BananaNab: Using Non-Traditional Time Visualizations to Mitigate Time Blindness in ADHD Individuals

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ABSTRACT

"Time-blindness" is a key trait in individuals with Attention Deficit Hyperactive Disorder (ADHD), defined by difficulty perceiving and adhering to normative structures of time. Thus, conventional timers have proven largely ineffective for such individuals. We target this opportunity gap by exploring alternative ways of visualizing the passage of time outside of usual numeric conventions to increase task focus, while minimizing distractibility. We created a time visualization tool that manifests as a Google Chrome extension to provide seamless integration into a user's existing browsing routine.

Author Keywords

human-centered computing, human computer interaction, adhd, time blindness

INTRODUCTION

Recent innovations in assistive technologies for ADHD aim to improve working memory (voice notes, reminder apps) and self-regulation (productivity apps, habit trackers). However, there are significantly fewer existing assistive technologies created to target another key ADHD characteristic: time-blindness, defined as difficulty in sensing the passing of time [4] [5]. Since ADHD individuals require different conceptions and representations of time, conventional timer and calendar apps have proven largely ineffective [6].

We're hoping to target this opportunity gap by creating a simple narrative visualization tool for time passage for people with ADHD. How can we maintain engagement and improve time consciousness, while not posing a distraction to ADHD individuals? How does our tool compare to traditional time management tools? Drawing on accessibility design theory, we want to shift our focus from *dis*ability to ability [11]. How can we build our system to best supplement the unique set of behaviors ADHD individuals exhibit, instead of focusing on what they are unable to perform?

RELATED WORK

In our review, we explored current research surrounding enabling individuals with ADHD to succeed with time blindness.

We first found alternate ways of understanding time beyond the standard analog or digital clock. Eriksson et al. built Takt, a wearable that uses haptic feedback paired with activity-based visual representations to enable ADHD individuals to tell the passage of time [7]. Rather than relying on traditional depictions of hours and minutes, Takt enabled ADHD individuals to organize a stretch of time into an ordered set of activities and use their senses to perceive time instead. The initial design includes haptic feedback in the form of a constant, interval-set vibration that constantly indicates the passage of time to the user, as well as visualization of time duration that is only visible when an activity is ongoing or activated by the user in order to reduce cognitive load. The visual stimuli paired with haptic feedback helped the users feel time, rather than simply tell time.

We also investigated fields that have proved beneficial for ADHD individuals. Video games seem to be an effective tool in increasing planning, decision-making, and communication skills. Researchers have recognized the effects of gaming intervention on individuals with ADHD for improving attentional performance [8], executive function [1], and learning in educational environments [3]. Supangan et al. created a gaming learning app with animated presentation and audio feedback that was approved for special education services [10], and Belter et al. explored the promising use of VR in formal ADHD education as a more engaging and immersive visual learning experience [2].

The use of immersive narratives has always been a key feature in modern games. The use of narrative as an element in alternative settings such as education and personal tracking has also gained traction. Murnane et al. presented a smartphone app system named WhoIsZuki that visualized physical activity goals with a narrative quest, and tied character and user progress together [9]. The paper explored alternative ways to encode data through narrative because of the strong body of literature that showed how narratives can be motivational through immersion and emotional engagement.

UNIQUE CONTRIBUTION

Related works in the literature have covered the psychology of different time encodings for ADHD individuals with time blindness. We have encountered papers that use wearables and others that use visualizations to encode the passage of time. However, we have not seen a visual implementation that specifically considers the influence of narrative as an aid for time blindness.

Inspired by all these ideas, we developed a visualization tool to encode the passing of time through an accessible web browser extension and incorporated narrative elements. We did not build a storyline as in-depth as WhoIsZuki, since we simply wanted to add some aspects of narrative such as granting our character a personality and a goal to enhance user engagement. We focused on features to minimize distractibility and stress while maximizing focus, such as rendering time as a fun visualization instead of a constantly ticking timer, keeping the visualization small enough to not obstruct the rest of

the browser, and allowing the user to dynamically change the timer.

In addition, an effective strategy for individuals with ADHD to mitigate time blindness is to track time spent on tasks and display it readily. It was noted that there was "a high opportunity" to create time visualization software that could allow the user to "see time visualizations constantly"[4].

To motivate the creation of our prototype, we hypothesized that our alternate visualization timer would keep users more focused on a current task as compared to the system timer one might find on their smartphone.

Our primary objective is to contribute the following:

- A novel approach for assisting ADHD individuals with time blindness through digital narrative-based time visualizations that incorporates theories on narratives, gaming, and effective data visualizations.
- A prototype of a browser extension that blends into a user's existing browsing routine, maintains primacy on the screen, and maximizes focus.

DESIGN & IMPLEMENTATION

System Overview

We created a Chrome extension that visualizes the passage of time through a monkey named Boomba climbing a tree to reach a banana. Time is encoded as Boomba's position on the tree and her position is calculated based on the initial timer value and the amount of time remaining. As the timer counts down, Boomba climbs the tree to reach the banana, making a happy sound once the timer is done to alert the user.

We drew upon previous papers and HCI theories to build our system, with a particular focus on the gap in time visualization tools that don't use numeric conventions [4]. We brainstormed ideas and features through an iterative design process, basing edits on HCI theories in accessibility and emotional immersion.

We chose to create our system as a Google Chrome extension because of its accessibility, ease of use, and simplicity of implementation. This choice was based on evidence that there was a high opportunity to accommodate the ADHD student more fully with a timer that overlays the user's working window [4]. This allows it to maintain visibility on the screen, even outside the page in which the timer was created. In addition, we wanted our system to be seamlessly integrated into a user's casual browsing routine, rather than an external tool that a user would have to go out of their way to check.

We created the tree, monkey, and banana pixel art through Piskel, a free online sprite editor. JavaScript, CSS, and HTML were used to code the Chrome extension.

The Timer

BananaNab's system consists of 2 main components: the timer and the visualization. To access the timer, the user can click on the extension icon in the Google Chrome extension toolbar. A popup will appear, containing all of the timer's controls. Here, the user is introduced to Boomba and her goal of reaching the banana, paralleling the user completing their task. Within this popup, users can:

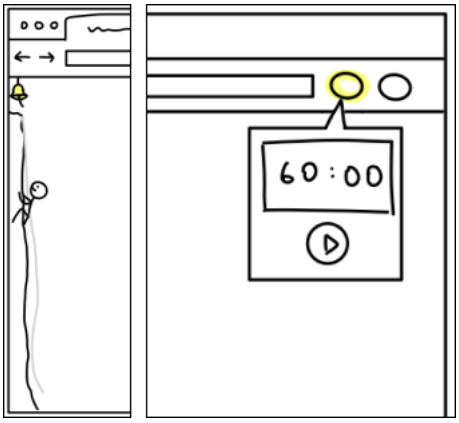

Figure 1: A preliminary low-fidelity sketch of the interface.

- Set an initial time
- Play
- Pause
- Stop
- Add 1 additional minute

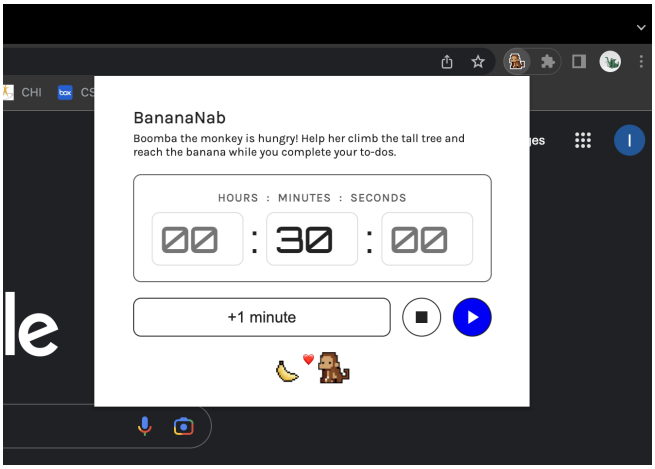

Figure 2: A screenshot of the popup when the user clicks on the extension logo and inputs a starting time of 30 minutes.

Set an initial time: When setting the timer, the user can input time in terms of hours, minutes, and seconds. Notably, the timer can also calculate irregular inputs. For example, given an input of 00:90:00 (90 min), the timer would re-calibrate to display 1:30:00 (1 hr 30 min) upon clicking play.

Play: Clicking the play button will start the timer and cause Boomba to start moving, as well as change the play button to a pause button. While the timer is running, users can click out of the timer popup, click on links in their current tab, and navigate to another tab all without interrupting the timer.

Pause: Clicking the pause button will temporarily stop the timer and cause Boomba to stop moving. However, the previ-

ous time will remain on the timer display, ready for whenever the user wants to resume.

Stop: Clicking the stop button will halt the timer and cause Boomba to reset to her initial position at the bottom of the screen. In addition, the timer display will reset to its placeholder values, ready for new input.

Add 1 additional minute: Clicking the "+1 minute" button will add one more minute to the timer. This feature was included to reduce stress around adhering to strict time conventions, allowing the user to dynamically adjust time as the task unfolds. If pressing the button causes the minutes displayed to reach 60, the timer will re-calibrate, incrementing the hours displayed to increase by 1 and resetting the minutes displayed back to 0.

The Visualization

The visualization component of BananaNab consists of Boomba the monkey, the tree, and the banana at the top of the tree. When the user opens the timer popup from the Google Chrome extension toolbar, the visualization will appear as an overlay on the current web page. This visualization overlay persists on the left side of the screen for the duration of the timer. from when the user opens the popup to when they close the tab. This is in contrast to the timer popup, which only appears when the user clicks on the extension icon in the toolbar, and will disappear if the user clicks elsewhere in their browser window.

Figure 3: Boomba while the timer is in progress.

Figure 4: Boomba when the timer is finished.

Initial state: When the timer is has no input or is set to 0, Boomba remains at the bottom of the screen.

Transitory state: Once the timer has been set, Boomba will start to move up, with her position calculated as:

$$\frac{\text{totalTime - remainingTime}}{\text{totalTime}} \times \text{windowHeight}$$

Here, time is calculated in terms of seconds.

End state: On the final second, Boomba will transition into her end state. Boomba rotates to face the banana and a red heart appears, mirroring the interface in the timer popup. Boomba has completed her journey to the top, just as the user has completed their task.

Connecting the System

Since the timer was contained in the extension popup and the visualization was contained within the web page, we had to ensure these two components were communicating and working in sync to execute proper timing. To explain how we accomplished this, we can first start with a brief explanation of Google Chrome extensions.

Parts of a Google Chrome Extension: A Google Chrome extension can consist of three parts - the popup page, the content script, and the service worker.

The popup page is what appears when the user clicks on the extension icon in the toolbar. In our case, it was our timer interface, and also the source of all user inputs. Once the user sets the timer and clicks play, that information is sent to the service worker.

The service worker contains scripts that monitor for and handle events. Events are browser triggers, such as navigating to a new page, removing a bookmark, or closing a tab. In contrast to the popup page that ends everything once the popup is closed, the service worker is always running in the background. This is particularly useful for keeping track of important variables like time remaining, and also receiving messages from popups or content scripts, all of which were used in BananaNab.

The content script is a file that runs in the context of the web page. By using the standard Document Object Model (DOM), the content script is able to read and change the web pages that the browser visits, as well as pass messages to other parts of the extension.

BananaNab Walkthrough: To understand how the popup, service worker, and content script were able to work together to power the timer and the visualization, we can walk through an example user journey.

Let's say the user is ready to start their task and use BananaNab. Upon opening the popup, the popup notifies the content script and instructs it to display the visualization, with Boomba at the bottom of the screen. The popup also asks the service worker for the time status, in case a timer had already been running. Since the status is undefined, the timer starts off with blank inputs and no running time.

The user then inputs a time of 20 minutes and presses play. In response, the popup updates its timer interface and notifies the service worker. The service worker keeps track of variables

like *remainingSeconds*, *totalSeconds*, *timerInterval*, and the booleans *running* and *paused*. The service worker updates its variables and sets an interval to update its time every 1 second. Also inside this interval, the popup notifies the content script to move Boomba, ensuring that her position will update every second. If the user ever leaves the popup, the timer will still be running the background, managed by the service worker. When the popup is opened in the future, the popup page will first ask the service worker for the time, and set the timer's time and running status accordingly.

The user then decides they want extra time, and clicks on the "+1 minute" button. The popup page sends a message to the service worker containing the new time information, and the service worker updates its own variables.

If the user ever decides they want to stop the timer, they can open the popup page and click the stop button. The popup page will then update its own interface and notify the service worker to end their interval and reset variables. In addition, the content script will also receive the message to reset Boomba's position, moving her back to the bottom of the screen.

After 21 minutes have passed, the timer is done! If the popup page is open, it will reset its interface and notify the service worker to stop its interval. The service worker will then pass along the proper instructions to the content script, including playing the Boomba's happy sound and displaying the visualization's loving end stage. With that, the timer is back to where we started, ready for another input and more rounds of communication across its different parts.

EVALUATION AND RESULTS

User Study Protocol

In order to test the usability and user affinity of BananaNab, we investigated its use against a traditional timer. To accomplish this, we conducted a preliminary evaluation of our BananaNab prototype with 6 college-age students (4 females, 2 males) from Stanford University. All participants had ADHD. Our study consisted of two trials.

- **1st Trial**: Participant uses the default timer on their phone.
- **2nd Trial**: Participant uses the prototype extension as their timer.

In each round, the participant was to complete two stages: read an opinion article (around 1130 words each) of our choosing from the New York Times that the participants had not read before, and write a short response to the article.

We chose reading and writing tasks because of three reasons. Firstly, reading and writing are tasks that require sustained attention and focus. Secondly, reading and writing are universal skills across different fields of study and majors, so our participants could work on a task that commonly occurred in their lives. This also meant that the task wouldn't require domain-specific knowledge, compared to answering math questions or coding. Thirdly, there was no clear end to the task— participants could keep writing until the timer was up or stop early.

Before starting each round, the participant estimated how much time it would take for them to finish both stages. The time estimation was not tested— we only wanted to see how the participant would use the timer as they would on a day-to-day basis. Once the participant was finished with each round, we asked several questions regarding their qualitative experience reading and writing with the respective timer. We also quantitatively measured the number of words written in each response, time remaining if any, and the Flesch-Kincaid Grade Level score of each individual writing response.

Discussion of Study Results

Most users had either neutral or positive opinions regarding the extension. Participant 1 stated that the fact that because there were no numbers explicitly shown on the visualization, it prevented them from fixating on the precise amount of time left. During the 2nd trial, this allowed them to focus more. Participants 1 and 3 said they noticed the visualization in their periphery throughout the task, but that it did not pose a distraction, while Participant 4 said they did not notice it at all until they were finished with their task. Participant 5 stated that the visualization was helpful towards the end of their task, and they were able to finish exactly on time as a result.

On the other hand, Participant 6 found that both the timer and the visualization for the 1st and 2nd trials were stressful. They also mentioned that they have anxiety, and prefer stopwatches to timers because seeing numbers counting down makes them anxious. They found the visualization very distracting in their periphery.

We also received feedback regarding additional features and different use cases. Participants 2 and 5 both stated that they would like to have milestones or checkpoints indicated along the monkey's path to help with time perception. Participant 3 stated that the visualization would have been more helpful if they were completing a time-pressure task; Participant 4 stated that they would rather use the visualization for tasks where they were frustrated or confused with work, which are points where he finds it difficult to maintain attention.

We calculated the Flesch-Kincaid grade level scores for the writing responses written by each of the users for both trials. This score is derived from a widely used readability formula that assesses the approximate reading grade level of a text. It is calculated as follows:

$$206.835 - 1.015\left(\frac{\text{total words}}{\text{total sentences}}\right) - 84.6\left(\frac{\text{total syllables}}{\text{total words}}\right)$$

We observed that 50% of participants increased their Flesch-Kincaid grade level score in the second round, while 50% decreased [Figure 5]. Overall across all participants, their Flesch-Kincaid grade level scores improved by 1.33% between the first and second rounds. In addition, the majority of participants in our study reached a writing score of grade 12 and above, indicating college-level writing complexity. However, our goal was not to ultimately achieve more complex writing, but rather to improve participants' focus and awareness of time and reduce distractions and stress. Because of

that, in addition to the variability in writing response length across participants, we cannot discern much more meaningful information based on the Flesch-Kincaid grade level scores alone. In further evaluations of this system, we hope to identify quantitative metrics that better capture the goals of our extension. An overview of key qualitative findings from our user study can be found in Table 1.

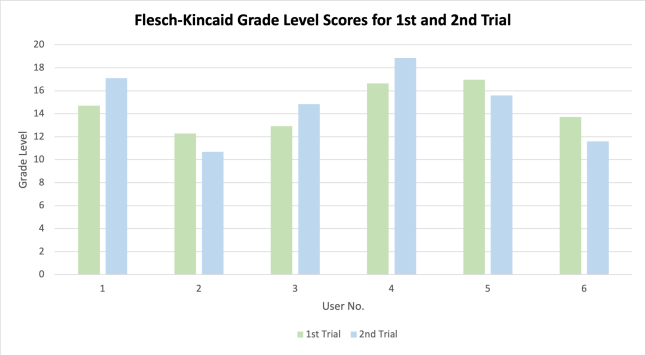

Figure 5: Flesch-Kincaid grade level scores for 1st and 2nd Trial writing responses for each user.

LIMITATIONS

In our study's limited time frame, we had to acknowledge several limitations of our prototype.

We still have a few bugs to fix. Firstly, we are able to get Boomba and her tree to appear on a tab by clicking on the extension's logo in the top-right corner, but the user has to click on the logo for every tab the user wants to see Boomba overlaid on. It would be more convenient for Boomba to show up on the user's entire window instead only on a singular tab. Secondly, when Boomba was open on multiple tabs, some tabs showed larger-scale Boombas as compared to other tabs. We found this bug during participant testing which may have impacted some participant results.

We also were testing with a fairly small sample size. Two of our participants had co-existing disorders (i.e. dyslexia and anxiety) that could have been confounding factors. One participant also mentioned that doing the same activity twice in a row made doing the activity the second time around easier than the first. In the future, we would like to change multiple aspects of our study. Firstly, we want to increase our study sample size. Secondly, we want to understand how confounding variables affect our study results and if we should change the design of our study to better identify the sole effects of our prototype. This would also be helpful for selecting metrics for the prototype's effects. We currently use Flesch-Kincaid Grade Level scoring but this identifies the grade level of the writing response, not how concise the writing is as mentioned previously. Some discussion may be needed for identifying a better metric for task focus.

FUTURE WORK

In the future, we plan to investigate greater personalization and functionality for user needs. Some users found a larger Boomba size (caused by a bug) to be very distracting, in

Table 1: User Study Key Findings

User No.	Key Findings
1	· Forgot to check system timer during first trial until notification lit up phone, then remained distracted by phone for the remainder of the task · While using extension, the lack of numbers prevented fixating on the amount of time left · Extension always in periphery but not distracting
2	· Did not check the system timer after set because said it was distracting and wanted to practice estimating time left · Thought it would useful to know how much time had gone past within the prototype timer (e.g. 5 min increments on a 15 min timer) · Also has dyslexia
3	· Found prototype easily viewable in peripheral vision and made them more aware of time · Mentioned that they usually read articles/papers over the span of several days or not at all · Said prototype may have been more helpful if under pressure from a deadline since overlaid timer kept him accountable under time
4	· Never looked at timer for both trials · Was invested in the monkey's progress because he found it cute · Did not find the monkey to be a distraction, did not notice it all throughout the 2nd trial · Would rather use the extension for keeping him on task when he is frustrated or confused with work (frequent points where he loses focus)
5	· Found that seeing the monkey towards the end of the timer (when it was higher up the tree) helped · Mentioned that writing the second time around was easier because they knew what they were doing
6	· Cringed when they heard the monkey sound at the end of the timer · Found the size of the monkey to be too big and distracting, especially during the writing stage. They felt accountable because but mentioned feeling "too accountable", and stressed her out to the point where they were "writing whatever" to finish before the monkey reached the top. · Also has anxiety

Table 2: User Study Flesch-Kincaid Scores

User No.	Round 1 FK	Round 2 FK	Percent Change
1	14.7	17.1	1.16
2	12.29	10.68	0.87
3	12.92	14.84	1.15
4	16.63	18.86	1.13
5	16.95	15.59	0.92
6	13.71	11.59	0.85

which case they wanted everything scaled down. A proposition would be to let users decide how large they want the assets to be. Other users found not seeing the timer ticking down to be very helpful, though wondered if there were tasks where it would be useful to know when they were halfway through the timer. A proposition of this would be to add bananas as milestones every 10-minute increment or so. We also plan to find more sounds that could be appropriate for the end of the timer. We plan to continue testing these changes with more studies in the future.

CONCLUSION

In this paper, we presented BananaNab, a Google Chrome extension for ADHD individuals and others with time blindness to help keep users on track while accomplishing their tasks. The preliminary evaluation our BananaNab seemed promising in helping ADHD individuals focus on tasks as compared to the system timer. Our results show that there are still many promising unexplored methods of visualizing time, and is encouraging in how narrative can combat time blindness for a wide range of individuals.

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