Assessment of Stimuli for Supporting Speed Reading on Electronic Devices

Tilman Dingler, Alireza Sahami Shirazi, Kai Kunze†, Albrecht Schmidt
VIS, University of Stuttgart
Stuttgart, Germany
{firstname.lastname}@vis.uni-stuttgart.de

†Keio University
Yokohama, Japan
kai.kunze@gmail.com

ABSTRACT
Technology has introduced multimedia to tailor information more broadly to our various senses, but by no means has the ability to consume information through reading lost its importance. To cope with the ever-growing amount of textual information to consume, different techniques have been proposed to increase reading efficiency: rapid serial visual presentation (RSVP) has been suggested to increase reading speed by effectively reducing the number of eye movements. Further, moving a pen, finger or the entire hand across text is a common technique among speed readers to help guide eye movements. We adopted these techniques for electronic devices by introducing stimuli on text that guide users' eye movements. In a series of two user studies we sped up users' reading speed to 150% of their normal rate and evaluated effects on text comprehension, mental load, eye movements and subjective perception. Results show that reading speed can be effectively increased by using such stimuli while keeping comprehension rates nearly stable. We observed initial strain on mental load which significantly decreased after a short while. Subjective feedback conveys that kinetic stimuli are better suited for long, complex text on larger displays, whereas RSVP was preferred for short text on small displays.

Author Keywords
Speed reading; RSVP; kinetic stimulus; mental load; comprehension

ACM Classification Keywords
H.5.2 User Interfaces: Style guides

General Terms
Human Factors; Design; Measurement.

AH '15, March 09 - 11, 2015, Singapore, Singapore
Copyright 2015 ACM 978-1-4503-3349-8/15/03 $15.00
http://dx.doi.org/10.1145/2735711.2735796

INTRODUCTION
Reading is an ancient activity traditionally taken up for information gain and pleasure. With the advent of the information age and the creation of electronic reading devices - such as mobile phones, e-readers or tablets - our reading behavior has been changing and we are facing new challenges, one of which being information overload. We are bombarded with an abundance of text on a daily basis: news, emails, tweets, feeds, books, papers, articles, technical literature and pleasure readings. But our reading strategy has mainly remained the same. Formal reading education stopped after graduating from primary school. From here, individual differences develop based on the amount and type of what people read [23], i.e. the development of reading practices.

Naturally people develop their innate reading, skimming and skipping strategies. Speed reading techniques are a much discussed topic that has gained many followers over the last decades. Studies conducted are often disputed, but agree on a natural trade-off between reading speed and comprehension levels. Various techniques are taught by books and seminars that allegedly enable speed reading, such as [5]. Rapid Serial Visual Presentation (RSVP) has been proposed as a reading technique to push a reader through a text by displaying single or groups of words sequentially in one focal point. Recent Web apps have spurred excitement around the prospect of achieving higher speed reading by effectively reducing eye movements (saccades). Other common techniques include the use of a kinetic stimulus (such as a moving hand, pen or finger) to guide a reader consistently across lines of text.

To investigate whether such techniques can be applied to reading on electronic devices and to explore their feasibility, we assessed two stimuli: 1) the RSVP method by using the open source framework *Squirt*[1] and 2) a kinetic stimulus in form of a dynamic text underline effect (Fig.1a). In two consecutive user studies we evaluated these approaches according to effects on reading speed, comprehension, mental load, eye movement data and subjective feedback. First, we conducted a lab study in which we collected data about eye movements, mental load and comprehension levels of 24 participants. In the second study, we collected subjective feedback data from 108 participants in an online experiment comprising reading text with both stimuli.

The contribution of this paper comprises the 1) description of applying speed reading techniques to reading on electronic

[1] http://squirt.io/ (last accessed 13.02.2015)

devices, 2) the introduction of a kinetic stimulus to actively increase users' reading speed, and 3) an investigation of the effects of RSVP and the kinetic stimulus on text comprehension, mental load, eye movements and subjective perception.

BACKGROUND AND RELATED WORK

In the following we point out related work that inspired this work and introduce basic speed reading approaches as they are applied by speed readers and commercially taught.

Cognitive effects of reading

Stanovich and Cunningham [23] applied the "Matthew effect" to reading, which describes the concept of a rich-get-richer and poor-get-poorer phenomenon. Hence, poor readers tend to expose themselves to less text than their more skilled peers, thereby increasingly corrupting their reading skill level. They showed that much of what we read directly influences our language skills and the size of our vocabulary. Boosted language skills again contribute to the development of higher cognitive functions like reasoning and judgement [17] and also lead to a greater general knowledge about the world. Pronin *et al.* [19], in a series of experiments, linked the acceleration of thought processes to joy-enhancing effects, rapid reading being one of those methods used for accelerating thought. Hence, we started looking into ways to help people read faster and more.

Increasing reading efficiency (speed reading)

Commercial tools facilitating reading on the web include, for example, *Readability*[2]: used as a browser plugin it cleans up web pages and displays content in a most readable manner. Another example is the *BeeLine Reader*[3], which aims at smoother line break transitions by guiding the user's eye through a color code from one line to the next. While these tools may facilitate reading on electronic screens they do not necessarily nudge readers to increase their reading speed.

Evelyn Wood, creator of the Evelyn Wood Method [5] and one of the pioneers of speed reading, was supposedly capable of reading 6000 words a minute. Techniques she developed and applied were 1) reading groups of words rather than single words, therefore she needed to train her peripheral perception, 2) avoiding involuntary rereading of passages and 3) using a finger or pointer to trace lines of text while eliminating sub-vocalization (i.e. reading out loud in reader's head). Wood noticed that the sweeping motion of her hand across a page caught her eyes' attention and helped them move more smoothly. Hence, the hand or finger could be used as a pacer. This insight inspired us to design an equivalent for electronic devices in form of a kinetic stimulus.

Hansen [8] reports on a series of studies on reading comprehension with rapid readers trained in the Evelyn Wood method. Her results showed that rapid readers were superior in comprehension of relational aspects of text and were able to recall significantly more information than normal readers due to the fact that they were able to read the material more than once given a time constraint. Especially, they tended to recall more idea clusters than normal readers, but less detail about each idea. Other studies on the Wood method reported that average comprehension levels went down as reading rate increased [1, 3, 7]. Carpenter and Just [14], on the other hand, show that training speed reading can increase the comprehension level on higher level information even on faster reading speeds. Yet, the increases also depend on text types and difficulty. They show that easy texts can be read very fast without loss in comprehension.

Rapid serial visual presentation (RSVP)

RSVP, a term coined by Forster [4], is an experimental model for examining temporal characteristics of attention. This method entails users to focus on visual items being continuously presented in the same place. High information transfer rates are thus possible because the need for saccadic eye movements is eliminated. For electronic devices RSVP allows space to be traded for time and hence can be used to support information browsing and search tasks on small displays [2]. However, Intraub [11] found that recognition memory suffers dramatically as the presentation duration for each stimulus goes down. Masson [15] reported reading studies using RSVP, in which participants were often able to correctly outline the essence of a passage without necessarily recalling specific words. Schotter *et al.* [21] on the other hand presented findings of how repressing regressions in reading, which RSVP effectively does, hinders text comprehension, especially when dealing with ambiguous sentence structures. Hedin and Lindgren [10] examined reading on mobile devices using RSVP in regard to reading comprehension and efficiency. In a user study they compared reading with RSVP vs. reading with scrolling using different reading speeds. They found that with RSVP speed and comprehension is high, but that users are generally uncomfortable with the technique.

There are different modes of RSVP as described by Spence [22], however for reading activities we focus on the sequential presentation of words in one spot, as it was used more recently by the commercial application *spritz*[4] as a text presentation technique on mobile phones and smart watches. Georgiev [6] investigated reading speeds on mobile devices compared to reading text on a PC screen and on paper using different methods for text presentation, including RSVP. Top reading speeds were achieved on computer screens with a font size of 14pt and on paper. In our work we apply these findings and focus on the effects of RSVP and the kinetic stimulus with the facilitation of speed reading in mind.

SYSTEM

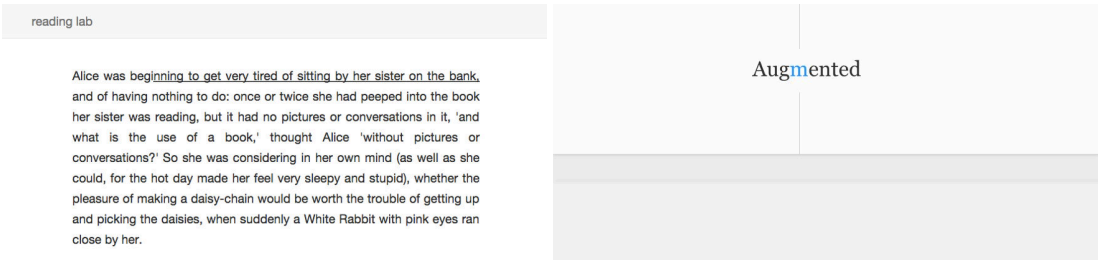
We implemented two stimuli with the goal of increasing reading speed by guiding the user's eye. We built our prototypes with a combination of HTML5, CSS and JavaScript to make our system not only run in the lab, but also on the web to make it accessible to a broad pool of study participants.

The first stimulus is modeled after the idea of swiping the user's finger or a pen across a text in order to keep a constant

[2]http://www.readability.com/ (last accessed 13.02.2015)

[3]http://www.beelinereader.com/ (last accessed 13.02.2015)

[4]http://www.spritzinc.com/ (last accessed 13.02.2015)



(a) Kinetic stimulus: A moving line as underline effect. (b) RSVP: sequentially displaying words in a focal point.

Figure 1. Reading with presented stimuli during lab and online study.

reading flow [5]. Initially, we had several prototypes of stimuli suggesting a constant motion across the screen. By conducting pilot studies and questioning independent researchers we decided to use the technique of dynamically underlining lines of text as kinetic stimulus for the user study. Using the html5 *canvas* element we implemented this dynamic line placed under a line of text that moves from left to right in a predetermined speed (Fig. 1a). Hereby not the entire line moves, but the left beginning of the line moves to the right end only underlining words that are still up for reading. This is intended to keep the eyes focused on the current line and avoid jumps of the eye between lines as well as regressions. Once the stimulus reaches the end of one line, the next line is underlined and the stimulus starts to run again. The entire text is visible at all times and the stimulus moves from left to right and line to line.

The second stimulus is modeled after the RSVP method where one word is displayed at a time at a focal point. We based our implementation on the javascript open source code of *Squirt*. It basically takes as input a text and a reading speed in words per minute (wpm) and displays this text word by word in the middle of the screen (see Fig.1b). A blue letter marks the position where the reader's eye is supposed to focus on. This letter roughly marks the first third of the character sequence, since in western cultures the perceptual span is skewed to the right, hence we perceive more letters to the right than to the left of our focus point [12]. The mark should suggest the eyes to keep their focus on this focal area. The script analyzes the text upfront and dynamically assigns viewing durations to each word, hence words with more characters are presented slightly longer. After a slight delay to prepare the reader, the presentation of words is quickly increased to its target speed. The same goes for words at the end of a sentence to indicate the beginning of a new one. The entire text is not displayed upfront and after finishing cycling through the text, the application closes its text window.

After a series of pilot studies where we raised readers' normal reading speed by varying amounts using both stimuli, we settled on an increase to 150%, since it seemed both significant and feasible. To assess the effectiveness of the system we conducted two user studies: 1) a lab study with 24 participants and a stationary eye tracker and 2) an online study to collect subjective feedback on the two speed reading stimuli.

LAB STUDY WITH EYE TRACKER

First, we carried out a lab study to assess the effect of sped-up kinetic and RSVP stimuli on reading performance of users. We recruited 24 participants (22 male, 2 female) with an average age of 23 (SD=2.28) years. We reached out to potential participants through university mailing lists and social networks. Most participants were students all of which indicated German to be their first language. Five participants indicated previous exposure to speed reading techniques.

Methodology

We designed the study using a between subject measure design with the reading stimuli as the only independent variable. The stimuli comprised two levels: *kinetic* and *RSVP*. Participants were asked to read four rounds of text with one corresponding stimulus, for each stimulus condition we had 12 participants. As dependent variables we measured text comprehension and mental load using the NASA-TLX questionnaire [9] after each round of reading. Using the eye tracker we also recorded average fixation durations and number of fixations as well as regressions calculated from saccades.

Apparatus

The study was conducted using the system described above. To record participants' eye movements we used the stationary SMI RED250 eye tracker with a sampling rate of 120Hz. For study purposes we integrated the browser-based prototype into a task sequence as defined in the study software of the eye tracker. To ensure the validity of measuring text comprehension we used an official text set from the *TestDaF* institute[5], which focuses on the development and application of tests to assess language proficiency of German as a foreign language. Each text comprised on average 583 (SD=19.8) words and came with a list of 10 questions for measuring the readers' text comprehension.

Procedure

After explaining the purpose of the study, the participant was asked to sign the consent form. We then randomly assigned the participant to one of the two conditions. We calibrated the eye tracker and conducted a test to assure the eye tracker worked properly, after which the actual experiment was started. In the initial phase we provided a text, which participants were asked to read as baseline condition without using any of our stimuli in order to calculate participants'

[5]https://www.testdaf.de/ (last accessed 13.02.2015)

regular reading speed (wpm). In the following, the participant read four texts in four rounds with 150% of her regular wpm rate. At the end of each round she was asked to answer 10 comprehension questions and fill in the NASA-TLX questionnaire. The study, including a short debriefing session, took approximately 60 minutes per participant.

Results

In the following we present both quantitative and qualitative results.

Mental Load

We analyzed differences in mental load between the two groups using the RAW-TLX scores. The homogeneity of variances was not violated ($p>.05$). The independent t-test revealed no significant difference in the mental load between the two stimuli in any round ($t(22)=.889$, $p=.38$). The average mental load across all rounds for the kinetic stimulus was 64.80 (SD=4.81) and for the RSVP was 67.41 (SD=4.35). Further, we investigated how the mental load changed between the first and last round within each stimulus. For the kinetic, the t-test showed that the mental load decreased significantly from the first round (M=74.41, SD=11.18) to the last round (M=61.75, SD=19.7) , $t(11)=3.22$, $p=.008$, $r=.70$. The effect size estimate indicates that the change in the mental load created by using the kinetic stimulus was a large and therefore substantial effect. No significant difference were found for the RSVP stimulus ($t(11)=1.72$, $p=.11$). The average mental load for the first round was 70.75 (SD=8.89) and for the last round was 63.58 (SD=19.30).

Comprehension

We compared the number of correct answers for each text to assess users' text comprehension. The statistical analysis between the two stimuli revealed no significant difference ($t(22)=.62$, $p=.40$). The average number of correct answers using the kinetic stimulus was 5.48 (SD=1.63) and using the RSVP stimulus was 5.18 (SD=1.72). Further, we investigated the comprehension scores between the first and fourth round within each stimulus. For both stimuli the t-test revealed that comprehension increased significantly (kinetic stimulus: $t(11)=2.80$, $p=.01$, $r=.65$; RSVP stimulus: $t(11)=2.75$, $p=.01$, $r=.64$). The effect size estimates indicate a large and substantial effect. The average correct answer using the kinetic stimulus increased from 5.25 (SD=1.48) in the first round to 6.08 (SD=1.67) in the final round. Using the RSVP stimulus, the average number of correct answers was increased from 4.58 (SD=1.431) to 6.0 (SD=1.65).

Fixations & Regressions

We further analyzed the fixation and regression information collected by the eye tracker during the study. Fixations can be a measure to assess engagement or difficulties in extracting information [13]. The average number of fixations for the kinetic stimulus was 381.31 (SD=63.22) and for the RSVP stimulus was 119.73 (SD=66.98). Such a significant difference between the two stimuli was expected due to the nature of RSVP where the user focuses on a single point instead of moving eyes across text. Further, we assessed the number of fixations and the average fixation duration between the first and fourth round within each stimulus. The t-test revealed no significant differences neither for the kinetic (number of fixations: $t(11)=-.07$, $p=.95$, fixation duration: $t(11)=-1.50$, $p=.16$), nor for RSVP (number of fixations: $t(11)=-.08$, $p=.94$, fixation duration: $t(11)=.49$, $p=.63$) stimulus. For the kinetic stimulus' first round, the number of fixations was 379 (SD=66.4) with an average fixation duration of 241.25 ms (SD=29.82), for the fourth round, the number of fixations was 379.92 (SD=66.1) with an average fixation duration of 248.9 ms (SD=36.40). During the first round of the RSVP condition, the number of fixations was 118 (SD=78.2) with an average fixation duration of 1044.07 ms (SD=352.22). In the fourth round, the number of fixations was 119.42 (SD=49.1) with an average fixation duration of 996.1 ms (SD=385.5).

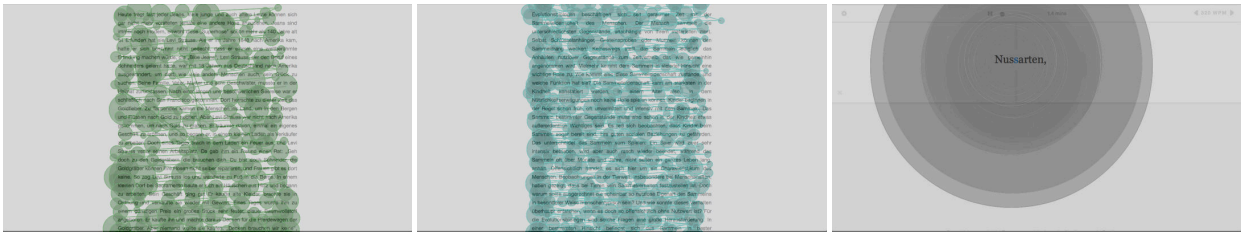
We also evaluated the regression information collected while reading the texts using the kinetic stimulus between first and fourth round. We define regressions as eye movements opposite to the reading direction. While regressions are negligible when using RSVP, in normal reading they generally indicate re-reading of words or entire sentences and hence slow down the reading process overall. The t-test revealed the regression decreased significantly from the first round (M=16.42, SD=11.15) to the last round (M=11.25, SD=7.1), $t(11)=2.877$, $p=.01$, $r=.65$. The effect size reveals that using the kinetic stimulus has a substantial effect on eye regressions while reading text.

Qualitative Assessment

Taking a look at scanpath visualizations of the eye tracking data of participants using different stimuli we notice some interesting differences. In scanpath visualizations each eye fixation is represented by a circle. The longer the duration of the fixation, the bigger the circle's radius. A line represents a saccade between two fixations. Fig.2a shows the scanpath of a participant freely reading text without any of our two stimuli present. Fixation durations are quite variable and a number of line jumps as well as regressions can be noticed. Fig.2b depicts the scanpath of that same participant directly thereafter when using the kinetic stimulus at 150% of her initially measured reading speed. Fixations seem more widely spread, which is probably due to the nature of the kinetic stimulus moving across all text. Fig.2c shows the scanpath of a participant reading with the RSVP stimulus. Obviously, far fewer, but longer fixations on the central focus are presented.

Discussion

Looking at the significantly decreasing strain on mental load after using the kinetic stimulus for a while, we conclude a strong learning effect while using this method. The same applies to the significant increases in comprehension. Initially, users seem challenged by having a stimulus dictate them where to read and at which speed, but they adjust relatively quickly, i.e. over the course of four trials. We further observed significantly fewer regressions after using the kinetic stimulus for a while. The eyes seem to adjust to following the stimulus and regressions are effectively reduced. The fact that, in accordance with fewer regressions, we also measured increasing comprehension levels contradicts findings of Schotter *et al.* [21], which is probably due to the nature of



(a) Free reading. (b) Reading with kinetic stimulus. (c) Reading with RSVP stimulus.

Figure 2. Scanpath visualizations of eye tracking data for participants reading freely, exposed to the kinetic and RSVP stimulus.

the text types used. Schotter *et al.* deliberately focused on ambiguous sentence structures in their studies. When designing such studies it is crucial to not only pay attention to the nature of the texts used, but also to the difficulty of assessing text comprehension. We opted for a solution in which the text came with pre-defined comprehension tests as they are used in assessing language proficiency, hence requires not only literal translation, but also transfer skills. When reviewing the test results we realized these type of questions were anything but trivial. However, we are positive that considering certain text types, comprehension goals and given that users take into account a practice phase, using such stimuli for reading is feasible.

ONLINE STUDY

To collect more in-depth data on user perception aspects of the presented stimuli we conducted an online study targeted at a broader audience. 108 participants (72 male, 34 female, 2 without gender indication) between 12 and 69 years old (M=27.9, SD=8.3) fully completed the study. We disseminated the study across university mailing lists, social networks and personal contacts in other research facilities across Europe and the U.S.. 78 completed the study indicating *German* as their first language, 30 in *English*. Participants' background ranged from students to engineers, business-related professions and lawyers.

Methodology

The study followed a repeated-measure design, so all participants were exposed to both conditions: RSVP and kinetic as independent variables. For each stimulus participants were asked to read a short paragraph of text comprising 284 words each. As dependent variables we collected subjective feedback in form of a Likert scale and free-text survey. The texts used for the study were taken from literature ("The Trial" by F. Kafka) and from a popular blog to ensure text diversity. We provided both English and German versions, self-selected by participants. Average time to complete the online study was M=8.5 (SD=4.8) minutes, variations depending on individuals' baseline reading speed and the time they took for filling in the surveys.

Apparatus

We used again the basic web implementation of the stimuli as described above. Additionally, we used a server running PHP as backend to collect and store the corresponding data. We designed a survey which was applied after each condition as well as a consent form with a basic demographic questionnaire and a final survey to collect more general feedback.

Procedure

On the landing page of the online study participants were asked to select their preferred language suggesting, i.e. English and German. After, they were redirected to a consent form explaining the background of the study and where they could enter their demographics including age, gender and profession. The first step comprised the assessment of general reading speed: participants were asked to fully read a paragraph of 521 words taken from "Alice in Wonderland" by L. Carroll. Completion time was measured from when they clicked on 'Start', on which the actual text appeared, until they clicked on 'Finished'. From this measurement we calculated their reading speed in words per minute (wpm), which was taken as baseline speed. From there we randomly assigned both stimulus and text order and increased participants' reading speed by 150% to a maximum of 600wpm. This cap seemed necessary to ensure that especially the RSVP condition did not completely overburden readers who might have read the initial text for speed assessment in overly rapid manner.

In the next step, for each stimulus one paragraph of text was read and 5 questions were answered using a 5-point Likert scale (1=strongly disagree, 5= strongly agree). Questions targeted subjective perceptions of text *comprehension*, reading *comfort*, *exhaustion* by reading, support in *speeding* up reading rates and perceived reading *duration*. After the last condition participants were directed to a final survey with three free-text questions where they could state their general preference for any of the stimuli. The questions included for what type of texts they could imagine using the presented reading techniques for and on what kind of devices. In the last text box we asked for general feedback and comments.

Results

Study participants on average reached 386 (SD=194) wpm during the speed assessment task. Hence, for the study we increased the stimuli speed on average to about 512 (SD=107) wpm. 42 participants (38.9%) were capped at 600wpm.

Figure 3 comprises the results of the list of questions we asked after each stimulus condition. The Wilcoxon Signed-Rank test revealed that there is a significant difference in rating of subjective text comprehension (Z=-2.18, p=.03), speed reading support (Z=-4.15, p=.0001), reading comfort (Z=-3.04, p=.002), and perceived duration (Z=-4.09, p=.001). In

these four aspects RSVP was rated higher than the kinetic stimulus. The rating of exhaustion showed no significant difference.

In the final survey 42.6% participants indicated to prefer the RSVP stimulus, 36.1% preferred kinetic, whereas 21.3% indicated no preference.

Text & Device Types

For the final survey of the study participants were asked to fill in for which types of text and devices they could imagine using these stimuli. For each stimulus multiple text and device types could be named, so that, in total, we collected 106 recommendations for text types and 121 recommendations for device types. To identify preferred types of text and devices for each stimulus, two researchers independently analyzed the free texts provided by participants and categorized possible types. Then, they crosschecked their categories and agreed on a set of text types and device types. In total 4 types of text, namely: *short texts*, *books*, *technical literature* and *news* were derived. The top three types of text participants mentioned for the kinetic stimulus being useful for were: books (30%), technical literature (23%), and news (15%). For RSVP on the other hand short texts were ranked highest (31%), then books (25%) and news (20%).

Regarding device types that may be fit for using the two stimuli for, 6 types were identified in total: *smartwatch*, *smartphone*, *tablet*, *e-reader*,*head-mounted display* and *PC/laptop*. The top three device types mentioned for the kinetic stimulus were e-reader (47%), tablet (45%) and PC/laptop (34%). Mentioned to be fit for RSVP were smartphone (68%), smartwatch (27%) and tablet (17%).

Qualitative Feedback

Looking at the general comments and feedback participants left in form of free text, we get a broader picture of subjective perception of using such sped-up stimuli for reading. Many participants doubted to have fully understood the texts, but also stated that for unimportant text little comprehension may be acceptable. Others indicated having lost the context because of a moment of inattention or due to the fast speed of the stimulus. At least with the kinetic stimulus some were able to catch up again, but with the costs of having missed some details in between. Many participants found the kinetic stimulus initially confusing while one of the problems with RSVP seemed to be a lack of sense of how far into the text the reader already was and how much more there was to come. One participant stated "the surrounding sentence is missing", which shares the general assessment of others in the difficulty to put the single words into the overall context. However, one participant stated that sequential reading turns boring stories into interesting ones, because she found "fun in being challenged not to miss the context of a single word".

One participant expressed her desire to go through different paragraphs with different reading speeds as to use her imagination in crucial parts of a story. There was quite some complain about the lack of manual control: "The kinetic method would be reasonable if it had some sort of 'pause' functionality". One comment stated "Speed reading is not about reading every word." Similarly, another one stated that there needs to be the chance to get an oversight of the text while reading. Further, the techniques should allow skipping entire sentences or paragraphs. We also had participants who complained about the slowness of the stimulus, since we had a cap on 600wpm for study purposes.

Numerous ideas to improve on the stimuli were brought forward, too. For example, the kinetic stimulus should be used for types of text where readers are inclined to easily digress from (e.g. mandatory texts/emails at work), especially for "long passages I just need to get through". Another participant imagined the idea of using a kinetic stimulus for collective reading as well as on public displays. Further, it could be useful on large screens with lots of text as some sort of "reading guide". Other application scenarios for the kinetic stimulus included highlighting and re-reading of important sentences/take-aways. RSVP on the other hand could be used for one-line ad screens at the bottom of cellphone screens or for displaying stock prices. Some participants mentioned that difficult words would need longer display time than others. One participant stated RSVP to be potentially useful for proofreading text.

Many comments focused on the issue of the speed of the stimuli in particular as well as increasing reading speed in general. One participant indicated the kinetic stimulus being 'too fast compared with my comfortable speed zone'. A great number of users mentioned that they would appreciate using the stimuli in a slower speed. Some felt especially pressured by the RSVP stimulus, as if "being in a challenge". Concluding, one participant stated "reading is more than simply a speedy transfer of data. Any 'quality reading' - at whatever speed - requires that the reader first understand the reading, next remember it, then analyze or intellectualize it from various reference points - in other words, think about the reading". Whereas another one summarized his comments with "Reading should be for fun, and not a race".

Discussion

As can be seen from the general comments left by participants, the stimuli triggered some mixed feelings in user perception. Whereas in terms of measures the RSVP stimulus was clearly preferred to the kinetic stimulus, comments mostly revolved around the feasibility of the kinetic approach, given some sort of user control. However, findings seem to convey various application scenarios for both stimuli. In that sense the kinetic stimulus was generally preferred to be used for rather long passages that require a certain amount of concentration. The RSVP stimulus on the other hand seems to be more suitable for short texts.

Further, users seem to prefer the kinetic stimulus when reading on sufficiently large displays as compared to RSVP, which they find feasible for small displays like on smartwatches or smartphones. Tablets seem to be the type of device that splits the categories: in case of larger available screen estate, RSVP was preferred; in case of smaller, the kinetic technique.This indicates that reading using two complementary devices as demonstrated by Piazza *et al.* [18] can make sense.

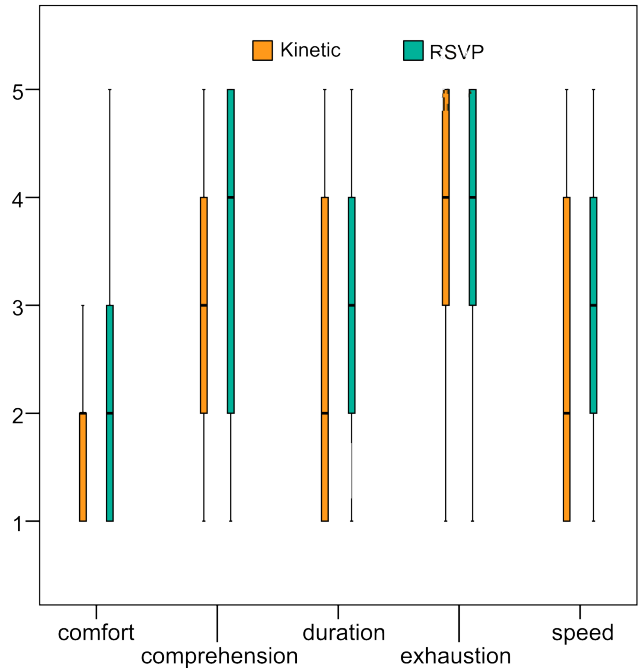


Figure 3. Subjective feedback on perceptions of text *comprehension*, reading *comfort*, *exhaustion* by reading, support in *speeding* up reading, and perceived reading *duration* using the kinetic and RSVP stimuli.

Obviously, speed was based on one single reading pass to determine the initial wpm rate. One participant stated he "didn't pay much attention to the text during the speed assessment and hence skipped some parts" which lead to a very high reading speed throughout the rest of the study. Further, these reading techniques are not suitable for all types of readings. It is generally difficult to decide on an appropriate selection of text passages. As the comments of some participants show, there are great differences in text complexity or readers' background knowledge for that matter, as for some, certain paragraphs were already known. Further, not all of the participants were native German or English speakers and thus were overwhelmed by being pressured to increase reading speed in a foreign language.

IMPLICATIONS

We set out with the goal to assess the feasibility of applying speed reading techniques to reading activities on electronic devices. Our qualitative analysis shows that the act of enforcing higher reading speeds seems to have an alienating effect on users, especially when reading naturally comes with the idea of pleasure and relaxation. However, despite initial discomfort we observed quick learning effects that lowered mental load and increased comprehension rates, which naturally go down when initially using such techniques. These findings encourage us to look into how such techniques can be further developed to lower the entry barrier for users to, slowly, but not drastically, pick up and increase their regular reading speed. Therefore, we identified a number of issues that need to be considered when designing such techniques:

Control

As we have learned from the qualitative feedback, it is crucial for users to remain in control over their choice of reading technique as well as over their current reading speed. Hence, possibilities to stop, start and pause stimuli need to be provided. Further, speed reading does not necessarily imply reading word by word. Hence, stimuli should take into account the users' inclination to skip words or entire paragraphs.

Retaining oversight

What comes naturally for conventional books is a challenge for electronic reading interfaces: a sense of size, position and oversight. When reading through an actual book, the page location and arrangement conveys a feeling of the whereabouts of the reader in the story. In ebooks, for example, this intuition is lost, even more so when using the RSVP stimulus as we have seen. Since a single eye fixation provides a view of the world that is roughly elliptical (about 200 degrees wide and 130 degrees high) [12], we can us this knowledge to adjust the number of words being displayed at once and make entire word groups graspable with one fixation, instead of displaying only one word at a time. Further, for text comprehension it seems crucial to be aware of the context of a word, sentence, even of the entire paragraph and hence adequate features should be provided.

Context-dependent variability of techniques

Obviously, different types of text require the reader to use different reading speeds. In such cases reading speed can depend on various factors, such as linguistic complexity or density of content, but also on the reading goals. In the first case, extracting language semantics could help as well as using reading models, such as [20], to dynamically adjust the speed of the stimulus. In the second case, readers should have the means to either push through a text or be allowed to skip certain parts where 100% comprehension may not be required, but skimming is acceptable. Further, device types should be taken into account since display size is an important factor for the choice of stimuli.

Taking into account user diversity

Reading is a highly complex psychomotor skill. There is a great variety of factors that influence reading performance, such as the reader's general background knowledge, familiarity with the language or with the type of text, and also eye mobility, attention span and current level of fatigue. Learning about users' reading habits can yield great adaption variability. Also, taking into account bio-feedback to dynamically pause stimuli or adjust reading speed may be feasible. Oliveira and Guimares [16] presented a tool to assess mental workload from electroencephalographic (EEG) signals and adjust reading parameters, such as text size, contrast and presentation speed in real-time. In case of high mental workload text presentation can be slowed down to reduce discomfort and on the other hand accelerated to make use of available mental resources. Further, eye tracking can be used to take bio-feedback into account and dynamically pause stimuli or adjust reading speed in real-time. As one study participant stated: "the kinetic [stimulus] could be a lot better if it were

combined with gaze detection – this would allow me to flip back and re-process a sentence that I had missed. [...] It could auto adjust the speed, rather than just ploughing on regardless".

CONCLUSION

We evaluated two approaches to increase reading speed on electronic devices by applying a kinetic and an RSVP stimulus to text. Therefore, we implemented an animated line that moves through the text as well as an RSVP stimulus, each moving at 150% of the reader's regular speed. In two user studies we collected quantitative and qualitative data on the effects and feasibility of such stimuli. Despite users being initially alienated by the approach, results show quick learning effects in adjusting reading speed, lowering mental load and increasing text comprehension levels. We concluded with a set of design guidelines for applications using such reading techniques: therefore users should be able to control their speed and mode of reading and be allowed to retain oversight. Readers' individual preferences and reading goals should be taken into account as well as the different types of text and particularities of devices. In the future we envision electronic devices to be able to detect the reader's skill level, automatically assess the pecularities of text types and adjust the text display accordingly. Based on that, such systems could offer a variety of reading strategies to facilitate reading tasks.

ACKNOWLEDGMENTS

We thank our study participants as well as Dominik Weber, Rufat Rzayev and Thomas Kosch for their active support. The authors acknowledge the financial support of the Future and Emerging Technologies (FET) programme within the 7th Framework Programme for Research of the European Commission, under FET grant number: 612933 (RECALL).

REFERENCES

1. Carver, R. P. *Sense and nonsense in speed reading*. Revrac Publications, 1971.
2. de Bruijn, O., and Spence, R. Rapid serial visual presentation: a space-time trade-off in information presentation. In *Advanced visual interfaces* (2000), 189–192.
3. Ehrlich, E. Opinions differ on speed reading. *NEA Journal 52* (1963), 43–44.
4. Forster, K. I. Visual perception of rapidly presented word sequences of varying complexity. *Perception & Psychophysics 8*, 4 (1970), 215–221.
5. Frank, S. D. *Remember Everything You Read: The Evelyn Wood 7-Day Speed Reading & Learning Program*. HarperCollins, 1992.
6. Georgiev, T. Investigation of the user's text reading speed on mobile devices. In *Proceedings of the 13th International Conference on Computer Systems and Technologies*, ACM (2012), 329–336.
7. Graf, R. G. Speed reading: Remember the tortoise. *Psychology Today 7*, 7 (1973), 112–13.
8. Hansen, D. M. A discourse structure analysis of the comprehension of rapid readers.
9. Hart, S. G., and Staveland, L. E. Development of nasa-tlx (task load index): Results of empirical and theoretical research. *Advances in psychology 52* (1988), 139–183.
10. Hedin, B., and Lindgren, E. A comparison of presentation methods for reading on mobile phones. *Distributed Systems Online, IEEE 8*, 6 (2007), 2–2.
11. Intraub, H. Presentation rate and the representation of briefly glimpsed pictures in memory. *Journal of Experimental Psychology: Human Learning and Memory 6*, 1 (1980), 1.
12. Irwin, D. E. Fixation location and fixation duration as indices of cognitive processing. *The interface of language, vision, and action: Eye movements and the visual world* (2004), 105–134.
13. Just, M. A., and Carpenter, P. A. Eye fixations and cognitive processes. *Cognitive Psychology 8*, 4 (1976), 441–480.
14. Just, M. A., and Carpenter, P. A. *The psychology of reading and language comprehension.* Allyn & Bacon, 1987.
15. Masson, M. E. Conceptual processing of text during skimming and rapid sequential reading. *Memory & Cognition 11*, 3 (1983), 262–274.
16. Oliveira, I., and Guimarães, N. A tool for mental workload evaluation and adaptation. In *Proceedings of the 4th Augmented Human International Conference*, AH '13, ACM (New York, NY, USA, 2013), 138–141.
17. Olson, D. R. Intelligence and literacy: The relationships between intelligence and the technologies of representation and communication. *Practical intelligence* (1986), 338–360.
18. Piazza, T., Fjeld, M., Ramos, G., Yantac, A., and Zhao, S. Holy smartphones and tablets, batman!: mobile interaction's dynamic duo. In *Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction*, ACM (2013), 63–72.
19. Pronin, E., Jacobs, E., and Wegner, D. M. Psychological effects of thought acceleration. *Emotion 8*, 5 (2008), 597.
20. Reichle, E. D., Rayner, K., and Pollatsek, A. The ez reader model of eye-movement control in reading: Comparisons to other models. *Behavioral and brain sciences 26*, 04 (2003), 445–476.
21. Schotter, E. R., Tran, R., and Rayner, K. Dont believe what you read (only once) comprehension is supported by regressions during reading. *Psychological science* (2014), 0956797614531148.
22. Spence, R. Rapid, serial and visual: a presentation technique with potential. *Information visualization 1*, 1 (2002), 13–19.
23. Stanovich, K., and Cunningham, A. What reading does for the mind. *Journal of Direct Instructions 1*, 2 (2001), 137–149.