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Reducing and Enhancing Visual Feedback: A mixed Strategy to Improve the Learning and Rehabilitation of Handwriting

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ABSTRACT

The acquisition of handwriting relies on complex sensorimotor coordination, involving the progressive integration of visual and proprioceptive feedback. This article explores the impact of visual feedback modifications on handwriting motor control. Different strategies are examined according to the nature of the modification (adding or reducing information) and the timing of its application (during or after movement). We focus on two main types of visual feedback modifications. The first involves reducing visuospatial information during movement to promote predictive control based on internal representations. The second involves enhancing kinematic information during or after movement to support evaluation, correction, and consolidation of learning. Drawing on literature, we discuss how these strategies can influence handwriting motor control and learning. We then present a series of studies (previously published) conducted by our team, investigating the combined use of reduced and augmented visual feedback in both children and adults. These studies suggest that combining reduced and augmented visual feedback may be of value in educational and therapeutic settings, especially when delivered through the application of interactive tools like "Light Painting" and "e-trace". Findings from our studies suggest that alternating reduced and enhanced feedback improves handwriting fluency, speed, and pressure regulation while reducing reliance on visual control. However, the transfer of these effects to conventional handwriting remains limited, especially in children. Further research is needed to optimize the long-term retention of these benefits.

Introduction

Learning to write is a fundamental aspect of a child's development, essential not only for academic achievement but also for communication and autonomy, and it requires complex sensorimotor coordination (Bara & Morin, 2013). The efficient integration of visual and proprioceptive feedback is essential for acquiring this skill. The mechanisms by which these feedback sources are processed, along with the informational content they deliver, change progressively with age and writing skill acquisition (Zesiger et al., 2000). Between the ages of 6 and 8 years, motor control relies primarily on visuospatial information derived from the emerging handwriting trace. At this stage, movement is mainly guided by visual input, while proprioceptive contributions remain limited (Fleishman & Rich, 1963). Proprioceptive sensitivity is not yet fully developed before the age of 7 (Laszlo & Bairstow, 1984). As a result, proprioceptive information has not been sufficiently consolidated to support the formation of stable internal representations capable of guiding action. With training, control gradually becomes more predictive, relying primarily on motor information related to movement execution (for a review, see Palmis et al., 2017; Grosberg & Paine, 2000). Around age 10, a balance emerges between predictive and feedback-based control mechanisms. This development supports smoother and faster handwriting, which tends to become increasingly automated, albeit sometimes at the expense of legibility (Thibon et al., 2018). Handwriting acquisition thus involves a progressive shift from a control mode based on sensory feedback to one grounded in internal predictive models. This transition can be challenging for some children. One possible strategy to support this process involves modifying sensory feedback itself (Biotteau et al., 2019). This article aims to review current strategies for modifying visual feedback during handwriting, through either reduction or augmentation, and to discuss their effects on motor control and learning, illustrated by a selection of previously published studies conducted by our team. The following sections are organized around this central issue.

Enhanced feedback

"Enhanced feedback" refers to extrinsic information generated by an external device that complements or reinforces the intrinsic sensory feedback arising from the individual. Various types of supplementary information can be provided, regardless of the sensory modality involved. Typically, two main types of feedback are distinguished: knowledge of results and knowledge of performance.

"Knowledge of results" refers to the outcomes of the action, such as the visible trace left on the page. It facilitates learning by confirming whether the intended outcome has been achieved and indirectly contributes to the stabilization of movement quality (Salmoni et al., 1984; Schmidt & Lee, 2018). Knowledge of results offers several advantages: it enhances learner motivation, reinforces learning, aids in error correction, and supports strategic adjustments for future attempts. One of its key benefits is its simplicity—particularly for novices—as it targets concrete, observable, and measurable outcomes. However, knowledge of results has qualitative limitations: it provides no information about how the movement was executed, which can hinder fine-grained performance improvements. Additionally, this type of feedback is delivered only after the action has been completed.

By contrast, "knowledge of performance" focuses on the quality of the movement itself, including the technical characteristics of motor execution. Knowledge of performance relates to gesture dynamics, such as joint positioning, movement sequencing, speed, and acceleration. It allows for movement refinement through the provision of detailed information about execution, which is especially beneficial for mastering complex motor skills. Knowledge of performance enables specific corrections, provided the information is not overly complex or abundant—particularly for beginners, for whom excessive detail may result in cognitive overload and decreased performance (Weil & Amundson, 1994). Unlike knowledge of results, knowledge of performance may be delivered either in real time during the task or afterward.

Modifying the visual perception of the trace

The rise of digital tablets offers new opportunities in handwriting acquisition by enabling real-time or delayed modifications of visual perception. Tablets can enhance sensory feedback by, for example, coupling musical cues with handwriting movement (Danna & Velay, 2017) or visually altering the resulting trace. Augmented feedback may facilitate the learning of handwriting or assist individuals who struggle with this skill (Biotteau et al., 2019).

While augmented feedback is often conceptualized as the addition of supplementary information, it is also possible to modify the perception of the trace by reducing specific visual cues to optimize handwriting control. This paper aims to describe various techniques for modifying visual perception during handwriting and to examine the demonstrated or hypothesized benefits and drawbacks of each approach with respect to handwriting performance.

Adding visual information

Vision is a sensory modality that is already heavily relied upon during handwriting control, particularly in the early stages of learning. As such, adding visual information after the movement seems to be a straightforward and accessible strategy. Søvik and Teulings (1983) investigated the effects of additional visual feedback after the movement on writing speed and fluency in a group of twelve 11-year-old children performing graphomotor tasks. The results showed an improvement in writing speed, though not in fluency. Importantly, spatial accuracy was not negatively affected. Over the past decade relatively few studies have specifically examined the effects of adding visual feedback after the movement. More recently, Bonneton-Botté et al. (2020) tested several types of enriched visual feedback focused on the product of writing. These included feedback on letter shape and size, stroke direction and order, and pen lifts. Their system also included a dynamic model that allowed the child to compare their own handwriting with a reference template. Results showed an overall improvement in handwriting scores, especially among children with average baseline performance. However, not all types of visual modifications were tested independently, making it difficult to identify which specific variables were influenced by each feedback component.

Visual information can also be provided during the act of writing. However, this can impose a cognitive load on the writer, especially since visuospatial cues are already heavily engaged, particularly when the motor gesture is not yet fully automatized (Danna & Velay, 2015). To overcome this limitation, several strategies have been developed. One involves modulating the colour or thickness of the ink based on dynamic or kinematic parameters (Danna & Velay, 2015). Loup-Escande et al. (2017) examined the effects of supplementary visual feedback delivered with a graphic tablet on cognitive load, user experience, and gestural performance in a calligraphy learning task in both novice and expert calligraphers. Two types of feedback were compared, colour modulation based on writing speed and thickness modulation based on pen pressure, mimicking the ink flow of a fountain pen. Results showed no significant difference in cognitive load between expertise groups, but the pressure-based feedback generated a higher mental load than coloured velocity feedback. No differences were found in user experience. Regarding gestural performance, experts were faster than novices, and coloured velocity feedback induced higher writing pressure than pressure-based feedback. In children, Bartov et al. (2023) investigated the effect of real-time augmented visual feedback in 27 participants aged 7-12 years diagnosed with developmental coordination disorder (DCD). Parents provided informed consent, and participants completed the DCDQ before baseline assessments, which included the MABC-2, the Hebrew Handwriting Evaluation, and a tablet-writing task administered individually in a quiet room. The intervention consisted of eight weekly 20-minute sessions. Each session began with a brief practice in which children traced five non-letter shapes for 20 seconds each to experience the principle of colour feedback according to pen pressure (e.g., red for excessive pressure, black for appropriate pressure). They then copied an excerpt of 47 words from a handwriting assessment (or for 5 minutes, whichever came first) twice, once with augmented visual feedback and once without (black trace). A within-subject design was used, with the order of conditions randomly counterbalanced across participants. Results showed reduced variability and more effective pressure regulation with augmented feedback, and these improvements persisted when writing new texts after the intervention.

Reducing visual information

The aim of reducing visual information during handwriting is to limit motor control based on visuospatial cues tied to the graphic trace and to promote greater reliance on proprioceptive and kinaesthetic inputs associated with movement execution. This reduction can take several forms: complete suppression of vision (e.g., eyes closed), occlusion of the moving hand, or partial or total removal of the graphic trace.

Chartrel and Vinter (2006) investigated the role of visual information during the production of isolated cursive letters in 48 children (aged 8–10 years) versus adults. Participants copied various cursive letters under three conditions: full vision, partial vision (hand and trace hidden), or no vision (eyes closed). When visual feedback was absent, adults showed only increased pen pressure. In contrast, children compensated by increasing movement length, movement velocity, and pressure, while maintaining constant movement duration. These results suggest that the disruption observed in younger children reflects an immature motor control system still dependent on visual feedback, whereas older participants likely rely on more automated, internally driven control mechanisms.

Portier and Van Galen (1992) explored the effects of suppressing both hand and trace visibility in a task involving the acquisition of Arabic characters in 36 adults. They manipulated visual feedback: immediate feedback, postponed feedback (static display after the trial), or both. Interestingly, their results revealed improved writing speed and fluency, suggesting that reducing visual input may foster motor automatization. However, legibility was not evaluated, and the authors cautioned that substantial visual deprivation might interfere with other aspects of motor control—such as hand posture or pen positioning.

To avoid the drawbacks of complete visual suppression, a more refined approach consists in partially or totally reducing the visibility of the written trace. In these situations, the reduced availability of visual cues during the act of handwriting creates a dissociation between feedback related to the process and that related to the product of writing. The idea is to direct the writer's attention toward the ongoing movement, while delaying access to the outcome. This strategy is expected to improve motor encoding and reduce visual overreliance, potentially enhancing the legibility of the produced trace. Bara and Bonneton-Botté (2021) tested a condition in which the writing trace was entirely suppressed, while preserving spatial cues from the hand and pen position. In preschool-aged children, this manipulation led to improvements in kinematic measures, although a decrease in spatial accuracy was observed. This reduction in graphic quality appears to be linked to the absence of delayed visual feedback, which prevented children from evaluating the correctness of their output. These findings underscore the importance of external visual cues in calibrating developing motor representations.

To counter the loss of spatial precision, Connan et al. (2021) proposed partial suppression of the trace using a digital stylus and tablet. In this approach, the trace is only displayed for a very short time—typically a tenth of a second—so that the writer cannot perceive the global shape of the letter while writing. Instead, a short trailing segment (resembling a "snake") follows the stylus tip (see video 1). The full trace becomes visible only after the movement is complete, allowing for comparison with a reference model.

Supplementary Video 1

In an initial study with adults, this method was found to produce positive effects during training phases. However, these benefits disappeared in post-tests conducted under standard writing conditions. This drop-off may be due to a guidance effect (Ronsse et al., 2011), where learners become reliant on external feedback rather than developing internalized control based on intrinsic sensory cues (Sigrist, 2013). The specificity-of-learning hypothesis (Proteau et al., 1998) also offers an explanation: when the modified visual feedback dominates during practice, it may hinder the integration of other relevant cues such as proprioception. These findings raise critical questions regarding the optimal frequency and sensory modality through which augmented feedback should be delivered, depending on the nature of the information to be conveyed.

Overall, this body of research converges on the idea that reducing visual feedback during handwriting affects sensorimotor resources in different ways depending on the writer's age and stage of motor development. While it may serve as a lever to promote automatization, it also introduces certain limitations, particularly in terms of spatial precision and trace legibility, especially in younger writers.

Combining reduced and augmented visual feedback

Combining visual feedback reduction during the action with enriched feedback delivered after the action represents a promising strategy. These two types of feedback engage distinct cognitive processes and may interact in complex ways. For example, Blandin et al. (2008) showed that terminal feedback can reduce dependency on concurrent feedback by limiting cognitive processing demands during movement execution. Concurrent feedback provides learners with immediate visual guidance to control the movement, while terminal feedback promotes deeper processing and supports the development of more autonomous control. Across the studies we conducted, we aimed to exploit this complementarity by developing an application inspired by the perceptual effects of Light Painting, designed to integrate these two types of feedback within a single framework.

Light Painting

Light painting is an artistic technique that merges photography and movement (Baitinger & Ouaki, 2012). It involves capturing the trajectory of a handheld light source through long-exposure photography in a dark environment. During the action, the performer perceives only a partial trace of the movement, as the moving light creates a visible trail. The length and intensity of the trail reflect the speed and dynamics of the gesture. After the movement, the resulting photograph displays the full trajectory and offers both a visual representation of the shape and insight into movement velocity via variations in light intensity (see Figure 1).

Figure 1 *Example of a photograph obtained using light painting (LP) with patients. Variations in light intensity indicate changes in movement speed.*

This technique alters visual feedback during writing in three main ways compared to conventional handwriting: (1) movements are broader; (2) they are performed in a vertical plane; and (3) they are executed in the air, without physical contact with a writing surface.

To investigate its potential, we tested several Light Painting-based setups in both adults (Connan et al., 2024) and children (Connan et al., 2023) during tasks involving the learning of novel letter forms. In an initial study with 16 adults, participants used a Light Painting device to draw in the air with their arm, while standing in front of a 1.2 m² frame. The control group completed the task on a whiteboard using a marker. Pre- and post-tests were conducted in a more handwriting-like setup, with participants seated and using an ink stylus on a paper fixed to a digital tablet (frame size: 16 cm²). Data were analysed using linear mixed models with group (Light Paining vs. Control) and time (Pre-test vs. Post-test) as fixed factors, and participants as a random factor. Dependent variables included writing speed, fluency, mean pressure, letter size, and spatial accuracy. Results showed that following Light Paining training, participants wrote faster, applied less pressure, and produced larger characters. However, spatial accuracy was not significantly improved in either group. In a second experiment, the Light Painting condition was made more like standard handwriting: participants were seated and used a luminous stylus (without ink) to write within a 20 cm² frame on a digital tablet. The control condition involved conventional handwriting using a pen on paper in the same spatial layout. Testing procedures were identical to the first experiment. As in Experiment 1, data were analysed using linear mixed models. Results revealed faster, more fluent movements, larger character size, and reduced pressure during Light Painting training. In this case, spatial accuracy improved post-training, regardless of condition. However, the fluency gains observed during Light Painting training did not persist in the post-test. This second protocol was then replicated with children in Grade 3 to evaluate whether Light Painting could support learning. However, the expected benefits were not observed. While performance improved during Light Painting training, the gains did not transfer to standard handwriting tasks. One possible explanation is that children rely more heavily on visual input, increasing the risk of feedback dependency. Reducing feedback frequency might enhance learning outcomes.

Light Painting was also tested in a rehabilitation protocol involving an 8-year-old child with DCD and severe dysgraphia, who exhibited very low motivation for writing. The program included 12 sessions—6 using Light Painting (in both standing and seated positions) and 6 using standard handwriting conditions. The intervention was structured in three phases, progressing from large-scale movements to typical handwriting spaces. For each phase, two sessions involved Light Painting and two used conventional tools (e.g., ink pen, marker). Our approach combined Light Painting and explicit letter instruction and metacognitive strategies (e.g., self-evaluation, self-instruction, problem-solving) to help the child interpret the feedback and monitor the progress. Two exercise modules were presented in each session: one focused on pre-writing motor patterns (based on Athènes et al., 2004; Danna et al., 2011, 2016), and the other focused on isolated letter and bigram learning, grouped by shared motor features. For each variable, we calculated the percentage of change between the sessions with and without Light Painting. These percentages for the sessions with and without light painting were compared using a Wilcoxon test. Positive effects were observed in writing speed and fluency. However, no significant differences between Light Painting and control sessions were found in terms of length, pressure, or legibility. The child's BHK score improved at the end of the 12-session protocol. Subjectively, parents reported increased spontaneity in writing, and the child expressed greater ease—except when writing quickly. Although this is a single case study with inherent limitations, it highlights the potential of Light Painting-based feedback in handwriting rehabilitation. Further validation using single-case experimental designs (SCED) with larger samples is needed.

In summary, Light Painting places the child in a novel situation, significantly different from conventional handwriting. This novelty can enhance engagement and rebuild confidence in children who experience handwriting difficulties. The act of drawing with light can even be perceived as playful. However, this novelty may limit the transfer of learning effects to typical handwriting conditions, especially in children. Additional research is needed to optimize Light Painting use and reduce feedback dependency.

The "e-trace" Application

To create a learning environment closer to traditional handwriting conditions, we developed a digital version of the light painting method for use on tablet devices. This application allows for precise manipulation of visual feedback, both by reducing information during the action and by adding informative cues after the action. Unlike Light Painting, which combines both modifications in a single trial, the e-trace application makes it possible to alternate these two types of feedback across trials. In this design, one trial implements the "snake" mode, where visual feedback is partially suppressed during movement: only a short trailing segment of the trace follows the stylus tip, and the full trace becomes visible after the movement is completed. The alternate trial displays the full trace during writing, but after the action, additional visual information is presented, such as movement kinematics (see figure 2). Alternating these conditions ensures that each type of feedback is delivered only 50% of the time. This lower frequency is designed to encourage the development of more stable internal representations that are less dependent on any single type of external feedback. This approach aligns with studies showing that reduced feedback frequency supports better retention and generalization (Kovacs & Shea, 2011; Winstein, 1991).

Figure 2 *Enriched postponed condition. Red dots indicate abnormal velocity peaks on the trace, revealed after the trial. These peaks, identified using the SNvpd index (Danna et al., 2013), were computed by comparing velocity signals filtered at 10 Hz and 5 Hz (Butterworth low-pass filter). They correspond to areas where handwriting was less fluent.*

We first tested this mixed-feedback strategy in adults during a task involving the learning of novel pseudo-letters with the non-dominant hand. Results indicated that this combined and alternating visual feedback approach was promising to facilitate short-term transfer of performance to more conventional handwriting conditions (Connan et al., 2023). Participants who trained with mixed modification demonstrated faster and more fluent writing, along with reduced pen pressure, immediately after the training. The control group used the same tablet setup but received no visual feedback modification. Unfortunately, these benefits did not persist in a delayed post-test conducted the following day, suggesting that while the strategy enhances immediate performance, long-term retention may require additional support. Nevertheless, the alternating feedback condition led to better transfer and reduced dependence compared to isolated feedback modification. This supports the hypothesis that alternating mixed feedback can foster more autonomous control and better generalization than repeated exposure to a single type of augmented feedback. We next asked whether this strategy could benefit children with handwriting difficulties.

To address this question, we designed an experimental rehabilitation protocol for children with dysgraphia, based on the mixed modification. All participating children met DSM-5 criteria for developmental coordination disorder (DCD) with associated dysgraphia, defined as either ≤ -2 *SD* in one BHK score or ≤ -1.5 *SD* in both. Participants were enrolled from the end of Grade 1to Grade 5. We made some modifications to bring the setup closer to Light Painting conditions (See supplementary video 2). Given the diverse mechanisms underlying dysgraphia, this protocol focused on difficulties in handwriting motor control. The program was delivered on a Windows® tablet using a custom-built application developed in Octave® (a clinical version is currently under development).

Supplementary Video 2

The twelve-week intervention included six sessions using visual feedback modification and six control sessions without it. The structure of the training followed the same principles as the Light Painting case study and included two modules: one for pre-writing motor training and another for explicit instruction of isolated letters and bigrams, grouped according to shared motor characteristics. We also incorporated evidence-based educational strategies known to improve handwriting outcomes: explicit instruction, metacognitive strategies (self-instruction, self-evaluation, problem-solving). In each session, children were explicitly trained in metacognitive techniques to help them assess their own handwriting and analyse the feedback provided by the application. Results showed a modest but statistically significant advantage in favour of the alternating mixed feedback condition. Globally, children also demonstrated improvements in both legibility and handwriting frequency on the BHK test administered at the end of the intervention. A manuscript on this study is currently being prepared for submission.

It is important to note several limitations. The e-trace protocol was designed as an experimental tool, alternating feedback and control sessions to isolate effects. A clinical adaptation of this protocol would likely involve different timing and frequency for feedback delivery. Based on our data and existing literature, a gradual decrease in augmented feedback toward the end of the intervention may enhance long-term learning outcomes. Another limitation is that no control group was included to specifically verify the unique effectiveness of the rehabilitation protocol, making it difficult to fully disentangle its effects from other potential contributing factors.

Conclusion

The digital age offers undeniable opportunities for enhancing handwriting control and supporting motor-based re-education through perceptual modifications. These tools allow for both the enrichment and reduction of sensory feedback, providing innovative approaches to handwriting learning and rehabilitation. In particular, mixed visual feedback strategies, which combine feedback suppression during action with augmented feedback after action, have demonstrated clear benefits, notably in improving handwriting fluency, speed, and pressure regulation.

The shared goal of these perceptual modification methods is to support the shift from a control mode based on the product of writing (i.e., the visible trace) to one based on the process of writing (i.e., the movement itself), as suggested by Biotteau et al. (2019). In the medium term, it may be advantageous to explore the integration of multiple sensory feedback modalities, such as visual and auditory channels, to evaluate their potential synergistic effects on learning and motor recovery.

However, modifying visual perception through digital tablets is not without limitations. Excessive reliance on augmented feedback may foster dependency, thereby hindering learners' autonomy and self-monitoring skills. Furthermore, the transferability of benefits to standard handwriting conditions remains limited, especially when feedback is highly specific or artificial. It is therefore crucial to optimize feedback design, ensure that gains translate to conventional writing tasks, and assess potential unintended effects.

One such unintended effect involves the low-friction surface of touchscreens, which alters the dynamics of handwriting. Studies have shown that writing kinematics on smooth tablets differ significantly from paper-based writing, particularly in children (Alamargot & Morin, 2015; Gerth et al., 2016a, 2016b). Alamargot and Morin (2015) suggested that reduced friction may impair proprioceptive control during handwriting, especially in children whose fine motor skills are not yet fully developed. To mitigate these effects, it is possible to use overlay films that increase the surface friction of tablets.

In conclusion, tablet-based therapeutic tools are not intended to replace handwriting with pen and paper, nor to substitute for the role of teachers or therapists. Rather, they are meant to serve as targeted, temporary aids that can be incorporated into existing pedagogical or therapeutic frameworks. Their purpose is to support struggling writers in developing the motor control necessary for more efficient and autonomous handwriting.

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References

Athenes, S., Sallagoïty, I., Zanone, P.-G., & Albaret, J.-M. (2004). Evaluating the coordination dynamics of handwriting. *Human Movement Science*, 23, 621–641. https://doi.org/10.1016/j.humov.2004.10.004

Alamargot, D., & Morin, M.-F. (2015). Does handwriting on a tablet screen affect students' graphomotor execution? A comparison between grades two and nine. *Human Movement Science*, 44, 32–41. https://doi.org/10.1016/j.humov.2015.08.011

Baitinger, F.-C., & Ouaki, G. (2012). *Jadikan: Lightning project* (1re éd.). Critères Éditions.

Bara, F., & Bonneton-Botté, N. (2021). Handwriting isolated cursive letters in young children: Effect of the visual trace deletion. *Learning and Instruction*, 74, 101439. https://doi.org/10.1016/j.learninstruc.2020.101439

Bara, F., & Morin, M. (2013). Does the handwriting style learned in first grade determine the style used in the fourth and fifth grades and influence handwriting speed and quality? A comparison between French and Quebec children. *Psychology in the Schools*, 50(6), 601–617. https://doi.org/10.1002/pits.21691

Bartov, R., Wagner, M., Shvalb, N., & Hochhauser, M. (2023). Enhancing handwriting performance of children with developmental coordination disorder (DCD) using computerized visual feedback. *Children*, 10, 1534. https://doi.org/10.3390/children10091534

Biotteau, M., Danna, J., Baudou, É., Puyjarinet, F., Velay, J. L., Albaret, J. M., & Chaix, Y. (2019). Developmental coordination disorder and dysgraphia: Signs and symptoms, diagnosis, and rehabilitation. *Neuropsychiatric Disease and Treatment*, 15, 1873–1885. https://doi.org/10.2147/NDT.S120514

Blandin, Y., Toussaint, L., & Shea, C. H. (2008). Specificity of practice: Interaction between concurrent sensory information and terminal feedback. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 34(4), 994–1000. https://doi.org/10.1037/0278-7393.34.4.994

Bonneton-Botté, N., Fleury, S., Girard, N., Le Magadou, M., Cherbonnier, A., Renault, M., Anquetil, E., & Jamet, E. (2020). Can tablet apps support the learning of handwriting? An investigation of learning outcomes in kindergarten classroom. *Computers & Education*, 151, 103831. https://doi.org/10.1016/j.compedu.2020.103831

Chartrel, E., & Vinter, A. (2006). Rôle des informations visuelles dans la production de lettres cursives chez l'enfant et l'adulte. *L'Année Psychologique*, 106(1), 43–63. https://doi.org/10.4074/S0003503306001047

Connan, J.-F., Jover, M., Luigi, M., Saint-Cast, A., & Danna, J. (2024). Benefits of a light-painting technique for learning to write new characters: A proof of concept with adults. *Perceptual and Motor Skills*, 131(1), 267–292. https://doi.org/10.1177/00315125231215724

Connan, J.-F., Luigi, M., Barthez, E., Saint-Cast, A., Danna, J., & Jover, M. (2023). Le light painting : Un outil artistique au service de l'apprentissage de nouvelles lettres chez l'enfant. *A.N.A.E.*, 186, 531–540.

Connan, J.-F., Jover, M., Saint-Cast, A., & Danna, J. (2023). Does modifying visual feedback facilitate learning to write new pseudoletters? *Human Movement Science*, 87, 103046. https://doi.org/10.1016/j.humov.2022.103046

Connan, J.-F., Jover, M., Saint-Cast, A., & Danna, J. (2021). Comment les nouvelles technologies peuvent-elles aider le scripteur à mieux écrire ? Étude pilote sur la modification de la perception visuelle de la trace. *A.N.A.E.*, 170, 1–11.

Danna, J., Athènes, S., & Zanone, P.-G. (2011). Coordination dynamics of elliptic shape drawing: Effects of orientation and eccentricity. *Human Movement Science*, 30, 698–710. https://doi.org/10.1016/j.humov.2010.08.019

Danna, J., & Velay, J.-L. (2015). Basic and supplementary sensory feedback in handwriting. *Frontiers in Psychology*, 6, 169. https://doi.org/10.3389/fpsyg.2015.00169

Danna, J., Velay, J.-L., & Albaret, J.-M. (2016). Dysgraphies. In *Traité de neurolinguistique* (pp. 337–346). De Boeck.

Danna, J., & Velay, J.-L. (2017). Handwriting movement sonification: Why and how? *IEEE Transactions on Human-Machine Systems*, 47(2), 299–303. https://doi.org/10.1109/THMS.2016.2641397

Fleishman, E. A., & Rich, S. (1963). Role of kinesthetic and spatial-visual abilities in perceptual-motor learning. *Journal of Experimental Psychology*, 66(1), 6–11. https://doi.org/10.1037/h0046677

Gerth, S., Klassert, A., Dolk, T., Brenner-Fliesser, M., Fischer, M., Nottbusch, G., & Festman, J. (2016a). Adapting to the surface: A comparison of handwriting measures when writing on a tablet computer and on paper. *Human Movement Science*, 48, 62–73. https://doi.org/10.1016/j.humov.2016.04.006

Gerth, S., Klassert, A., Dolk, T., Fliesser, M., Fischer, M. H., Nottbusch, G., & Festman, J. (2016b). Is handwriting performance affected by the writing surface? Comparing preschoolers', second graders', and adults' writing performance on a tablet vs. paper. *Frontiers in Psychology*, 7, 1308. https://doi.org/10.3389/fpsyg.2016.01308

Grossberg, S., & Paine, R. W. (2000). A neural model of cortico-cerebellar interactions during attentive imitation and predictive learning of sequential handwriting movements. *Neural Networks*, 13(8–9), 999–1046. https://doi.org/10.1016/S0893-6080(00)00065-4

Kovacs, A. J., & Shea, C. H. (2011). The learning of 90° continuous relative phase with and without Lissajous feedback: External and internally generated bimanual coordination. *Acta Psychologica*, 136(3), 311–320. https://doi.org/10.1016/j.actpsy.2010.12.004

Laszlo, J. I., & Bairstow, P. J. (1985). *Perceptual motor behavior: Developmental assessment and therapy*. Praeger.

Loup-Escande, E., Frenoy, R., Poplimont, G., Thouvenin, I., Gapenne, O., & Megalakaki, O. (2017). Contributions of mixed reality in a calligraphy learning task: Effects of supplementary visual feedback and expertise on cognitive load, user experience and gestural performance. *Computers in Human Behavior*, 75, 42–49. https://doi.org/10.1016/j.chb.2017.05.006

Palmis, S., Danna, J., Velay, J.-L., & Longcamp, M. (2017). Motor control of handwriting in the developing brain: A review. *Cognitive Neuropsychology*, 34(3–4), 187–204. https://doi.org/10.1080/02643294.2017.1367654

Portier, S. J., & Van Galen, G. R. (1992). Immediate vs. postponed visual feedback in practising a handwriting task. *Human Movement Science*, 11(5), 563–592. https://doi.org/10.1016/0167-9457(92)90016-5

Proteau, L., Tremblay, L., & Dejaeger, D. (1998). Practice does not diminish the role of visual information in on-line control of a precision walking task: Support for the specificity of practice hypothesis. *Journal of Motor Behavior*, 30(2), 143–150. https://doi.org/10.1080/00222899809601331

Puyjarinet, F. (2019). Intérêts de la pratique de l'imagerie motrice dans la rééducation de l'écriture des enfants dysgraphiques. *A.N.A.E.*, 159, 365–374.

Ronsse, R., Puttemans, V., Coxon, J. P., Goble, D. J., Wagemans, J., Wenderoth, N., & Swinnen, S. P. (2011). Motor learning with augmented feedback: Modality-dependent behavioral and neural consequences. *Cerebral Cortex*, 21(6), 1283–1294. https://doi.org/10.1093/cercor/bhq209

Salmoni, A. W., Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: A review and critical reappraisal. *Psychological Bulletin*, 95(3), 355–386. https://doi.org/10.1037/0033-2909.95.3.355

Schmidt, R. A., Lee, T. D., Winstein, C., Wulf, G., & Zelaznik, H. N. (2018). *Motor control and learning: A behavioral emphasis* (6th ed.). Human Kinetics.

Sigrist, R., Rauter, G., Riener, R., & Wolf, P. (2013). Augmented visual, auditory, haptic, and multimodal feedback in motor learning: A review. *Psychonomic Bulletin & Review*, 20(1), 21–53. https://doi.org/10.3758/s13423-012-0333-8

Søvik, N., & Teulings, H.-L. (1983). Real-time feedback of handwriting in a teaching program. *Acta Psychologica*, 54(1), 285–291. https://doi.org/10.1016/0001-6918(83)90040-9

Thibon, L. S., Gerber, S., & Kandel, S. (2018). The elaboration of motor programs for the automation of letter production. *Acta Psychologica*, 182, 200–211. https://doi.org/10.1016/j.actpsy.2017.12.003

Weil, M. J., & Amundson, S. J. (1994). Relationship between visuomotor and handwriting skills of children in kindergarten. *American Journal of Occupational Therapy*, 48(11), 982–988. https://doi.org/10.5014/ajot.48.11.982

Wilson, P. H., Thomas, P. R., & Maruff, P. (2002). Motor imagery training ameliorates motor clumsiness in children. *Journal of Child Neurology*, 17(7), 491–498. https://doi.org/10.1177/088307380201700704

Wilson, P. H., Adams, I. L. J., Caeyenberghs, K., Thomas, P., Smits-Engelsman, B., & Steenbergen, B. (2016). Motor imagery training enhances motor skill in children with DCD: A replication study. *Research in Developmental Disabilities*, 57, 54–62. https://doi.org/10.1016/j.ridd.2016.06.014

Winstein, C. J. (1991). Knowledge of results and motor learning—Implications for physical therapy. *Physical Therapy*, 71(2), 140–149. https://doi.org/10.1093/ptj/71.2.140

Zesiger, P., Deonna, T., & Mayor, C. (2000). L'acquisition de l'écriture. *Enfance*, 53(3), 295–304. https://doi.org/10.3406/enfan.2000.3186