Direct versus Indirect Visual Feedback: the Effect of Technology in Neurorehabilitation

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Rehabilitation Practices & Introduction of Technology

Besides specific practices such as the Mirror Therapy or Prism Adaptation Intervention, traditional rehabilitation practices rely on movement repetitions performed with a direct, non-modified, visual feedback.

Direct feedback is predominant in standard practices

Technology has introduced an indirect visual feedback

Indirect feedback is currently the standard for robotic and interactive devices

ArmeoPower (Hocoma)

M2 (Fourier Intelligence)

InMotion Arm (Bioniks Labs)

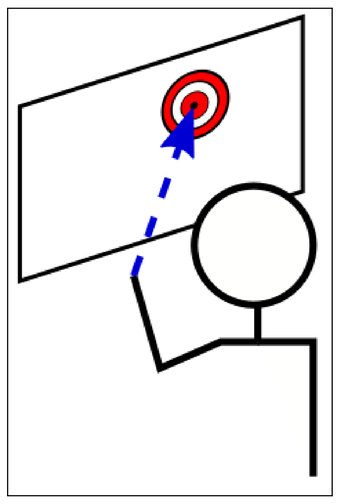
Pablo (Tyromotion)

A few exceptions

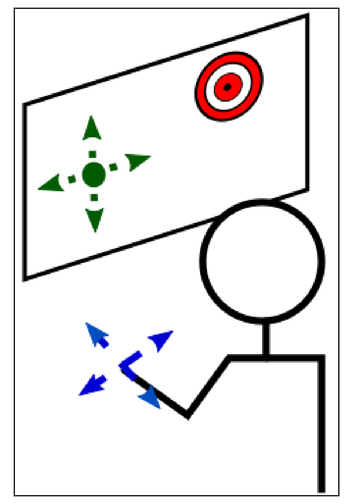
Myro (Tyromotion)

EMU ([1])

Direct



Indirect

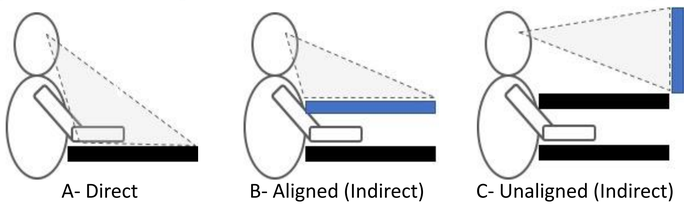


Does the type of feedback matter?

A structured literature review

Motor learning - Neurophysiology - Technology - Neurorehabilitation

Learning, Adaptation & Transfer



A- Direct B- Aligned (Indirect) C- Unaligned (Indirect)

Immediate effect

Movements performed under Indirect feedback (B or C) are:

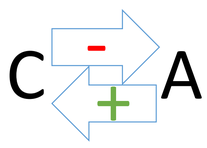
- slower and less straight [2]
- less accurate [3]

than the ones performed under Direct feedback (A).

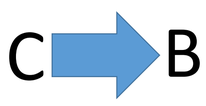
Skills transfer

Stronger adaptation in Direct Feedback (A) [4]

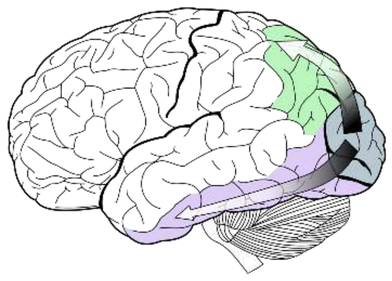
After-effect translates more efficiently from Direct (A) to Indirect (C) [4].



Some transfers occurs from a training with aligned (C) to a practice with aligned feedback (B) [5].



Neurophysiological Considerations



The Milner and Goodale two-streams hypothesis where the dorsal stream (green) is dedicated to spatial representation and the ventral stream (purple) is dedicated to identification and recognition. They originate from a common source in the visual cortex.

If the two-pathways hypothesis is disputed in favour of a more complex interconnection, it seems that goal directed actions (of interest in rehabilitation) are mostly driven by the Posterior Parietal Cortex (from the Dorsal Stream) [6].

Neurophysiological experiments suggest that spatial representations for action are expressed in an egocentric coordinate system [7]. But in recent experiments, Renault et al suggested that subject and movement characteristics dependent [8].

Additionally, macaques experiments suggest that different areas are selectively sensitive to either self-movements or external movements [10].

Conclusions

No strong evidence in literature in favour of either direct or indirect visual feedback in neurorehabilitation.

- Indirect feedback slightly complexifies the learning which may affect the instantaneous training difficulty and thus the patients motivation.
- Motor adaptation and learning can transfer from training with indirect feedback to direct feedback, but more specific studies on the effectiveness of this transfer are required.
- Neurophysiology suggests that indirect and direct feedbacks are relying on different pathways.

References

[1] Fong et al, “EMU: A transparent 3D robotic manipulandum for upper-limb rehabilitation." ICORR 2017.
[2] Bo et al, “Effects of increased complexity of visuo-motor transformations on children’s arm movements,” Human Mov Sci, vol. 25, no. 4-5 (2006), pp. 553–567.
[3] Messier et al., “Differential effect of task conditions on errors of direction and extent of reaching movements,” Exp Brain Res, vol. 115, no. 3 (1997), pp. 469–478.
[4] Norris et al., "Prism adaptation of reaching is dependent on the type of visual feedback of hand and target position." Brain Res 905.1-2 (2001): 207-219.
[5] Lhuisset et al., "Developmental aspects of the control of manual aiming movements in aligned and non-aligned visual displays." Exp Brain Res 146.3 (2002): 293-306.
[6] Galivan et al., “The dorsal "action" pathway“, Hand of Clin Neuro (2018);151:449-466,
[7] Buneo et al., "Direct visuomotor transformations for reaching." Nature 416.6881 (2002): 632.
[8] Renault et al. "Individual movement features during prism adaptation correlate with after-effects and interlimb transfer." Psy Res (2018): 1-15
[10] Hietanen et al., "Motion sensitive cells in the macaque superior temporal polysensory area: response discrimination between self-generated and externally generated pattern motion." Behav Brain Res 76.1-2 (1996): 155-167.

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