Immediate effects of short-duration wellbeing practices on children's handwriting and posture guided by a social robot

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***Abstract*— Handwriting practising, as any other repetitive task, often leads the practiser to an overconcentration state where their performance might be affected by postural and mental fatigue. Short breaks to perform unrelated activities, especially relaxation exercises, have shown to be a simple alternative to soften or postpone this phenomenon. Therefore, in this paper we are investigating the immediate effects of different types of short-duration relaxation exercises in the handwriting and posture of children aged from 8 to 10 in handwriting training. We divided 40 children in two groups performing the sessions, guided by a social robot, with small exercises of mindfulness or stretching in the middle of their training. Additionally, we analysed participants' perceptions towards the robot leading these interactions. Results showed improvements in participants' handwriting quality and posture maintenance regardless of the condition. Additionally, more positive feedback about the pause was reported from individuals in the mindfulness condition.**

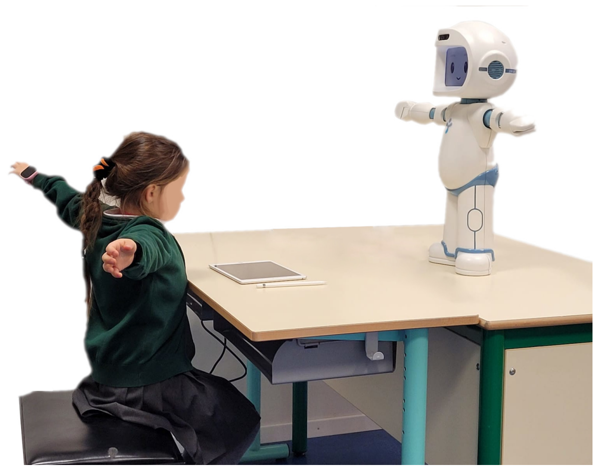

Fig. 1. Robot guiding a stretching session.

I. Introduction

When practising handwriting, physical and cognitive skills are required. Fine motor coordination, to manipulate the pen, as well as efforts to either remember a known word or to learn new ones, are examples of these two natures of exigence. Evidently, demands for both physical and cognitive charges for this activity are higher at the early stage of one's education. This is one of the reasons handwriting is a technique that takes several years to be mastered, and the lack of its practising commonly leads to a decrease in its quality [1].

On top of the cognitive challenges to mastering handwriting, external factors also affect learners' performance. Motivation and wellbeing, for instance, are constantly related to learning outcomes. Repetitive and demanding cognitive assignments - as learning handwriting might be - are normally avoided by young students due to the bad effects that frustration in not achieving good results can bring to them [2]. Additionally, young students may present even poorer results when not under the supervision of a tutor, which is becoming more common since teachers have no time to address handwriting as their regular activities as before [3]. Due to this fact, social robots (as shown in Fig. 1) are used as an alternative to provide learners with a companion, sometimes serving as a personalised tutor or a peer, and boosting, even momentarily, their motivation to keep going on such exercises [4]. Advantages offered by the robot, however, are not physiologically increasing human's physical and mental workload tolerance, of course. There are complementary factors to be addressed, such as fatigue and external motivators.

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Making a short pause is a simple and efficient strategy used to retake focus and productiveness during repetitive tasks, and deploying this strategy in a tutor robot has shown beneficial for learning setups [5]. When regaining the awareness of our cognitive and physical actions, one is interrupting the continuous overconcentration flow that may cause brain and muscles overload. As a result, intervals between executions of a task are often reported as beneficial, since it brings our mental load closer to a comfortable state once again. Mindfulness practicals, which are a combination of breathing exercises with meditation, are expected to accelerate this process [6]. More than gaining awareness, some low-energy demanding techniques for body dynamization, like stretching by doing smooth movements with upper limbs, may promote momentarily boosts of blood circulation and instigate flexibility increasing sensations, promoting feelings of muscular tension relieves [7]. Not coincidentally then, body awareness is important in this context, since one's external behaviours, such as the posture, may play a key role in the learning experience [8]. However, although we are using wellbeing promotion techniques in this study, we are not measuring any metric related to them, such as arousal, stress, or anxiety, since their impacts are already well-explored in literature and their analysis requires long-term experiments [9].

In our previous study [10], children that have their posture corrected by a human after training handwriting for around 20 minutes, immediately presented a higher quality in their handwriting's kinematic dimension. During the posture correction, the human was retrieving the child's attention back from the handwriting exercises and explaining the ideal posture for the given task. Nonetheless, it was unclear whether the noticed increase came from the posture correction or from the simple pause children have after writing for a while.

Therefore, motivated by these findings and by the benefits of relaxation exercises, in this study, we are investigating potential impacts of short-duration relaxation practices on the quality of children's handwriting and posture. For a deeper understanding of this work in its assorted directions, we structured our objective in the following Research Questions:

- **RQ1**: Can relaxation practices of short duration have an immediate impact on children's handwriting quality?
- **RQ2**: Are there different variations in the handwriting quality dimensions according to different types of relaxation practices?
- **RQ3**: Do different types of practices affect differently children's posture quality?
- **RQ4**: What are children's perception about relaxation exercises guided by a social robot?

To investigate these questions, we implemented relaxation exercises of short-duration in a robotic architecture for handwriting training [11] and assigned users in two conditions, where they engaged in interactive sessions with a social robot. To the best of our knowledge, this is the first study to evaluate the effects of relaxation exercises in a child-robot interaction setup using automated measures of handwriting and posture.

The remainder of this paper is organized as follows. In Section II, related works that motivate and sustain this research are presented. Section III presents the used architecture, how we implemented the relaxation exercises, and our experimental design. In Section IV, information about the experiment and its results are reported. Conclusions follow.

II. Related Work

Prioritizing the wellbeing of students in educational settings is key, as it encompasses physical and psychological capabilities that are essential for academic success, caused by a reciprocal relationship between wellbeing and academic achievement [12]. The same principle applies to handwriting, since the success of early education achievements and most of the evaluations are still based on handcrafted material [13].

A comprehensive systematic review of the connections between physical activity, cognitive function, and academic achievement in children was conducted by Donnelly *et al.* in which these concepts were concluded to have a positive correlation to each other. Among the studies that investigated the immediate effects of acute bouts of physical activity in classroom settings, 3 out of 4 have shown positive results in terms of time off tasks or attention [14]. Mahar *et al.* presented that measured the time off task before and after 4-minute activity breaks increased by more than 8 % for second and fourth-graders. [15] Zenner *et al.*'s (2014) meta-analysis examined the effects of mindfulness-based interventions on cognitive outcomes in children and adolescents across various school settings. The analysis found that such interventions can improve cognitive capacity for attention and learning by almost one standard deviation [16].

Recently, socially assistive robots have become new resources for promoting children's mental wellbeing. Kacacińska et al.'s scoping review on the use of social robots to promote children's mental wellbeing indicates that these robots have become a new method of support [17]. The review found that 50 % of the 30 studies investigated showed statistically significant results, with the most significant improvements seen in reducing depression/anger and increasing positive affect/mindset.

Research indicates that the positive effects of increased learning through social interaction between humans can also be extended to interactions between humans and robots [18]. As a result, the educational field has shown interest in social robots and their potential benefits for learning. While laptops and tablets can serve as educational tools with similar capabilities as virtual agents, the use of social robots offers several advantages, such as suitability for curricula that involve physical engagement with the environment, additional social behaviours that enhance learning, and higher potential for learning gains [19].

As such, compared to virtual agents, physical robots have an added advantage in their capacity to stimulate social behaviours that are more supportive of learning. This is due to the fact that robots are perceived more favourably by users, as they could be more engaging and entertaining [18]. Combining the ideas presented above, social robots can be utilized as relaxation mediators for children while also providing benefits to their learning and cognitive abilities.

III. Methods

A. Architecture and metrics

The iReCheck architecture was used in this study [11]. The required setup is an iPad running the Dynamilis app, the QTrobot to guide the session, a RGBD intel realsense camera on the lateral of the main desk to keep track of the posture, and a laptop to integrate all these devices by running the iReCheck ROS nodes. Students can interact with the system by performing the tasks being asked by the robot on the iPad. Tasks are Dynamilis activities that can be a handwriting analysis or gamified handwriting training activities.

In the handwriting analysis, children have to draw a cat and copy a text provided by the app using an Apple pen. Based on these inputs, Dynamilis provides measures in four handwriting dimensions: *tilt*, *static*, *pressure*, and *kinematic*, and also a *global* score, which is a combination of the previously mentioned dimension, as shown in [2]. All these measures are provided in a normalised range from 0 to 1. Normally, it takes approximately 7 seconds from the moment the user finishes their inputs on the iPad to have access to the result.

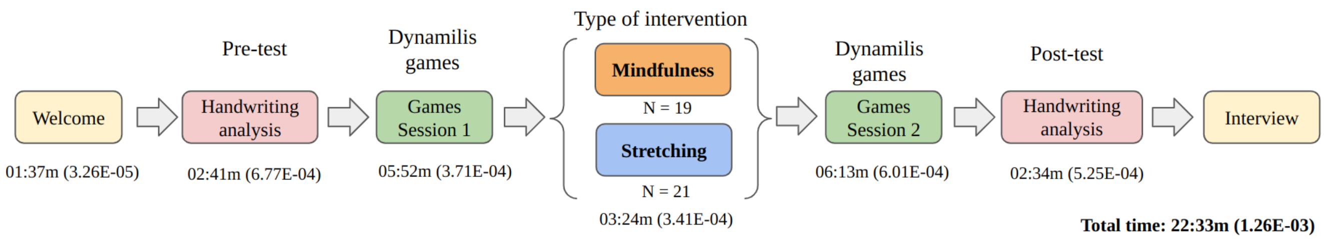

Fig. 2. Experimental design steps, activities played, average time (in minutes) of participants in each step (with standard deviations), and the full session average on the bottom right.

For the body posture evaluation, we used the Rapid Entire Body Assessment (REBA), a biomechanical tool that evaluates the ergonomic risks associated with workplace tasks. This approach considers several factors, including the posture of the whole body, the force exerted, and the duration of the task, to provide an overall risk [20]. The autonomous pipeline to calculate the REBA scores [10] takes as input the joint values of the children's skeletons, provided by the *nuitrack* library when applied to the videos of the interactions recorded by the RGBD camera.

B. Relaxation interventions

Endowing to amplify the potential effects of different relaxation practices, we chose two types of these techniques. On one side, we took more dynamic exercises and on the other, more static ones (giving the limitations of being sitting on a desk while performing them). Hence, two types of relaxation practices were used in this study: Arms and neck stretching poses, and deep breathing and meditation exercises.

1) Static intervention: Mindfulness exercises of deep breathing and meditation activities were adapted from [21] and [22] for the set of exercises that require less movement. On them, first, the robot invites the user to stay sitting straight with their hands on their legs. Then, the robot invites the user to inhale (for 2 seconds) and exhale (for 3 seconds) for 5 times in a row. After that, the robot guided two rounds of meditation exercises. In the first one, it kindly suggests the user to close their eyes and think about things that make them happy, proceeding by acknowledging that it will count to 15 silently, so the user performs the meditation while slowly breathing as they like. After the given time, the robot asks the user to open their eyes again and it asks how the person is feeling. No answer is programmed to this question, being that just as a check-up and ice-break between the two meditation rounds. The second round then starts and the robot suggests to the user to close the eyes again and do exactly like last round but now thinking about their favourite song. The same time (15 secs) is given to complete this round and then the same check-up simulation is performed.

2) Dynamic intervention: Stretching exercises in our implementation are 5 poses of moving the neck and, after, the arms while sitting on the chair. Based on the stretching suggested by [23] for workers at office under long-time tasks on desks, we adapted these exercises to be easy to be executed for kids. For every move, the robot performs it first and then invites the user to mimic it when it holds the pose for 4 seconds each time. It starts by (1) moving the head to the users' left while keeping the trunk straight, (2) then doing the same to the user's right, then after (3) moving the head up, and, finally, (4) moving the head down. For the arms, first (5) stretching the arms forward, then (6) wide open to the sides (as shown in Fig. 1), and, finally, (7) stretching both arms up.

At the end of either practices, the robot celebrates with positive messages and gestures, and congratulates the use for having finished successfully this task, even if no validation of users' performance is performed.

IV. Experiment

A. Participants and Protocol

A total of 40 children (23 girls and 19 boys aged M = 8.83 years old, SD = 1.19) from an international school in Switzerland participated in this experiment[1]. They came from diverse socioeconomic backgrounds and are all English speakers and writers. One at a time, they were called out of their classrooms and briefed about the experiment by the researchers. The goal of this talk was to explain what participants should expect from their interaction with the robot; that they could ask questions or resign from the experiment at any time; and they were explicitly told to immediately report any discomfort they might feel to the experimenters. Before starting, experimenters also made sure the seat was correctly configured according to each kid. All participants are familiar with tablets, but none of them claimed being familiar to writing on tablets. Although it might seem to be a problem, studies showed that the same features of mistakes made on papers are kept in tablets, being evaluations on tablets comparable to the ones made in papers [24].

B. Experimental Design

Fig. 2 summarises the designed interaction of our experiment, where the blocks are the activities they performed at each step, below the blocks are the average time participants took to complete the corresponding step, and on top of the

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

blocks are the labels of how these steps are related to our experimental design.

In total, the session lasted around 22 minutes. We based this activity's duration on the time provided by the school for each child, and our previous study, that pointed out this duration as being enough time for perceiving initial outcomes. Participants performed a pre- and post-test, where their handwriting qualities were assessed using the Dynamilis handwriting analysis. Each handwriting analysis lasted around 2 minutes and half. Then, they did 2 game sessions of personalised handwriting training activities, by playing the Dynamilis game activities, for more than 5 minutes in each session. Between the handwriting training exercises sessions, they performed a pause more than 3 minutes longer, in which the robot invited them to participate in relaxation exercises that the robot guided them. The two conditions were static (mindfulness) and dynamic exercises (stretching), as shown in the *Type of intervention* step of Fig.2, where 19 participants were randomly assigned to the mindfulness condition and 21 participants to the stretching condition. Both conditions had a very similar average duration time, as shown by the small value of the standard deviation of this step (0.000034).

Handwriting scores provide by Dynamilis were used to evaluate our RQ1 and RQ2, while the REBA value of the postures was used for the RQ3 evaluation. To evaluate children's perception about their experience, RQ4, we asked children to verbally answer 3 questions, each corresponding to a 10-points Likert scale going from "very non-enjoyable" to "very enjoyable". The questions relate to: (1) how much did they enjoy the activity as a whole, to measure their overall enjoyment; (2) how much did they like the Dynamilis games in specific, to check how much they would attribute the enjoyment to the games; (3) how much did they like the relaxation exercise they performed, to check how much they would attribute the enjoyment to the type of break they did. Additionally, one open question regarding (4) how did they feel just after the break; and a question with three options, being: (5) how they would prefer doing the relaxation practical they were submitted to: Guided by the robot, as it was performed, guided by another human, as they are used to doing in their sport classes, or by themselves without external intervention.

V. Results and Discussion

A. Impacts of relaxation exercises on handwriting quality

Scores of the two Dynamilis handwriting analysis from all participants are reported in Fig 3. After confirming data are normally distributed using Shapiro-Wilk test, we applied the paired T-test to check if the variations were significant with $\alpha = .05$. While the increases in the *global* and *kinematic* dimensions were statically significant, with *p-values* 0.01 and 0.02, respectively, the other dimensions presented increases that were not confirmed.

B. Differences according to type of relaxation exercise

For the analysis of latent impacts according to the relaxation exercise, we separated the data by condition. The graphs in Fig. 4 and 5 show, respectively, the average scores of all dimensions from the pre- and post-test of the mindfulness and stretching conditions. Although no significant difference was found using a paired T-test, all the dimensions showed increases and a marginally significant difference was perceived in the *kinematic* of the stretching condition ($w = -2.0186$, $p = 0.057$).

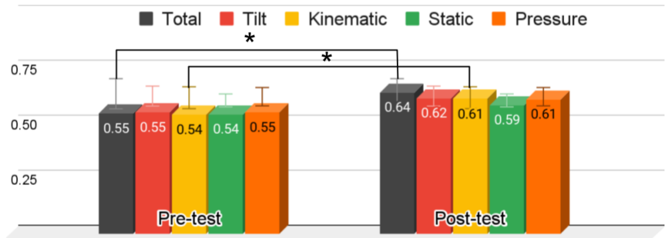

Fig. 3. Average of handwriting dimensions scores of all participants.

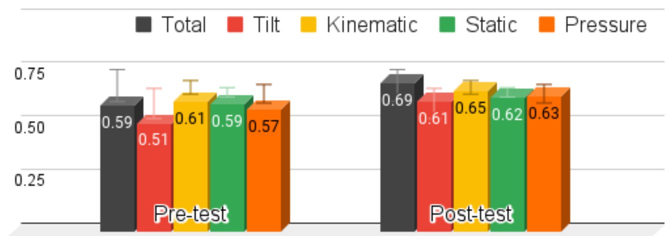

Fig. 4. Average of handwriting scores in the *mindfulness* condition.

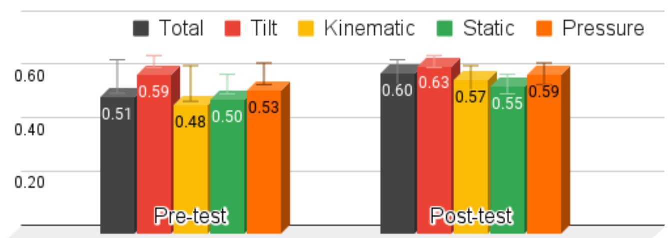

Fig. 5. Average of handwriting scores in the *stretching* condition.

C. Impacts of relaxation exercises on posture quality

Aiming at investigating the impact of relaxation practice on children's posture quality (RQ3), the REBA score was computed for both pre-test and post-test. Due to technical constraint, the skeleton data was only extracted for 26 children (10 in the stretching and 16 in the meditation groups). The two-sided paired Student T-test was conducted on the REBA scores between pre and post test, which indicates that there is no statistically significant change in posture quality after relaxation practices for both the stretching group (T=-1.2870, $p = 0.230$) and the mindfulness group (T=-0.0875, $p = 0.931$). Besides, we did the independent Student T-test on the change of REBA score from pre-test to post-test. The result shows that the difference in the postural changes is not statistically significant between mindfulness and stretching groups (T=0.8951, p=0.380).

D. *Children's perception about social robots for relaxation promotion*

1) Enjoyment of overall experience, Dynamilis games, and relaxation exercises: We asked participants for their enjoyment perception about (1) their overall experience, (2) Dynamilis games, and (3) the relaxation practice. Their answer's average score are illustrated in the graph of Fig. 6. The three averages are slightly higher in the stretching condition, despite no statistical significance was found in any comparison using T-test of independent means.

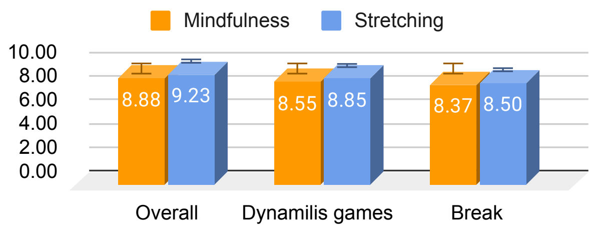

Fig. 6. Average scores of children's perception.

2) Self-reported feeling after the relaxation exercise: Regarding the open question of how did students feel after the relaxation exercise, they reported different answers. In the mindfulness condition, the following answers were given to the question "I felt...": calm (26.3% of the answers of 19 participants), normal (21.1%), good (15.8%), relaxed (15.8%), better (10.5%), happy (5.3%) and breathing (5.3%). In the stretching condition answers were: normal (33.3% of the answers of 21 participants), good (19%), really good (4.8)%, relaxed (4.8%), more flexible (4.8%), less tired (4.8%), afraid of being hurt but relaxed (4.8%), handwriting increased (4.8%), nothing (4.8%), tired (4.8%), weird (4.8%), and better (4.8%).

When clustering these answers in three superclasses of *positive*, *neutral*, and *negative* feedback, the mindfulness condition outperforms the stretching one, as displayed in the graph of Fig.7. The majority of participants (73.7%) in the mindfulness condition gave positive feedback, while roughly one quarter (26.3%) gave neutral feedback. Moreover, none of the answers was taken as negative. Conversely, in the stretching condition, there was no major agreement in participants feedback, where 14.3% gave negative feedback, 38.1% were neutral and 47.6% had positive reactions regarding their self-reported feeling.

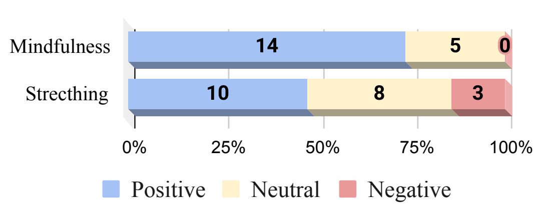

Fig. 7. Users' self-reported feeling about the relaxation exercise.

3) Guidance preference: Finally, when asked about their preferences for doing the relaxation activity between guided by the robot, guided by another human, or alone, most students in both conditions claimed a preference for the robot, as shown in Fig. 8. We also asked for the reason of their choices. In the mindfulness condition, among the children who preferred the robot, 6 of them said "Because it is cool" (31.57%), 1 (5.26%) said it was because the robot can not judge during the exercises, and 1 (5.26%) reported that it was because, differently from people, the robot seems more patient. Among the ones who reported a preference for a human guidance, 1 (5.26%) claimed it was because an interaction with a human seems more real, and 1 (5.3%) reported that the human has more knowledge to do so. All other 9 participants (47.3%) said they couldn't justify their choice. On the other hand, for the stretching condition, among children who preferred the robot, 6 said "Because it is cool" (30%), and 2 (9.6%) said it was easier than what they normally did in their sport classes. Out of the two who preferred the human, 1 (4.8%) said because it is faster and 1 (4.8%) because a human is more familiar. For the ones who preferred doing it alone, 1 (4.8%) claimed they think they could perform better alone and 1 (4.8%) prefers no external interference. Again, 9 (42.8%) participants couldn't justify their answer.

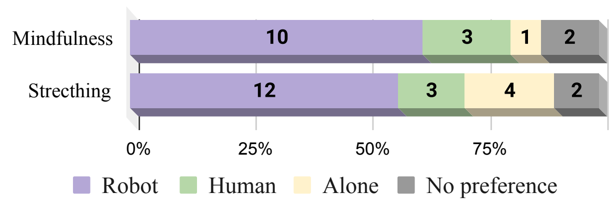

Fig. 8. Users' preference for guiding the relaxation intervention.

E. *Overall discussion*

The comparison of the handwriting quality at the beginning and at the end of the sessions showed significant increases in the overall and kinematic scores, supporting partially answer to our RQ1. Interestingly, a previous study requiring children to interact with the exact same setup and practice handwriting via the Dynamilis app for a comparable amount of time (15-20min) but without breaks, revealed no significant improvement in pre-post test handwriting analysis [11]. This contrast suggests the existence of potential causalities or correlations between these two elements, handwriting and relaxation pauses, worth to be further explored. Nonetheless, when analysing this effects by condition, the stretching presents slightly better scores with no statistical evidence, suggesting a negative answer to RQ2 for the collected data. Participants's posture quality did not present statistically significant variation from the beginning to the end, concluding also a negative answer to RQ3. This fact could be considered an advantage, taking into account that, in our previous study, significant decrease in the measures of REBA in the trunk part was detected in similar setups for the same period [10].

Findings of children's perceptions regarding the robot for relaxation practices are in line with the literature [25], with the majority of the respondents preferring the robot over another human or being alone, although this could be possibly due to the novelty effect. Lastly, when evaluating their perception by condition regarding the self-reported feeling towards the intervention, most of the participants from the mindfulness condition gave positive feedback and none gave negative ones. The same did not happen in the stretching condition, where some participants did give negative feedback and less than half of participants reported feeling better after the intervention. Therefore, our findings suggest that the answer for RQ4 depended on the type of intervention, where only a difference was noted regarding children's positive feedback on the mindfulness condition.

VI. Conclusions

Although preliminary, our results captured specific aspects of the investigated types of pauses. While the mindfulness intervention was superior to the stretching intervention in promoting subjective relaxation among participant children, the stretching intervention demonstrated a marginally significant improvement in one dimension of their handwriting, suggesting better physical performance. Nevertheless, when combining the results, the pause was effective in increasing overall handwriting quality and maintaining posture scores.

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