The iReCheck project: using tablets and robots for personalised handwriting practice

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ABSTRACT

Handwriting is an important skill in children development as well as in education that take years to be mastered. While keyboards and similar technological devices increasingly become more popular, new tools and engaging approaches are also required to keep children motivated in the learning process of this fundamental fine motor skill. In this paper, we present the iReCheck platform, an innovative multimodal interactive system capable of providing personalised handwriting training through a social robot companion and serious games in a tablet, easily adoptable by teachers and therapists in their daily educational practices. Results from studies in multiple contexts, such as schools, clinics, and hospitals are showing the potential application of our proposal not only to investigate handwriting itself but also in strongly correlated aspects, such as inner-motivation and student's posture.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; **Collaborative and social computing systems and tools**; **Interaction design theory, concepts and paradigms**.

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KEYWORDS

Handwriting training, social robots, serious games

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1 INTRODUCTION

One third of all children between 4 and 12 years are affected by handwriting difficulties [13], and 8% displays severe difficulties or *dysgraphia*, a Neuro-Developmental Disorder (NDD) defined as the inability of writing coherently[2]. Since such difficulties can cause tremendous and long-lasting damage to a child, to the point of instigating school avoidance and low self-esteem, early detection and remediation is key for effectively overcoming them [11].

A major hurdle towards this goal is the *vicious circle* (Figure 1) that handwriting difficulties create: children with handwriting difficulties find it hard to write and obtain lesser results than their peers. Hence, as in figure 1, they avoid writing as much as possible, which results in lagging further behind their peers and an even stronger desire to avoid writing altogether[5]. For this reason, remediation activities, which necessarily have to involve writing sooner or later, are typically met with significant resistance.

In an attempt to overcome this resistance, a number of approaches have been recently proposed which rely on digital devices such as tablets[3] and robots[8]. On the one hand, such approaches rely

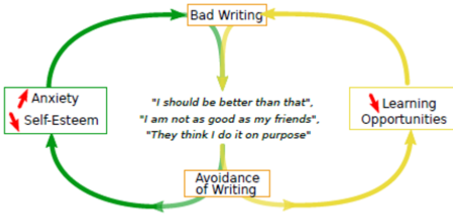

Figure 1: The vicious circle created by bad writing: writing avoidance bring high anxiety and low self-esteem, pushing towards less learning opportunities, reinforcing dysgraphia.

on the *novelty effect* and *gamification* to counterbalance a child's reluctance to engage in handwriting practice; on the other hand, the rich sensory information made available by digital devices allows for a monitoring of the child's progress and personalisation of the exercises, with interesting results[6].

In this article, we build over such previous achievements proposing the architecture of a system for handwriting training, which relies on a digital tablet for the automated, real-time assessment of handwriting quality and areas of improvements and on a social robot to assure engaging, interactive training sessions motivating the child. The system is developed in the context of the bilateral Swiss-French project *iReCheck*[1], involving engineers, teachers, therapists and medical practicioners, composing an unique, appropriate multidisciplinary environment.

2 MATERIALS AND METHODS

The iReCheck project aim to offer an interactive way of enhance handwriting skills for students in their developmental age. As in in figure 2, our architecture proposes the use of a social robot, an iPad with an iPen, and some external cameras or RGBD cameras. In accord with a learning-by-teaching approach, a social robot acts as child companion, introducing the handwriting training activities proposed by the tablet app Dynamilis[2]. The robot can be either autonomous or teleoperated though a second tablet, using a web interface, adapting the use of the system to the different needs of users in different educational scenarios.

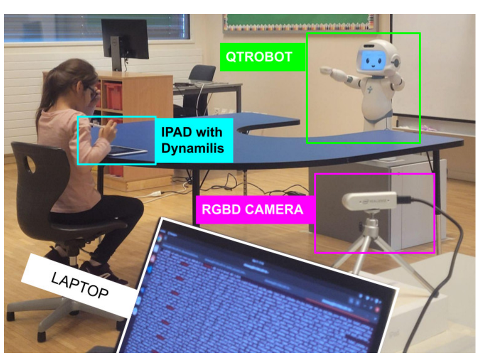

Figure 2: The iReCheck system in a typical session.

[1]https://irecheck.github.io/
[2]https://dynamilis.com/

2.1 System's architecture

The proposed system has been implemented through the high-level, modular architecture illustrated in Figure 3, using the ROS framework. The architecture is mainly composed by: the *camera network* modules, focusing on posture and face analysis; the Dynamilis interface (Dynamilis Listener), exchanging data with the Dynamilis serious game; the *iReCheck controller*, implementing the Human Mediator Interaction module (HMI), the decision-maker module and the iReCheck manager orchestrator system; and the QTRobot controller module, implemented by its manufacturer. Our code is available in the project's repository on GitHub[3].

2.1.1 The social robot. The QTRobot platform (visible in Figure 2) is a 64cm tall social robot developed and commercialised by LuxAI[4]. It has a humanoid shape with a pinned base in the shape of legs, a torso, two 3DOF arms and a 2DOF head with a tablet allowing for displaying a range of facial expressions. The robot has a RealSense RGB-D camera and 4 microphones on the forehead and an Intel NUC i7 processor in the torso running Ubuntu and ROS. Face/emotion detection and recognition functionalities, speech recognition and voice synthesis are provided off-the-shelf via the Nuitrack[5] and Acapela[6] SDKs. QTrobot has been used in a number of studies involving children, for purposes ranging from the development of Computational Thinking skills of typically developed children [10], to the emotional ability training for children affected by Autism Spectrum Disorder [4].

2.1.2 The serious game. The *Dynamilis* app, running on iPad and requiring the use of an Apple Pencil, includes an activity for runtime automated handwriting assessment, and a number of games for handwriting training, targeting different sub-skills related to handwriting (e.g., modulation of the pressure applied on the tablet via the pencil, or speed control while following a trajectory). The *handwriting analysis* activity is a two-steps activity that first asks the child to draw a cat and then to copy a short text shown at the top of the screen. The reason for the two steps is to mitigate the negative attitude towards writing and decouple handwriting difficulties from reading difficulties. Each analysis produces a handwriting quality

[3]https://github.com/irecheck
[4]https://luxai.com/
[5]https://nuitrack.com/
[6]https://www.acapela-group.com/

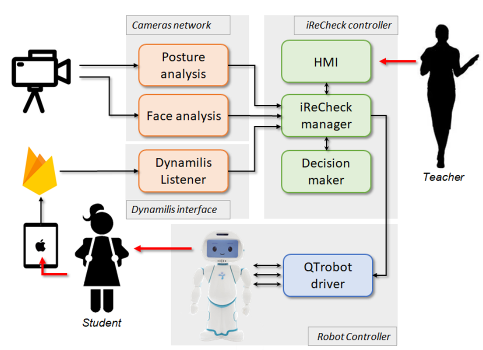

Figure 3: An high-level scheme of the software modules.

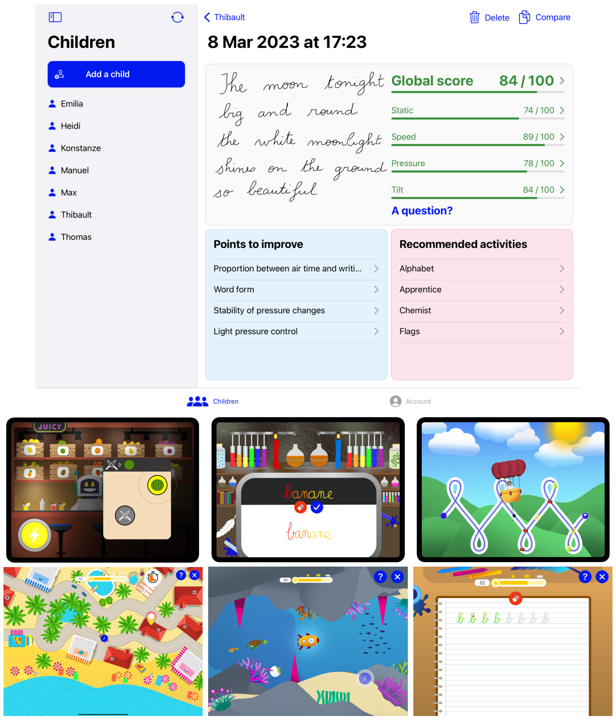

Figure 4: *Dynamilis* screenshots: On top, the screens of the handwriting analysis scores. Then, from mid-left to bottom-right, screenshots of the *Juice*, the *Chemist*, the *Pursuit*, the *Pizzaiolo*, the *Submarine* and the *Alphabet* games.

score (expressed in the [0,100] range) along the dimensions of *static*, *speed*, *tilt* and *pressure*, plus a *global* average, as shown in the top image of Figure 4 and proposed in [1]. Dynamilis proposes also several games to approach each dimension training: some examples are shown in the images on the bottom of Figure 4.

2.1.3 Cameras network. External cameras are used to acquire 2D or 3D information about the child's behavior. Full-body posture, in particular, was acquired through the Intel RealSense D435 RGB-D camera[7]. The RGB-D camera is envisioned to be positioned laterally to the child, approximately 2.5 meters away, as shown in Figure 2, while other RGB cameras can be conveniently positioned to acquire facial expressions, hands movements, ... Exploiting the distributed computing capabilities of ROS, cameras can be directly connected to the main computer controlling the system or to a remote Raspberry Pi: this modularity allows the distribution of the computational load of the whole system into components spread over the network[7].

2.1.4 iReCheck controller. Children interact with the system individually, in a series of sessions carried out as discretionary extracurricular activities. While we guarantee the presence of an adult at all times during the sessions, ready to intervene in case of need and upon request, the iReCheck training sessions can either be autonomously managed by the system, through a decision-making module, or feature a teacher taking over the control of the interaction, thanks to a Human Mediator Interaction web interface accessible through a tablet.

The autonomous system: the decision-making module allows the system to autonomously guide children among several training activities. While sessions are expected to significantly change from one child to the other as well as over time or due to contingency factors, they are envisioned to last between 10 and 30 minutes and will likely include:

(1) A *greeting* phase, in which the social robot welcomes the child and either brings up events and achievements of past sessions or engages him/her in a short conversation. In both cases, the phase ends with the request for the child to play the *analysis* activity on the *Dynamilis* iPad app, which performs the automated handwriting assessment.
(2) A *training* phase, during which the robot uses the assessment information provided by the *Dynamilis* iPad app and external sensors at run-time to suggest and orchestrate appropriate handwriting training activities, stretching and similar simple physical exercises to improve one's posture, or pauses. The system's ability to correctly detect and react to *fatigue* [12], low *productive engagement* (defined as the type of engagement that's conducive to learning) [9] and other relevant factors affecting the child's attitude towards and performance in the training activities is fundamental for the success of this phase and thus the whole interaction.
(3) A *goodbye* phase, in which the robot wraps up the session, emphasising on the achievements. This phase might include a second handwriting assessment via the *analysis* activity on the *Dynamilis* iPad app, as well as inquiries of the child's experience of the activity and the interaction with the robot, via interviews and/or questionnaires (such as the Godspeed questionnaire [18]).

The teleoperated system: an HMI web interface accessible via a tablet can take the control of the system, allowing the teleoperation of the robot and the production of fine tailored feedback. This is particularly useful in scenarios where such personalization is crucial, as the handwriting training of children with neurodevelopmental deficit. The behaviours of the robot, categorized in semantic groups, can be triggered by clicking the correspondent button in the web interface. As shown in figure 5, tabs differentiate groups of behaviours that can open to more behaviours according to each semantic group.

The conception of the behaviours, together with an effective and easy-to-use design of the web interface, has been object of a 3-rounds co-development involving 6 children, 3 teachers and 3 special education therapist: at each design round, users enjoyed the system for 3 training sessions; then, feedback about the system were collected and took in account in the next development round[19]. The final version of the system proposes 124 behaviours spread out in 23 categories.

3 ONGOING STUDIES

We envision the interaction between children and the proposed handwriting training system to unfold as at school, with children in typical development, and in special educations contexts, training

[7]https://www.intelrealsense.com/depth-camera-d435/

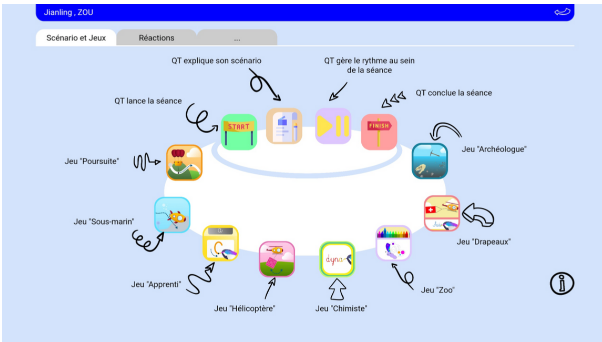

Figure 5: The web interface to teleoperate the robot.

children with neuro-developmental deficits[8]. The effectiveness of the system with the children will be evaluated in both cases through the clinical validated BHK scomeasure[6].

3.1 Handwriting training at school

The importance of having an autonomous and customised system to interact with students emerges from the lack of time teachers are facing nowadays to fit all the curriculum in the given time. This phenomenon is approachable with our solution, where students can have access to personalised tutoring from the robot while practising the handwriting without interfering in teacher's regular time or curriculum. Therefore, both teachers' and students' perceptions of this setup is being investigated [15]. In studies with the iReCheck setup in schools, we are also evaluating how the posture is an important factor in the handwriting. Initial studies revealed an existing relation between posture quality and handwriting, specially between some handwriting dimensions and specific body limbs [16]. The evaluation is performed extracting participants' joint angles by using the NuiTrack SDK[9] algorithms in the images afforded by RGBD camera, shown in Figure 6. As part of such studies, we are investigating the different manners of interfering in children's posture during these activities, by using either elements of the iPad screen [17] or the robot [14]. Finally, studies to evaluate the added value of the robot in long-term interactions in this setup are also being studied.

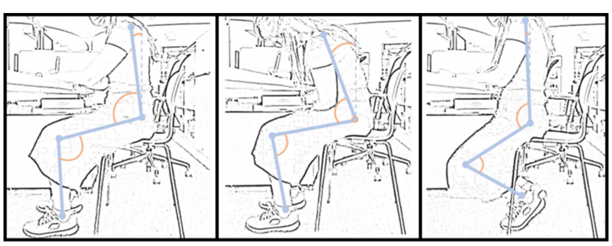

Figure 6: Posture information from the RGB-D camera.

[8]This project has received ethical approval from the Human Research Ethics Committee of EPFL under protocol HREC 057-2021 and by the Comité d'éthique de la recherche de Sorbonne Université under protocol CER-2020-103.
[9]https://nuitrack.com/

3.2 Training of children with neuro-developmental deficits

In children with neuro-developmental deficits, dysgraphia emerges as a fine motor skills deficit in a complex context of impairments. Due to this complexity, motivation and remediation can be particularly challenging. We proposed the use of iReCheck handwriting training platform to the Pitié-Salpêtrière Medical Hospital in Paris, as convenient method to overcome such difficulties in special education scenarios. A specific request of the therapist working in this scenarios in a tight collaboration within the iReCheck project was to have a fine control of the robot's feedback and behaviors. The teleoperated system fully integrated in the scenario seemed the most efficient way to provide an effective but simplified control of the robot. As shown in 7, the teleoperated system is part of a triad composed by the child, the robot and the therapist: while interacting with his peers, the therapist can control in real-time, with his own tablet the robot, guiding the therapy, the feedback given to the child and the choice of the Dynamilis activities. Future experiments will focus not only on the children's handwriting improvements, but also on their self-esteem and on the ability of the system to enhance motivation and engagement.

Figure 7: Robot, child and therapist interact in a special education setting.

4 CONCLUSION

The iReCheck platform proposed in this paper, seemed to be well-fitted in keeping pupils' motivation, affording personalisation throughout the sessions. Implementing a system with multi-level of autonomy of the robot has proven crucial to current and future studies that investigate handwriting and its correlated aspects in different scenarios, since handwriting exercises can be performed alone or supervised by a tutor. Our studies will hopefully pave the way towards further investigations on handwriting skills and on its related subjects, in an era in which such skills are increasingly harnessed and integrated with technological tools.

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