directly with a finger without requiring a standard lasso selection of a set of strokes with the pen. This is important as lasso selection disrupts the notetaking workflow: requiring to change mode of the pen [21], either by selecting a different instrument in a menu or by using the physical button which may cause users to readjust their grip. People can also directly manipulate blocks.

Dividers as layout instruments. We propose attributing *physical* properties to ink, thus leveraging commonly found divider elements to push and align ink content (Figure 4). This type of ink we call ***collision ink*** generates potentially large and evolving *implicit* selections (as a ink is pushed, it may gets close to other ink and thus pushes it as well) rather than a series of multiple user-specified and explicit ones. Dividers allow moving multiple items at once (either

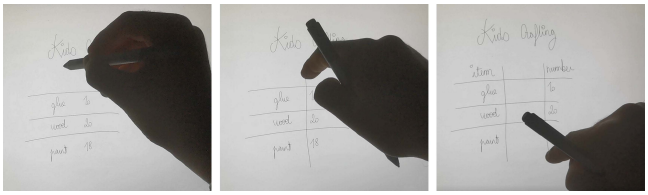


Figure 4: Demonstrating the use of collision ink by using a divider to make space for new content.(a) Users inking a line to push content in a table (b) Users touching the divider to interact with it (c) Users moving toward the right the divider to move content

groups of ink or groups of blocks) and aligning them to compose more complex arrangements.

While dividers are naturally found in notes, since they are only strokes, they can also be easily drawn to suit a particular layout need then erased. An interesting property of leveraging ink as a layout instrument is that such instrument can really take any shape desired, such as a semi-circle (Figure 1). We do recognize however, that it may be challenging to create long straight lines to rigorously align content. We thus also offer a bimanual gesture to create straight lines using pen and touch (Figure 5). This divider may remain in the canvas if users lift their pen first, or disappear altogether if users lift their finger first.

4.2 A Dynamic Palette for Styling Ink Strokes

All notetaking tools offer a level of styling of ink *(D1)*. Most advanced notetaking tools contain a palette enabling users to select a specific *color* and stroke *thickness*. Tools typically offer at least two types of pen: regular pencil and highlighter, enabling users to also control the *opacity*. Styling often requires switching between pens and navigating menus, which may prove inefficient *(D2)* or disruptive *(D3)* in multiple ways:

(1) Adjusting stroke properties (e.g. highlighter is too narrow for the size of the handwriting) may require back and forth between navigating the menu and inking on the canvas until the desired stroke look is achieved;
(2) while some more advanced interfaces such as OneNote allow to save the configuration into an additional type of pen, it requires navigating the interface to save and then later retrieve it among a set of pre-built pens;
(3) when available, changing ink laid out on the canvas requires selecting it first before applying it.

We propose to revisit the concept of digital tool palettes, reflecting on the initial role and function the real object played in the life

Figure 5: Bimanual interaction for creating temporary or permanent straight line dividers.

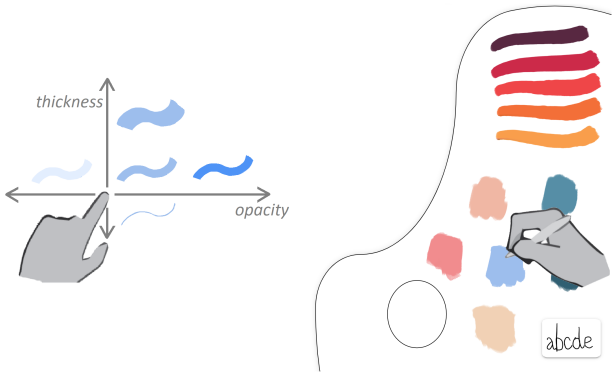


Figure 6: Direct manipulation of ink in the palette.

of painters. The ***artist's palette*** actually serves as place, separated from the canvas, for painters to experiment with mixing a set of pre-made colors, achieving exactly the desired brushwork and hue. As painter mix colors together they may also adjust them to better fit with each other. The palette hence offers a quick way to switch between multiple colors and swatches of mixed paints. The palette has been designed to match with what current painter are using when drawing on a canvas. Relying on real-world metaphor minimizes the need to learn new interaction techniques, and instead allows relying on the intuition and affordance of real-world objects. The type of instrument or brush used by painters to mix paints on the palette also offers a preview of the thickness and textures of strokes laid out on the canvas. Our goal is to bring back these essential aspects to the user interface component.

Our palette is a place for ***experimenting***, where users may draw strokes in the shape and form they desire, and modify their properties dynamically to get an overview of what the stroke looks like. It offers an empty "mixing" space — clearly separated visually – where users can lay down ink, to experiment and see how it will look before committing it to their notes on the canvas. Dedicating a space for drafting and one for crafting may naturally fit in peoples workflow [44]. To avoid the back and forth between settings properties and trying them out, we propose a bimanual interaction (Figure 6): users use their non-dominant hand to adjust opacity and thickness while pausing their writing, pen down, with the other.

Our palette also serves as a place for ***storage & quick access***, where users have visual examples combining complex properties at their fingertips (in a similar spirit to reified header styles in document editing software). Tapping a stroke on the palette "loads the brush" (pen) with it for re-use. Or users can then tap in the canvas to apply their custom-crafted pen style to existing ink.

4.3 Fillable Pens to Keep the Pen in Hand

A key asset of taking notes digitally is to leverage the computing power and functionalities inaccessible from analog (physical) media. We propose to surface these functionalities *(D4)* to users via a new type of pen, rather than navigating menus *(D3)*. By definition, the pen adds content [22]. While we expand the functionalities of what types of "digital ink" objects (or commands) a pen can contain, we

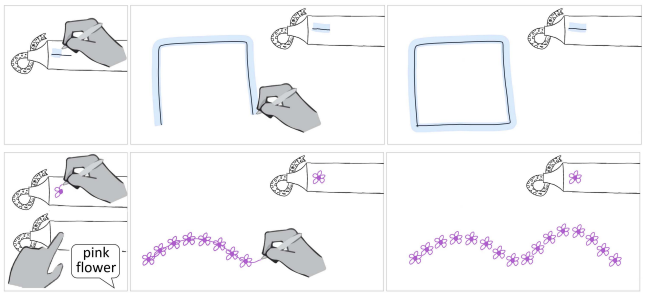


Figure 7: Drawing ornate borders with compound-ink pens.

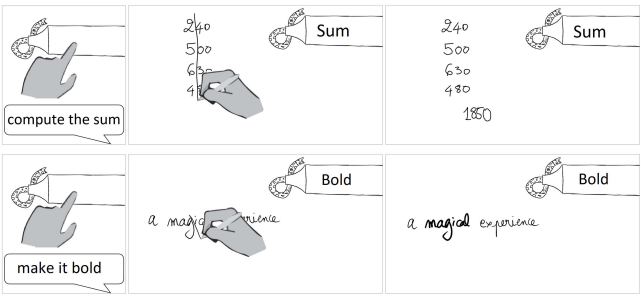


Figure 8: Content-aware pen providing font formatting shortcuts and simple arithmetical functions for numerical content.

always preserve the pen's key affordance of laying hand-crafted strokes on the page.

Compound-ink pens. contain sets of strokes to be laid out on the page following the pen trajectory. The content of the pen can be drawn inside the pen instrument with a regular ink pen, or more advanced functions generating ink strokes can be inputted by voice or keyboard.

- Composite ink made from applying multiple strokes is applied to the pen trajectory, eliminating the need for multiple successive and precise strokes of different visual properties.
- Patterns drawn in the pen are repeated along the pen trajectory. Inspired by doodling methods [15], this is a common embellishment for the borders of bullet-journal blocks *(D1)*.
- Alternatively, voice commands such as "draw smiley" can enable to filling the pen with ink content extracted from a library of hand-drawn assets, repeated along the pen trajectory.
- Ink content may also be populated from system variables dynamically updated by a computer. A classic example is "today's date", but other information feed could be available such as "today's weather".

Content-aware pens. contain digital functions that return ink, based on other ink-content as input. These pens allow users to leverage standard functions familiar from text editors and spreadsheets, but in a way that applies to ink content.

- Arithmetical functions over numerical ink content such as averaging or summing numbers. The pen gather ink inputs in a single stroke and display the result as it is computed.
- Text functions available in document editing tools such as "define word" "correct typo" or "thesaurus" cause the resulting word(s) to be added to the canvas.
- Visual text annotations such as highlighting or making text bold. Recognizing underlying ink content allows users to perform approximate ink strokes yet achieving adequately positioned visual annotations of ink.

5 STYLE BLINK PROTOTYPE

We describe our implementation of the components and techniques described above in a prototype ***Style Blink*** (Style Blocks + Ink) and describe how these enable to create a fluid and interactive notetaking experience [3].

5.1 Implementation

We implemented our system as a web-based application in JavaScript and run on a NodeJs server. We have used Paper for handling the geometry of the shapes, and collision. Our system support a reasonable amount of sentences/words which can be limited from the web technology we have chosen (Scalable Vector Graphics). Heuristics to build list items have been customized using pilot studies. The way to group elements in SyleBlink is to create a block of ink. One hierarchical level can then be created, avoiding nested structure to disambiguate case where children might have two different parents which might lead to some inconsistency, and incoherence in the interaction. All graphical elements are replicable using a touch+pan gestures avoiding then repetitive gestures.

5.2 Interaction

We outline below the overarching principles to create, modify and reuse the three basic components mentioned above (Dividers, Blocks, and Tags).

Users carefully hand-craft the style and/or content of a component with their pen to reuse it later. Taking the example of blocks, user can craft a particular style of block with a frame and ornamented bullets *(D1)*. This block can be then filled out later with content, in the spirit of a digital post-it.

Users duplicate a hand-crafted component in the page, saving substantial time *(D2)*. Holding the component with a finger and drawing the path to duplicate and lay them out with the pen. Components can be stored for future reuse in borders of the interface.

Each copy is separately editable both in style and content. Taking the example of blocks, altering the style of one block border will not change the others. Transferring style is however possible by holding the block with a finger and tapping an existing one allowing styling experimentation *(D4)*.

Users may lay out each component in more specific arrangements. They may also duplicate components filled with content or change their styles at any time. Taking the example of blocks,

[3] Short videos demonstrating the system are available as supplementary material and at https://styleblink.github.io/styleblink/

one can then fill them up and move them later as one would with post-it notes.

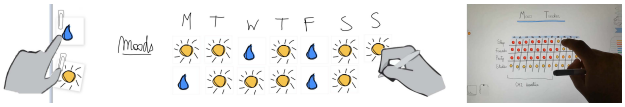


Figure 9: Creating and reusing tags enables composition of a unique set of visuals to categorize and encode information to create visual mood trackers. (a) Touching stacked tags with left hand (b) and draw using right hand to duplicate tags. (c) Resulting visualisation in the StyleBlink tool

5.3 Just one group level coupled with styling

Selecting the right tradeoff between the cost of an interaction technique and the value of its outcome is critical. In the case of notetaking, we believe that the cost of creating and navigating group hierarchies does not necessarily matches the value of crafting complex nested inked structures. It is especially true for live notetaking (as opposed to bullet journaling), as taking the time to navigate a menu or craft complex nested group structure in the UI, takes time and attention away from notetaking and may result in missed content. This is certainly why most notetaking software we surveyed do not offer any particular support for the creation of lists, tables and calendars.

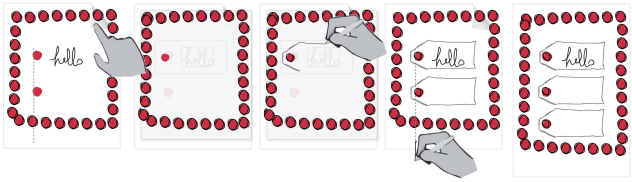
Figure 10

The tradeoff we propose is a single level of grouping coupled with a visual style that is reusable. Thus, each block of content has a style layer allowing users to craft (1) the block background, including its border; and (2) the style of a list item (bullet and item background).

A block can be created from existing content, or from scratch. To access the style layer of a block post creation, one uses the finger or pen to swipe in the top right corner of the block. This interaction dims the ink in the background and reveals the style layer. Figure 11 illustrates the creation and styling of Blocks. Note that blocks adjust to the size of their content or can be expanded explicitly. Blocks' styles can be applied to other blocks using bimanual gestures (hold a style layer and tap a different block), allowing for rapid experimentation while preserving blocks' content. ***Style-Blink*** also enables storing them in a pile, for quick access and reuse.

5.4 Annotating and indexing ink

Several elements and symbols are recurrent in notes, such as day-of-the-week *headers* in calendars, or stars and hearts *icons* denoting importance or appreciation. Headers play a big role when styling



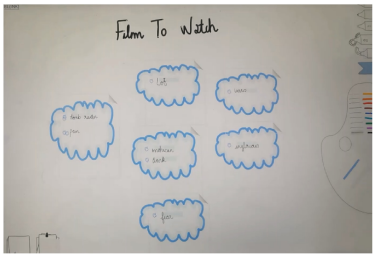


Figure 11: (a) Creation and styling blocks (b) Reusing blocks styling to create more content

notes given their saliency in the page. Their recurrence and positioning often contributes largely to giving a sense of organization to the notes. Icons, on the other hand, play a role in visual search and embellishments. Enabling notetakers to take time to craft these elements, but then also store and reuse them during notetaking, is designed to increase the visual quality of the output without requiring post-hoc styling, while minimizing disruption of the notetaking process.

Notes also contain recurrent keywords and *symbols* devised by the notetaker [12]. Some of these symbols are quite universal. For example, checkboxes placed in front of each item in a Todo list, are later checked or filled to indicate completion. Bullet journals [13] push this notion further and propose more extensive conventions for bullets to place in front of items, enabling people to keep track of multiple aspects evolving in their life. For example, notetakers encode different types of entries: • Task - Note o Event. Then, for each, evolve the bullet over time: • Task X Complete > Postponed. Supporting the creation of unique symbols (and their evolution) encourages a rich and personal notetaking experience.

We group headers, icons and symbols under the concept of Tags. Tags is a different type of instrument we provide for digital pens, in the spirit of physical bookmark stickers as stationery supplies. Users can spend time crafting beautiful headers for each day of the week, or devise their own bullet systems using Tags to reuse them multiple times in their notes. Tags are also *stackable* by dragging them on top of each other. A tap with a finger cycles through the content of the stack, making them interactive toggles that iterate through the states represented by the Tags (Figure 12).

Figure 13 illustrates how users can use tags in blocks. Tags are duplicated with a similar bi-manual mechanism as blocks. Users can store tags by dragging them to the side of the screen, thus pinning them in place despite navigating to different places in the canvas, which makes them conveniently available and easy to insert during the notetaking process.

Figure 14 illustrates the general walkthrough leveraging tags, fillable pens, collision ink and palette to craft interactive visual

Figure 12: Creating and stacking tags.

tables with ***Style Blink***. Our companion video available in supplemental material provides additional examples of the sequence of interaction to craft styled lists, tables, calendars and visual tables.

6 USER FEEDBACK

To gather different perspectives on the concepts we proposed, we recruited participants from two different backgrounds. Four participants –(J)ournalers– had experience in creative bullet journaling and analog self-tracking, while the other four –(N)otetakers– had experience in digital notetaking .

To gather hands-on feedback on our prototype and interaction techniques, we recruited five additional participants –(U)sers – all interested in journaling and owning a pen and touch device.

Given COVID-19, we conducted remote sessions via video conferencing. Journalers and Notetakers saw videos, while Users accessed the online application from their own devices. We followed a semi-structured interview format. In the first part of the study, we collected study participants' background and gathered their thoughts about digital inking, focusing on strenghts and limitations of current tools they experienced, what they thought were barriers to adoption as well as investigated their thoughts and ideas on styling ink. The remainder of the study was devoted to collecting immediate reactions on each concept illustrated in the video or experienced with the prototype one after the other. The interviewer delved into both positive and negative aspects for each concept, concluding the 1-hour session by asking about their most salient impressions. Note that the goal of this study was to gather high-level feedback on the core concepts proposed in this paper in the spirit of [45], rather than pinpoint low-level usability issues with the developed software. We thus report on users' general understanding and experience with our prototype and reflect on most/least compelling concepts introduced, as well as new interactive components and interactions proposed.

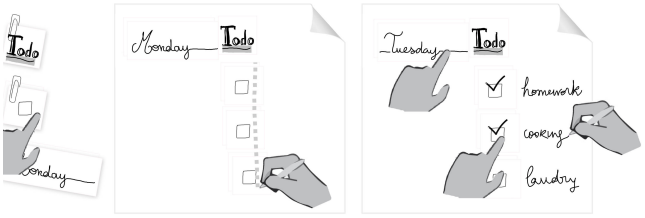


Figure 13: Duplicating stacked tags in blocks to create "interactive" headers and checkboxes.

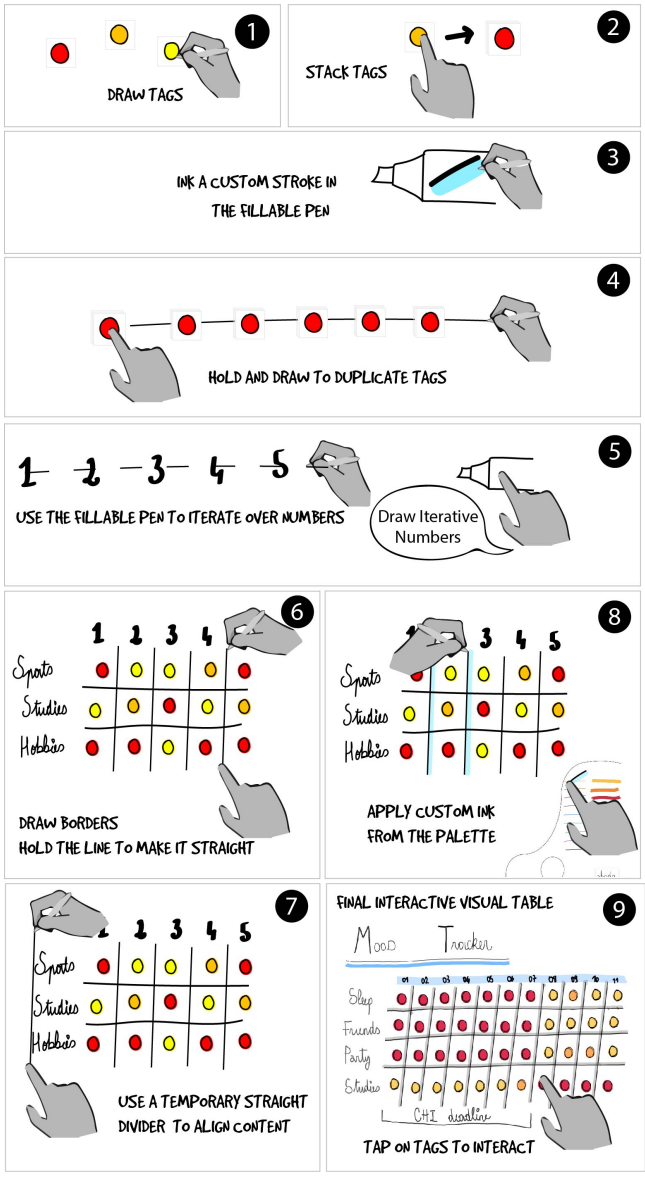


Figure 14: Crafting an interactive visual table in 9 steps.

In addition, it is important to note for the hands-on Users, that given the large number ideas and components featured in the prototype, not every participant explored them at same depth, nor were they ask to complete specific walk-through tasks from start to finish. Instead, we gathered feedback on individual concepts and components that participants experienced in a free-form manner.

6.1 Barriers to the adoption of digital inking

We report here feedback pertaining to the barriers of digital ink adoption for journaling and notetaking gathered in the first part of the study. We report how these comments relate to and support the design goals we articulated to compose rich and expressive notes.

Digital technologies **fail to support styling** *(D1)*, causing participants to have a harder time parsing and reading through their notes, and a loss of retention of the information. N3's comments reflected the general sentiment of our 13 participants regarding digital technologies for notetaking: *"I have tried to go paperless. But I'm not as successful as I want to be."* Depicting her own practice centered on styling notes with spacing, indentation and different encoding in the handwriting itself, N3 explained the main issue for her was this lack of styling made it difficult to read back the notes taken: *"At the end the problem is I can't, like, read through it."* She also reported that typing in her note resulted in *"less writing, so there's less retention"*.

In addition, participants reported that styling requires **a substantial investment** *(D2)*. All 4 journalers noted that they could not find any suitable software enabling them to *craft* their journal *"like an art project"*(J4). Two participants commented on their abandon of journaling altogether as it ended up taking too much of their time. *"I think like it was cumbersome and time consuming, more than providing value at the time"*(J3).

Participants also reported that digital interfaces are **disruptive** *(D3)* and a few indicated their wish for **more direct interactions** *(D4)*. They reported trying multiple apps and software on variety of devices and reported that *"the experience was getting in the way of the flow"*(J2). Too many menus and buttons were *"interrupting me, cognitively. So much that I couldn't use it, I just couldn't"* (J2). N3 also commented on transforming her ink noted she often just wanted ink to remain ink: *"like ou just draw lines. So like if I don't ever touch these lines, they don't change"*(N3). Finally, N1 noted that more *"natural"* interactions for moving ink must exist: *"I tend to start writing stuff and then think, oh, shoot, I wish I could move this and I do not like the lasso tool"*.

6.2 The value of styling

All 13 participants gave us insights on different aspects they valued when styling ink and described a variety of ways they used styling.

- **Organizing notes.** All four notetakers value styling as a tool to structure and categorize notes helping them parse, read and memorize the information.
- **A visual summary.** *"I write the notes, but then the notes have colored highlighting so that I can read at the like broad level"* (J1)
- **Crafting artifacts.** *"I enjoy the process of writing, but I do that [styling] more when I am creating something that's going to stick a little longer like a quarterly To Do List or whatever"* (J2)
- **Making it personal.***"The things that I really enjoyed the most was the like making it personal to me. It was a bit therapeutic."* (J3)
- **An emotional support.** *" To bring joy to my planner, which normally is kind of depressing ... So when I look at it, it's not as discouraging"* (J4)

While we might expected journalers to use an especially rich variety of styling strategies, notetakers also leverage multiple aspects of styles. For example N1 described the need for an extensive color palette: *"I do like having options that I can pick, like as many color options as I can pick for my own inking.. [unlike] notability [in which] color options are pretty limited"*. Notetakers already invested time and effort to fulfill their exact styling needs: *"Why I made them [list and calendar layouts]? so I was going to buy them ... but they didn't have the kind of patterns I wanted."* (N2) Participants commented on the **personal meaning of styling** they created for themselves:*"Bold mean something to me, like italicized mean something to me, also, like if I write something bigger"* (N3). They also described a constant evolution of their styling strategies over time: *"I started doing like little icony things for the accomplishments"* (N4)

6.3 Feedback on key concepts

Crafting & reusing blocks. to achieve larger designs is perhaps the idea that resonated most with participants to save them time and effort. J3 commented that this strategy addressed the main issue with analog journaling: *"This is exactly why I stopped bullet journaling. It is because like with pen and paper, you can't save time on creating each and everyone of these things and then also, for example if you like decide to put more content than you expected, then you have to restart all"*. Notetakers also appreciated eliminating redundancy: *"I feel like there's a lot of redundancy that it takes care of styling, highlighting"* (N2)

Journalers commented positively on the **aesthetically pleasing uniformity** of the templates they could create: *"I like how it's so uniform like this, it appeals to me these boxes over there just like having the same highlighter [stroke] in the background"*(J4). In contrast, notetakers were generally more excited by **styling *a posteriori***, rather than creating templates: *"so you're setting up your canvas and I think for me I don't ... I do not do pre-formatting"* (N3).

our users generally found the interaction to duplicate easy to perform. Only U2, left-handed, noted that it was a bit awkward for her. However, she appeared delighted at first few uses and commented *"it [duplication] is super useful for styles, especially across pages"*. She thus asked for additional ways to interact to duplicate elements, possibly just by using a single hand. Three out of five of our users struggled to access and modify the styles of blocks. Part of such struggle was the learning curve, and part was the usability (participants often dragged rather than swipe on the corner). U2 found it natural to create with the special pen, and appreciated it mostly as a *"group of ink that you can move together"*. U3 noted that it was valuable but she likely would not have discovered it.

The dynamic palette. was also unanimously praised by participants, several commenting on a metaphor of the real painter's palette: *"It's like back to true like ink artist palettes, which is like you can be super organized and like draw a little squares [or] you draw whatever you want. And I like that. That speaks to me." (N3)*. They also emphasized several other aspects for their positive reactions.

- A less disruptive interaction: *"I feel like right now there's one of my frustrations with using pen in the apps. Is like you have to do this stuff and then you have these like weird, unnatural steps to change color or thickness or like fighting with it." (N4)*
- A more direct visual feedback: *"It's more like immediate visualization as opposed to like abstract line thickness that you see." (N2)*
- Feeling less limited: *"this is definitely way nicer because it's like you are not limited to whatever the palette gives you." (N2)*

- A compact and custom storage: *"I love the idea of being able to save your strokes, like with the thickness and the colour there in a more compact way than a separate pen each time." (N3)*
- Changing ink a posteriori: *"I really I'm so color sensitive and that's why I have so many pens, so having the ability to have some control after the fact ... that would be amazing." (J2)*

Hands-on users generally had a few minutes of learning curve for the bimanual interaction to control stroke thickness and saturation. Yet, all commented positively on it. U5 noted that changing stroke thickness was *"a bit unusual"* but useful to *"match the stroke to the script size after the fact"*. U3 stated that the palette was valuable as *"a mini workspace, you can store your own ink the way you want"* but that *"it looks a bit messier"* and thus, while for painting or sketching it would be fine, one might require a cleaner more organized look when collaborating with people over work sessions.

The concept of collision ink. was also very well received by all of our participants, commenting on its seemless integration without the need to switch to particular pen instruments our insert a specific object. *"This is very nice is it like an organic table formation." (N2).* Several participants described situations where they would choose to not use special objects of features leading to frustrating erase/rewrite cycles. It is interesting to note that their perceived effort to insert a special table object or fix the result of an ink-to-table conversion is higher than erasing and rewriting large portions content. One participant also noted leveraging ink as a layout instrument as she *"frequently misjudge spacing"*, noting that she would *"use it as a mechanism for just moving stuff around instead of using the lasso or using the sticky note thing that you just shared, like I would draw lines and move things and then maybe erase the line if I didn't want the line there." (N1)*

This was perhaps the most exciting feature for our hands-on users. Participants found the ripple effect *"fun" U1* even though, it became noticeably slower in our prototype implementation when reaching a substantial number of strokes. Users commented positively on using collision ink for aligning ink: *"If you do bullet journaling, you do a lot of alignment, this [bimanual pen and touch gesture for straight lines and colision ink] would be super useful" (U5).* U3 was the only one with a more nuanced opinion *"Part of me is like Wow, it's really nice cause I can draw anything. But I am not sure I would use it that much for layout, I am used to [lasso select + move]"*.

Tags & interactive visual tables. Journalers were particularly excited about duplication and piling of tags, as it enabled them to limit time invested in filling their journals: *"you can invest some time in creating your own stickers and stuff and going through that process 'cause that's part of why bullet journaling is great, but you don't always want to do that ... I like that it reduces that everyday time investment. Because, like, that's basically one of the biggest barriers to entry and keeping one of these things." (J3)* Six of our participants expressed the magical and "cool" effect produced by piling tags and the potential they wanted to explore. It intrigued them to think of what designs they could create *"I'd certainly want to try it and see if it got me excited about digital journaling." (J1)*

Users generally loved the concept of tags and 3 of them highlighted it as their most wanted feature from the prototypes. Usability was very good and users drew different types of interactive tags, commenting on their own personal visual vocabulary.

While the four concepts above were received very positively by our participants, the other ideas we presented on bimanual gestures and fillable pens gathered more polarized feedback.

Fillable Pens. were intriguing to many of the participants. All eight of them commented on the compound-ink pens as *"such a cool idea"*, *"enticing"* and providing a simple mechanism to craft uniform and beautiful border and decorations. However, participants were more reserved on using fillable pens to apply particular functions such as summing numbers as we demonstrated. They either felt the interaction of loading the pen disruptive *"I would actually prefer that you could just say what it is as you are circling." (N3)*, or could not think of frequent situations where they would need such functions.

In contrast, all five hands-on users loved using the fillable pens. *"You have no idea how much I love these fillable pens. I absolutely want these"* (U3). Users often made delighted sounds as they used them across the canvas *"whoohooo! that is definitely cooool" (U2)* and commented positively on the resulting strokes: *"If I sent people cards, this [results of strokes with fillable pen] would make them smile" (U5).* U2 also commented on the value of these pens stating that *"it makes it a lot faster to try and make cute designs"*. The only comment about usability was the size of the canvas to draw within the pens *"it's a really small area to draw in" U1*, especially on a smaller form factor (U1 used a 12-inch surface pro 3).

Direct manipulation & bi-manual gestures. also received polarized reactions. N3 summarized the problem most participants related to: *"With gestures it is just like I think they are super cool. But I can never remember what they are." (N3).* Several participants also commented on the difficult to discover and learn these gestures in the first place. However two participants found an important value in using these bimanual gestures and noted that they resonated with them: *"it immediately just like makes sense" (N4).*

Users also echoed these concerns and the need for more traditional alternatives. U2, left handed, express some awkwardness at performing bimanual gestures. U5 noted *"it's a little annoying. It makes you feel like a super user, a little bit of pride, but a bit fiddly."*.

Overall, seven participants commented on their excitement of trying the system compare to existing software: *"what's interesting is most of the things that I've seen digitally have not really felt like I was even going to care to connect those pieces 'cause they were so far from what I would use, but this one I actually got like, oh OK, I could actually see using that." (N4)*

7 DISCUSSION AND FUTURE WORK

We first discuss what aspects transfer from styling visual journals to styling notes. We then discuss a set of implications for the design of digital applications supporting the styling of notes.

7.1 From styled journaling to styled notetaking

Our initial intent was to learn from bullet and visual journaling to design styling interactions and tools for notetakers. Reflecting on our designs and feedback from both population of users, we identified salient commonalities and differences between these styling practices:

A different planning investment. Journalers invest substantial time and effort to setup their journal whereas notetakers have a very low investment in planning. In fact, their threshold for this initial effort *before* taking notes is extremely low. They would not even navigate the UI to insert specific objects or turn on a ink-to-table feature. Yet they spend much time organizing and fixing once content is in.

A different learning investment. Journalers spoke of community and following various accounts and tutorials to learn styling techniques and discover assets or applications to help them in their practice. The time, energy and pleasure they invest for discovering and learning styling features is much more substantial, more akin to what one would engage to for a hobby. In constrast, notetakers expect an immediate and tacit use with minimal investment for learning, as they would take note on analog medium.

The key role of styling. Styling is important to both journalers and notetakers, although from slightly different angles. Our interview confirmed that offering styling mechanism within notetaking applications would benefit the larger audience.

Personal and evolving strategies for styling. Our interviews only uncovered a small part of the richness and diversity of styling techniques. A key insight reported by the majority of the participants is the constant evolution and refinement of these strategies overtime, whether for journaling or notetaking.

A limited bandwidth for editing styles. Erroneous or imperfect styling yields frustration, yet participants have a limited bandwidth for editing or fixing issues. Journalers, often relying on an analog medium have limited tools to fix issues and often report choosing to invest effort to restart from scratch. Notetakers, on the other hand, have limited time to fix these issues as they are often occurring in live sessions, and rarely spend time afterwards.

7.2 Design considerations and open problems

Synthesizing the insights we gained from our prototype and user feedback, we formulate key learnings for the design of interface components and interactions focused on styling of notes, outlining open problems for future research.

The "small building blocks" principle. Our study suggests that providing building blocks, coupled with styling for users to craft and compose larger design is a promising idea. As styling strategies are personal to individuals and in constant evolution, building blocks offer a greater flexibility than impersonal full-page templates. However, hands-on users had some learning curve and did not immediately understand the interaction model to access block styles. This suggests investigating different interaction mechanisms for style-blocks.

Post-hoc granular interactions. Because of the limited bandwidth users have to alter or fix issues while taking notes, making interactions easily accessible (as direct as possible), granular (not requiring series of steps at once) and seemless between styling and capture is important.

Magical vs Predictable. While everyone reported excitement and wonder about AI-based experiences such as our function pen recognizing inked numbers and summing them, notetakers also explained that, as enticing as they are, they had often abandoned similar "magical" experiences in the past. Their reasons for doing so mostly dealt with the lack of predictability of their results, either because of the unreliability of the underlying recognition mechanism, or because they expected it could achieve more than it actually did. Exploring ways to making these magical experiences predictable appears an interesting avenue for future research.

Discoverability & learnability. We received positive feedback on the discoverability and learnability of instruments employing physical metaphors (e.g notion of post-it for style blocks and stickers for tags). However, discoverability of more abstract concepts such as which digital functions are possible to load into fillable pens was more reserved. Participants also reported concerns for gestures and bimanual interactions, noting that inconsistency with existing apps dmade them doubt whether they would be able to remember such gestures. Considering these issues and tending towards a universal interaction language remains one central goal our community should pursue.

7.3 Future Work

In future work, we are keen to explore the generality of the concepts we have explored in this paper. Our work hints that it is possible to reconcile computational or programmatic notions of style with free-form, non-disruptive natural interactions using pen and touch. Additionally to the user study we have performed to evaluate StyleBlink features, we'd be interested in exploring the use, re-appropriation, and sustained adoption of the StyleBlink tools through a longitudinal study.

8 CONCLUSION

Our research explored styling for semi-structured notetaking, proposing a set of ideas to enable users to handcraft styled structures such as *lists, tables and calendars*. We implemented these ideas in the ***Style Blink*** prototype, surfacing styling as a first-class activity and providing several mechanisms — *Style Blocks, Dividers, and Interactive Tags* —, and pen instruments — *Fillable with Commands, Composites, and Patterns* to accomplish it. The interview feedback from 13 users (4 bullet journalers, 4 digital notetakers and 5 users) outlined promising concepts while also revealing further opportunities for research. We believe these concepts could be extended beyond notetaking, especially to graphic designers or infographic designers.

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