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Full Length Article

# Reading tilted: Does the use of tablets impact performance? An oculometric study ☆

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ABSTRACT

Electronic devices such as tablets often imply new postural behavior in our everyday life and little is known about the influence of these postures on cognitive processes. In this study, postural aspects of reading on digital tablets are investigated to test whether reading speed or comprehension may be affected by different positions of the head or of the device. The first aim of this study is to evaluate the effect of a lateral tilt of the head and/or a tablet on reading performance. We found that a small amount of tilt did not impact reading, subjects were able to adapt to this situation. For each eye tracking metric, there was a strong correlation between every condition of head and tablet tilt (for each one, $r > 0.73$). Tilting the head or some particular visual stimuli can also lead to a specific movement of the eyes called cycloversion. A second experiment was designed to ascertain the presence of such eye movements when reading on tablet. It emerged that reading on a tablet induced this movement, which could explain, to a certain extent, the adaptation we observed in the first experiment.



## 1. Introduction

Assessing visual and reading performances on visual display terminals has been an important field of research in cognitive psychology and ergonomics since computers have become widespread in the context of work as well as leisure. The emergence of electronic displays turned a page in the history of reading, contrasting with millennia of reading on physical supports: scrolls, codex, books, etc. (Baccino, 2004). Most of the studies in this area have compared reading performance between electronic supports and paper (Dillon, 1992; Gould et al., 1987; Noyes & Garland, 2008). If legibility used to be best on printed texts, today this difference between reading media tends to decrease. The improvements in screen resolution, contrast and the development of new technologies such as e-ink seem to allow similar reading performances to the classic support (Siegenthaler, Wurtz, Bergamin, & Groner, 2011). Visual aspects however are not the only parameters to have evolved; the adopted postures of the reader are also changing. While the computer was formerly confined to a desk, it is now possible to use light weight and highly mobile devices such as tablets in many more situations. This allows the reader to adopt new postures and as a consequence might affect reading performance. The paper aims to investigate the effect of different postures on the reading process.

Straker et al. (2008) compared postural behaviors of children interacting with a desktop computer, a tablet and paper. One of their results showed that the use of tablets implied more asymmetrical postures than for traditional computers' users. A mean lateral flexion of the head by 11° was measured, whereas this angle was less than 4° for the desktop computer. Nothing is known though about the effect of this particular posture on reading. If we consider that the tablet and the head are not aligned, this implies that the user does not read a horizontal text, but a rotated one, relative to his head. Cohen, Dehaene, Vinckier, Jobert, and Montavont (2008) showed that word identification slows down when words are displayed non-horizontally. Similar issues have been addressed by Hock and Tromley (1978) in a classical mental rotation experimental paradigm using letters instead of three dimensional objects. Subjects had to tell if the letter was a standard "*F*" or a reversed one, for a number of different rotations. Response times were longest for large amounts of rotation, shortest when there was no rotation, and increased linearly with small increments of rotation even if the letter was perceptually considered as upright. Could this kind of result be observed in an ecological context, namely, reading entire texts displayed in whole with a

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small amount of rotation? A straightforward hypothesis would be that, if letter and word processing is impacted, albeit weakly, by a small rotation, reading a full text (i.e. processing several words successively) should multiply this effect by the number of words read.

Eye movement recording is often used to assess reading performance through the analysis of number of eye fixations, fixation duration and amplitude of saccades, etc. (Rayner, 1998; Schmid & Baccino, 2003; Siegenthaler, Bochud, Bergamin, & Wurtz, 2012). However, other metrics of eye movements can also be employed. Lateral tilt of the head is known to induce an eye movement called counter-cycloversion (Collewijn, Steen, Ferman, & Jansen, 1985). This movement consists in the rotation of both eyes about their visual axis. The eyes rotate in the same direction, opposite to the direction of head tilt. Through this mechanism, the counter-cycloversion partly compensates the rotation of a horizontal line on the retina. Moreover, cycloversion can also be induced by a non-horizontal visual stimulation, whether it is stable (Goodenough, Sigman, Oltman, Rosso, & Mertz, 1979) or rotating (Ibbotson, Price, Das, Hietanen, & Mustari, 2005). In such cases, the cycloversion follows the direction of the stimulus' tilt. In the following study, we consider both head and tablet tilt. When only the head is tilted, the ocular counter-cycloversion mechanism would decrease the amount of text rotation on the retina, mitigating the aforementioned slower processing of rotated words. The words would be less tilted on the retina than relative to the head. Similarly, if reading on a non-horizontal tablet generates visually driven cycloversion, it would also partly compensate the rotation of the words. To better understand the effect of head or tablet tilt on reading, two experiments were designed to measure performance and cycloversion while reading.

## 2. Experiment 1

The first experiment is a typical eye tracking study. The aim was to investigate the effect of head and tablet tilted positions on reading performance.

### 2.1. Methods

#### 2.1.1. Participants

28 subjects aged 20–45 years (mean: 30 years, *SD:* 7) participated in the first experiment. Older subjects were excluded to avoid the potential occurrence of reading difficulties due to presbyopia. The subjects comprised 12 men and 16 women, used to reading on digital devices with no optical correction, or with contact lenses. They were all able to read and understand texts written in French, and they had no history of visual or musculoskeletal disorders. All provided written informed consent.

#### 2.1.2. Apparatus

To record eye movements, we used a "Dikablis" eye tracker (Ergoneers GmbH, Manching, Germany). This device is a head-mounted monocular eye tracker (left eye is tracked), with a recording rate of 25 Hz.

A Latitude ST tablet was used (Dell, Round Rock, USA). Its luminance was fixed to 94 cd/m$^2$, and the contrast was 0.010 (Michelson), measured by a LS-110 (Konica Minolta, Tokyo, Japan). A wireless mouse was linked to the tablet so that the subject could use the two buttons to interact with the device.

We designed a desk, a head and chin-rest and a tablet support to control tablet and body positions. The dimensions of the apparatus were based on the work of Young, Trudeau, Odell, Marinelli, and Dennerlein (2012), so that we could replicate natural postures. They measured the posture of 15 subjects using media tablet computers. We used their data (in the "lap-hand" condition) in order to build this apparatus (Fig. 1). We designed these supports to achieve a head downward pitch of 10° and tablet pitch of 36°. Only gaze distance was different to the one given in these authors' results (55 cm instead of 50 cm). The subjects could adjust their chair to the height of the desk. The lighting conditions of the room were controlled so that illuminance on the desk was 456 lux, assessed by a LX100 (Kimo, Montpon Menéstérol, France). This illuminance value corresponds to the recommendations of a French standardization association (AFNOR, La Plaine Saint-Denis, France) for office working.

The rotation of the head was controlled by an adjustable chinrest allowing positions of 0°, 10° clockwise, or counter-clockwise. The tablet itself could be rotated in the same way thanks to an adjustable support. The support and chinrest were designed such that the eyes and the corners of the tablet maintained the same distance when the head and the tablet had the same amount of rotation.

#### 2.1.3. Stimuli

The script used for displaying texts on the tablet was written in Python 2.7.4, with the module Pygame 1.9.1. Screen resolution was 1280 * 800. The font was "Arial", size 65 pts so that a 30-word-text could be displayed on 4–7 lines, and the lowercase letter "o" subtended a visual angle of 39 min.

Texts were in French, extracted from Wikipedia using the random search function. When necessary, texts were modified to be 30 words long (±3 words). 5 subjects who did not participate in the experiment evaluated the difficulty of each text on a 5 points Likert scale. Texts evaluated as "very difficult" were removed. Words' lexical frequencies were computed with Lexique 3 (New, Pallier, Ferrand, & Matos, 2001); mean logarithm to base 10 of all words' lexical frequencies, for 1 million words was 2.593 (*SD*: 1.429). The texts were distributed in each condition so that mean logarithms of word frequencies and mean difficulties were similar in each condition. Mean word frequency of each condition was 2.739 (*SD:* 0.028). Mean difficulty of each condition was 2.01 points on the scale (*SD:* 0.07). All texts were followed by two multiple choice questions.

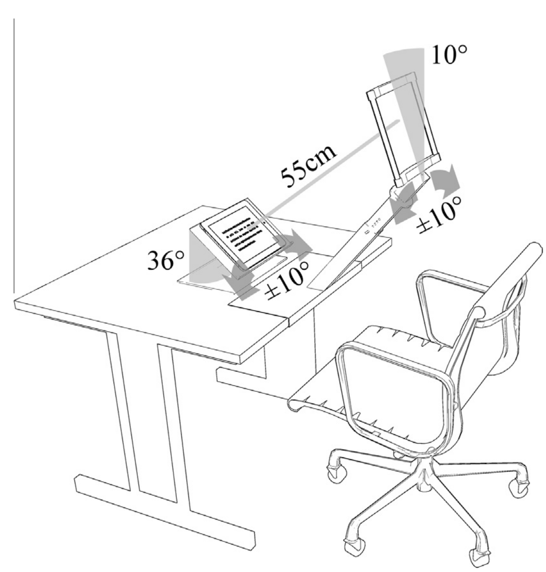


**Fig. 1.** Schematic description of the desk, chinrest and the support used to induce the tilts of the head and the tablet.