# Unobtrusively Regulating Children's Posture via Slow Visual Stimuli on Tablets

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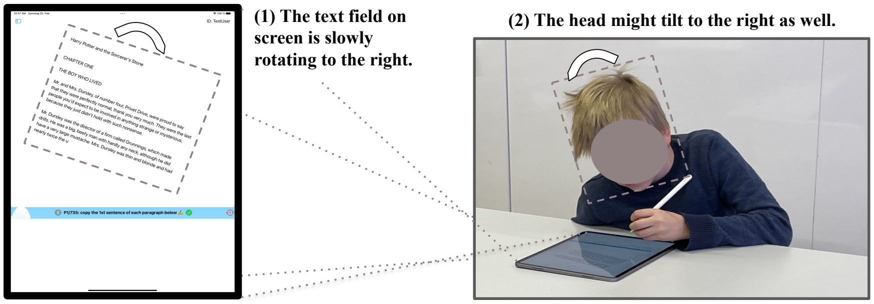

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Harry Potter and the Sorcerer's Stone

CHAPTER ONE

THE BOY WHO LIVED

Mr. and Mrs. Dursley, of number four, Privet Drive, were proud to say that they were perfectly normal, thank you very much. They were the last people you'd expect to be involved in anything strange or mysterious, because they just didn't hold with such nonsense.

Mr. Dursley was the director of a firm called Grunnings, which made drills. He was a big, beefy man with hardly any neck, although he did have a very large mustache. Mrs. Dursley was thin and blonde and had nearly twice the u

P1/735: copy the 1st sentence of each paragraph below ✍ ✓

(1) The text field on screen is slowly rotating to the right.

(2) The head might tilt to the right as well.

**Figure 1: This article proposes an approach to unobtrusively induce posture changes, e.g., head rotation, for tablet applications by slowly deforming visual UI elements on the screen (dashed lines and arrows are annotations and do not appear in the application).**

## ABSTRACT

Children's retention of a proper body posture while interacting with educational tablet applications is important for both their physical health and task performance. In this work, we propose a new approach to unobtrusively induce postural changes in children by applying a slowly deforming visual stimulus appearing on the tablet screen. To preliminarily validate our approach we designed a reading-and-writing tablet application for children, during which 8 different slow visual stimuli would be provided, and monitored the children's posture via a vision-based automated posture tracking system. Results from 10 children aged 6-11 suggest that the proposed approach is suitable for unobtrusively changing children's postures and will stand as the basis for the future design of an adaptive unobtrusive posture regulation system.

## CCS CONCEPTS

• **Human-centered computing → HCI design and evaluation methods**.

## KEYWORDS

Body Posture Regulation, Child-Computer Interaction, Slow Visual Stimuli

## 1 INTRODUCTION

Digital tablets are widely adopted in children's school and family education. The children's posture while learning with tablet applications is not only worth attention from an ergonomics perspective [8], but has also been identified as a factor affecting their performance in educational activities [2]. Researchers identified that a long-term improper body posture when using tablets has hazardous effects on children's physical health, such as increased discomfort, postural deviations, musculoskeletal disorders [8] and even myopia [4]. Conversely, beside ergonomics advantages, a proper body posture also has a positive impact on learning performance when training with digital tablets, especially for motor skills learning tasks such as handwriting training with stylus [9]. An effective intervention scheme to regulate children's posture during the interaction with educational tablet applications is thus of paramount importance.

To the best of our knowledge, only a few works in HCI focus on posture correction or intervention when interacting with tablets, relying on sensors like the camera[1] and Inertial Measurement Unit (IMU)[2] to monitor body posture and a direct alert via an on-screen pop-up window, sometimes combined with a sound or vibration, as intervention. However, the effectiveness of automated direct alerts is known to decay fast due to habituation [1], while excessive numbers of pop-ups, alerts, and reminders on digital devices have already been identified as a major interruption on work tasks [13].

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[1] https://play.google.com/store/apps/details?id=com.Vipered.SitUpStraightbyVipered&hl=en&gl=US

[2] https://www.uprightpose.com/

As a first step towards posture regulation, in this work, we propose to unobtrusively induce postural changes in children by applying a slowly deforming visual stimulus on the tablet screen. We hypothesize that (i) the children would adjust their body posture according to the deformation of the visual UI elements, e.g., tilting their head to follow the rotating text field on the tablet screen as shown in Figure 1, and that (ii) if the speed of deformation is slow enough the children would not immediately notice the visual change and thus not be interrupted in the learning task.

The proposed approach and hypotheses are grounded in theories and findings about human perception and behaviour: *(i) Alignment Behaviour*: Nakashima *et al.* [7] found that humans usually try to align the reference frame of their head and eyes to the visual object's frame in order to focus their attentional resources; *(ii) Pursuit Behaviour*: Smooth pursuit [5] is a typical eye movement behaviour, by which a human's eyes naturally fixate on and follow a moving object. The same mechanism applies to head movement, which usually follows the moving object coordinating with eyes [12]; *(iii) Change Blindness*: Change blindness refers to people's failure to detect changes in their visual environment in certain circumstances [11]. The former two points support the hypothesis that our proposed approach can effectively yield changes in the children's posture; following the latter, we postulate that the speed of our visual transformation speed will be below the human perception threshold.

To preliminarily investigate the feasibility of the proposed approach and the validity of our hypotheses, we thus designed a reading and writing learning scenario with digital tablets and implemented a children-computer interaction system which can generate different slow visual stimuli while tracking the children's posture. Concretely, in a user study involving 10 children from a local primary school, we investigated the following two research questions:

RQ1: How do the slowly deforming UI elements influence the posture of children?
RQ2: How slow should the deformations be in order to be unobtrusive?
RQ3: How much task load does the system have?

## 2 REGULATING BODY POSTURE BY SLOW VISUAL STIMULI

### 2.1 Interaction Scenario

We take the reading and writing task as our interaction scenario because it is one of the most common exercises in school [3], that children are familiar with and would thus engage with adopting a relaxed, natural posture. As Figure 1 shows, we implement such a learning activity on a digital tablet, where the child sits at a table on which the tablet is located. The app is designed in the portrait layout and the child is asked to read the text in the upper part of the screen and write down the first sentence of each paragraph on the blank area in the lower part of the screen using a digital stylus. Once the child has finished the current page, they can click the green check button and move to the next page.

### 2.2 The Design of Slow Visual Stimuli

To the best of our knowledge, no guideline exists to inform the design of tablet applications for posture regulation. Our best reference is the work of Shin *et al.* [10], who studied the impact of the rotation and translation of an actuated desktop monitor on the posture of university students and showed that it can be used to correct the unbalanced sitting posture [10]. In line with them, we decided to apply the two basic 2D affine transformations on the tablet visual UI elements: rotation and scaling. We envisage two Intervention Effects (IE) on the corresponding posture elements:

IE1: by rotating the text field (left rotate and right rotate) on the tablet screen as shown in Figure 1, we expect the children to try to tune their head angle accordingly (e.g. turning left when the text rotates leftwards).
IE2: by scaling the text field (scale up and scale down), we expect the children to try to move farther or closer from the tablet, thus modifying their head-screen distance.

The virtual deformation of visual UI elements on a screen is very different from the physical movement of a real object, as was done by Shin *et al.* [10]: to verify whether our stimuli could induce posture changes we conducted a formative study in the lab with two university students. The participants were asked to use our application for around one hour, during which the system randomly applied the four types of visual stimulus (left rotate, right rotate, scale up and scale down). Each type of visual stimulus was applied three times, at three different speeds (rotation: 0.05, 0.10, and 0.15 deg/s, scaling: 0.001, 0.002, and 0.003 /s[3]), thus yielding a total of 12 stimuli. Each stimulus was applied for 3 minutes, after which the text field was reset at a fast speed (rotation: 3 deg/s and scaling: 0.1 /s ) to the initial scale and rotation. Direct observation suggested that most interventions can induce postural changes and participants stated in a post-experiment interview that they only noticed the visual deformations after a while, once the deformation was large enough. The positive, albeit qualitative, outcomes of the formative study motivated the design of a preliminary experiment involving children and relying on quantitative data.

## 3 EXPERIMENT

### 3.1 Apparatus

The interaction system relies on a camera-based posture tracking component to objectively and quantitatively evaluate the postural reaction of children to slow visual stimuli. As shown in Figure 2, the setup includes: (i) an iPad Pro (12.9-inch, 6th generation) running the developed reading and writing application, paired with an Apple Pencil, in which the first chapter of *Harry Potter* is pre-loaded as reading material, (ii) an RGB-D camera (*Intel RealSense* D435) to track the upper body posture of the child, which is placed on a tripod in front of the child 1 meter away, and (iii) a laptop with wired connection to the RGB-D camera, running the posture extraction middleware *Nuitrack SDK*[4] online, and communicating with the iPad through UDP socket.

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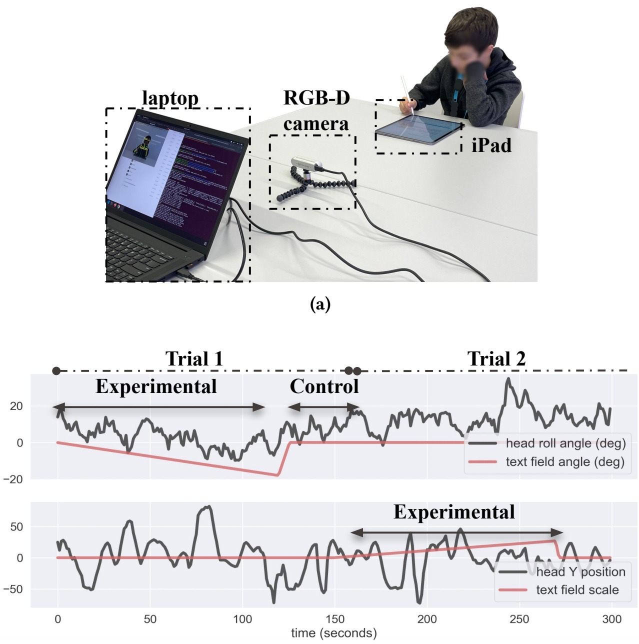
[3] The unit of the scale of the visual stimulus is 1: a scaling up speed of $x/s$ thus means that the scale of the object is $1 + x * t$ after $t$ seconds.

[4] https://nuitrack.com/



(a)

(b)

**Figure 2: (a) The experiment setup. (b) A sample of the postural signals (black) and the visual stimulus signals (red) collected in the experiment (Subject S4). In the experimental interval of trial 1, the text field first rotated to the left (text field angle decreasing): notice how the child's head pose was similarly adjusted (head roll angle decreasing). In the experimental interval of trial 2, the text field scaled up (text field scale increasing) and the head-screen distance (head Y position) grew as well.**

## 3.2 Participants

We invited 10 children (4 girls and 6 boys aged M = 8.46 years old, SD = 1.45) enrolled at a local international school to take part in the study[5]. All the children use spoken and written English in their daily life at school. Seven of them stated that they use digital tablets for reading and writing in their daily routines, while the other three only use them for reading. The experiment took place at the school's STEM centre.

## 3.3 Experimental Procedures

Due to the school schedule, the experiment could only last approx. 35 minutes per child, including a short introduction to the task and the tablet application. During the interaction, the system applied the same four types of visual stimuli (rotate left/right and scale up/down) of the formative study, each at two levels of speed (rotation: 0.075 and 0.15 deg/s, scaling: 0.0015 and 0.003 /s) due to the limited experiment time. Each visual stimulus was applied for 2 minutes, after which the text field was reset to its default scale and angle at a fast speed. Each reset was followed by a 30 seconds interval without any intervention before a new stimulus was applied. To quantitatively measure the unobtrusiveness of our scheme (RQ2), children were asked to click a button on the application each time they noticed a significant visual change in the text field throughout the experiment. This action would not influence the deformation of the text field, and just allow for recording the timestamp at which children became aware of the stimulus. After the interaction, the child was verbally guided to answer the Task Load Index (TLX) questionnaire version for elementary school children [6].

## 3.4 Measures

### 3.4.1 *Objective Measures.*

*On the Posture Intervention Effect.* Two types of time-series signals were measured throughout the experiment (see Figure 2b): *visual stimulus signals*, which include (i) the rotation angle over time of the text field and (ii) its scale over time; and *postural signals*, which include (i) the head roll angle over time, and (ii) the head-screen distance over time. Visual stimulus signals were retrieved from the application log, the head roll angle was directly taken from the 3D head pose estimation provided by *Nuitrack* and the head-screen distance was approximated as the vertical coordinate of the 2D head position in the image plane, since the tablet was fixed on the table.

The scarcity of literature on this topic also brings a lack of metrics to quantitatively assess the impact of the visual stimuli on the children's posture (RQ1). To this end, we introduce the *Posture and visual Stimulus Alignment Level* (PSAL). Let us consider a time interval of interest $w = \{t|t_0 \leq t < t_1\}$ and let us denote as $l_p(t)$ and $l_v(t)$ the linear approximations (computed with least mean squares method) of a postural signal $p(t)$ and visual stimulus signal $v(t)$, respectively. The PSAL is then computed as the cosine similarity between $l_p(t)$ and $l_v(t)$. Intuitively, higher values of PSAL denote cases in which the trend of the postural signal more closely matched the one of the visual stimulus, and vice-versa. As shown in Figure 2b, we define each application of a visual stimulus as a *trial*, composed by the interval of actual application of the stimulus (the *experimental interval*) following the reset and the subsequent 30s of default configuration (the *control interval*). By comparing the PSAL values within the experimental and control interval we can estimate the influence of the visual stimulus on children's posture.

*On the Reaction Time.* As discussed in Section 3.3, to quantitatively measure the unobtrusiveness of our scheme (RQ2), we compute the reaction time to each stimulus as the time interval between the beginning of the visual stimulus and the moment in which the child clicks on the aforementioned button.

### 3.4.2 *Subjective Measures.*

To measure the task load of the interaction (RQ3), we asked children to answer the six questions of TLX for elementary school children [6], which include mental demand, physical demand, temporal demand, performance, effort and frustration. Children were also asked "*How disturbing was the visual on-screen elements' motion to your activity?*" to evaluate the *Disturbance* of our design. All questions were rated on a 5-points Likert scale.

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[5] This study has received ethical approval from the Human Research Ethics Committee of EPFL under protocol HREC 057-2021.

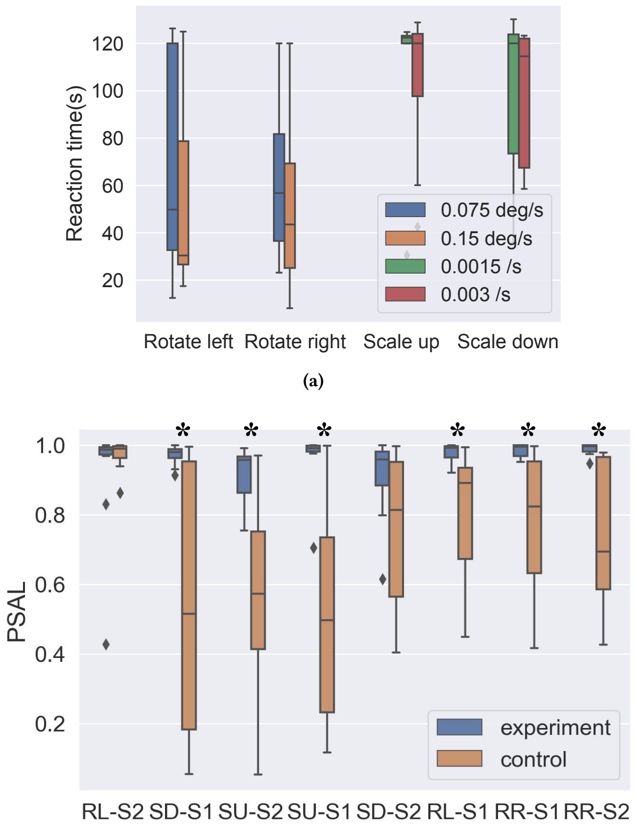

**Figure 3: (a) Reaction times to the 8 visual stimuli. The speed is encoded by colors. (b) PSAL values of 8 trials in the experiment and control intervals. The visual stimuli are denoted in the trial labels as follows: rotate left (RL), rotate right (RR), scale down (SD), and scale up (SU). Speed I (S1 in the trial labels) represents 0.075 deg/s for rotation and 0.0015 /s for scaling. Speed II (S2) represents 0.15 deg/s for rotation and 0.003 for scaling. Asterisks mark differences in PSAL between the experiment and control intervals which are statistically significant ($p < 0.5$).**

# 4 RESULTS

## 4.1 Objective Results

*4.1.1 Unobtrusiveness.* As reported in Figure 3a, the 8 tested visual stimuli are, on average, detected only after 84.70±41.47 seconds. Additionally, the impact of the following independent variables on the reaction time was investigated: (i) Speed: comparing the reaction time between two levels of speeds, we found that the faster the deformation was, the shorter the average reaction time was (see Figure 3a), although a Wilcoxon signed-rank test revealed that the decrease in reaction time was not significant. (ii) Direction: there was no statistically significant difference in reaction time between left and right rotation (W=25.0, p=.798). Similarly, scaling up yielded a longer reaction time (110.43±22.54 s) than scaling down (98.04±29.12 s) but the difference was not statistically significant (W=21.0, p=.157). (iii) Rotation vs. scaling: by taking the average reaction time among all speeds and directions, we found that the reaction time to scaling visual stimuli was statistically significantly longer than that to rotations (W=8.0, p=.015).

*4.1.2 Effectiveness.* We report the PSAL values for the experiment and control intervals for all trials in Figure 3b. The paired Student T-test indicates that for 6 of the 8 trials, the PSAL values are statistically significantly higher ($p<.05$) in the experimental interval with $p_{SD-S1} = .041$, $p_{SU-S2} = .013$, $p_{SU-S1} = .047$, $p_{RL-S1} = .045$ $p_{RR-S1} = .026$ and $p_{RR-S2} = .027$. Please notice that there is no significant difference in PSAL values among the 8 control intervals. Concretely, our analysis suggests that children's posture tended to follow the visual stimulus, while it was applied. Moreover, we checked the impact of the following factors on the PSAL: (i) Speed: concerning rotation, by taking the average of PSAL of two directions, there was no statistically significant difference between speeds of 0.075 and 0.15 deg/s ($p > .05$). However, the PSAL of scaling with the speed of 0.0015/s (.96±.05) is statistically significantly higher than that with the speed of 0.003/s (.91±.06) with $T = 3.44$ and $p = .011$. (ii) Direction: the differences of PSAL between left and right rotation and between up and down scaling are not significant ($p \gg .05$). (iii) Rotation vs. scaling: by taking the average values among all speeds and directions, we found that there was no significant difference between rotation and scaling on PSAL values in our study ($p = .231 > .05$).

## 4.2 Subjective Feedback

The results of the TLX questionnaire show that the children did not feel the slow visual stimulus very disturbing, with a reported disturbance value (M=1.89, SD=0.78). The task was not perceived as effortful (M=1.33, SD=0.50), nor demanding (physical demand M=1.44 and SD=0.73; mental demand M=1.22 and SD=0.44; temporal demand M=1.78 and SD=1.30) or frustrating (M=1 and SD=0) and children were quite satisfied with their performance (M=3.33 and SD=1.12). Five of the children explained that they realized the text field was deforming only when the rotated angle or the scaled size was distinct enough. Subject S7 reported that he could easily detect the text scaling up since the default font size was a bit small for him.

# 5 DISCUSSIONS

*Design of Slow visual stimuli.* Albeit preliminary, our results suggest that applying slow visual stimuli on the tablet screen is a promising approach to influencing children's posture. All four deformations yielded the desired IE, with slower deformations seemingly more effective than faster ones for scaling (see Section 4.1.2) but not for rotation. Cases like Subject S7 complaining about the default font size, and more generally the uniqueness of each child in terms of perception sensitivity, posture and personality, indicate that a key future improvement is the design of personalised slow visual stimuli. Moreover, Subjects S8 and S10 tried to adjust the position of the tablet during the experiment but were stopped by the researcher, since our design required it to be in a fixed position with respect to the table. This fact further highlights the importance of personalisation and inspires us to revise the design of slow visual stimuli to consider the user's habits for the tablet placement.

Indeed, changes in the tablet pose might have an impact on the pose of the child. Moreover, the physical size of the visual stimulus can be a factor influencing the effectiveness of our approach, which to the best of our knowledge has no precedent in the literature. Further experiments should assess the impact of the screen size on the results.

*Limitations.* In the experiment, the control interval was placed right after the experiment interval as Figure 2b. One control group without any visual stimulus should be added in future work for better comparison. Besides, we only measured the short-term effects of the proposed approach. Future work could focus on the long-term effects on children's working posture with tablets.

*Adaptive Interventions.* Towards the final goal of unobtrusively regulating children's posture via slow visual stimuli on tablets, in this study we only preliminarily demonstrated that slow visual stimuli can induce postural changes. Our next study will investigate the design of an intervention strategy to adaptively apply slow visual stimuli according to the detected improper posture of children, which implies identifying reliable triggers for interventions and selecting the most effective stimulus given the situation.

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