Short-term effects in undisturbed postural control induced by visual feedback training
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INTRODUCTION
The visual feedback (VFB) technique is recognised as an appropriate tool for re-establishing postural stability following various motor dysfunctions. Indeed, VFB training programs are used to improve postural balance after a number of diseases such as hemiplaegia (Shumway-Cooke et al.; 1988). These studies have shown that, with daily and weekly training sessions, a decrease in amplitude of postural oscillations can be observed. Most of the time, these training protocols are programmed for rather long periods. Only a few studies have been focused on the short term VFB effect on postural control for healthy individuals (Takeya et al., 1976; Clarke et al., 1990). The former report observes a slight augmentation of stability after five sessions of three trials (30s) with 20-30s rest periods whereas the latter observes a deterioration in performance after three training sessions of four trials (1mn) with short rest periods.

Classically, postural investigations quantify the postural control by analysing the centre of pressure (CP) trajectory, which is appropriated through a force platform. The study of this global signal does not include the two elementary tasks involved in maintaining postural balance: the limitation of variations of resulting moments in ankles and the restriction of the centre of gravity (CG) motions in a reduced zone. Consequently it seems coherent to dissociate these CP trajectories into two elementary components: the vertical projection of CG (CG_v) and the difference between the former and the latter: CP-CG_v (Rougier et Caron; 2000). Biomechanically, the CG_v variable represents the net postural performance (Winter et al., 1998) whereas the proportionality existing between CP-CG_v amplitudes and CG horizontal accelerations (Caron et al., 2000). Even decomposed, these different motions are controlled. To this aim, recourse to mathematical models such as fractional Brownian motion (fBm), constitutes a very sensitive analysis method. This study is thus aimed at establishing the short-term effects of a training protocol during which healthy subjects repeatedly perform this VFB task. With this aim in mind, a comparison between pre-training and post-training with closed eyes is made to observe modifications in postural control.

METHOD

Data acquisition:
Eighteen subjects stood barefoot on a force platform in a natural position (feet abducted at an angle of 30°) and were asked to decrease their amount of body sway as much as possible with their arms at their sides. Postural sway was evaluated using a force platform to obtain the CP trajectories, the latter being then decomposed into antero-posterieur (AP) and medio-lateral (ML). Three conditions were successively performed:
- a pre-training test with closed eyes (pre-T)
- a VFB training session (VFB)
- a post-training test with closed eyes (post-T1) immediately after VFB

Each session included five trials of 64s (sample frequency: 64Hz), rest periods between trials of a similar length being allowed. In addition, a longer period (10 minutes) separated pre-T and post-T conditions. The VFB condition consisted of three sessions of five trials with rest periods of 10 min between each session. The gain of VFB, i.e. the ratio between the real displacements of the CP and their display on the screen was twofold for both directions. After the third training session, the subjects were immediately re-tested. The first trial of post-T was noted post-T1.

Calculation of CG_v and CP-CG_v:
A simple method, based solely on the CP trajectory recordings, was used to determine the CG, and consequently the CP-CG, motions. The mathematical model (Brenière, 1996), based on an amplitude ratio between CG, and CP motions as a function of sway frequencies, establishes a low-pass filter given by the following formula:

$$\frac{CG}{CP} = \frac{\Omega_o^2}{(\Omega_o^2 + \Omega^2)}$$

Where $\Omega$ is the pulsation and $\Omega_o$ is a biomechanical constant relative to the anthropometry of the subject.

CP, CG, and CP-CG motions were then studied through parameters issued from fBm modelling (Mandelbrot et Van Ness, 1968). Recourse to this model means that a trajectory may be quantified by a fractional i.e., a non-finite integer space dimension. To this aim, variograms, i.e. plotting mean square displacements measured along each direction $<\Delta x^2>$ and $<\Delta y^2>$ as a function of increasing time intervals ($\Delta t$), are computed for each trial. In order to quantify the variogram’s slopes, an automatic method (Rougier, 1999) was employed in order to define the spatio-temporal co-ordinates of the slope inflection (transition point) for each direction. CP and CG motions being, by definition, in phase, the temporal co-ordinate would be necessarily identical for both elementary motions. The scaling exponents H (indexed as short and long latencies $H_{sl}$ and $H_{ll}$), which allow to determine the respective contribution of stochastic and deterministic control mechanisms, were then calculated through a least square method for preceding and succeeding points, respectively. Each parameter was computed for both pre-T and post-T1 conditions and compared through a paired non-parametric T-Wilcoxon test.

**RESULTS**

The averaged variograms display differences when pre-T and post-T1 are compared.

**Figure 1:** Variograms of one subject for both CG, and CP-CG, motions and for the two experimental conditions Pre-T and post-T1.

- CP-CG, motions
  As for CG, motions, the VFB induces a real effect on CP-CG, motions for 2/3 of subjects on post-T1. Consequently, in more than 2/3 of subjects post-T1 elicits an increase in the horizontal accelerations transmitted to the CG. Indeed, fourteen subjects increase their $H_{sl}$ values immediately after FBV for at least one direction. To be precise, seven subjects increase their $H_{ll}$ in post-T1, when compared to pre-T, in both ML and AP directions, whereas two and five subjects demonstrate similar effects only in AP and ML directions, respectively. VFB seems to have no effect for four subjects immediately after training. Fifteen subjects reduce their spatial threshold of correction once the sway has been detected.

- CG, motions
  From the results, it appears than 2/3 of the subjects improve their corrective control mechanism immediately after training. Indeed, thirteen of the eighteen subjects demonstrate decreased $H_{ll}$ values on post-T1 for at least one direction. In particular, five subjects display $H_{ll}$ decreases in both directions (AP and ML) whereas six and two subjects decrease $H_{ll}$ only in AP and ML directions, respectively. It should
be noted that five subjects have opposite effects i.e., their values of H\(ll\) in post-T1 are similar or superior to pre-T H\(ll\) in both ML and AP directions. Moreover, as for CP-CG\(_v\), most subjects display reduced values for spatial correction thresholds.

**DISCUSSION**

The concomitant decrease in the amount of CG\(_v\) motions and the increase in the resultant joint stiffness are linked to modifications induced by VFB when compared to the eyes open condition (Rougier, 2001). On the other hand, these results demonstrate an improvement in postural control for two thirds of the subjects immediately after 16’ of VFB. These conclusions are closely akin to Takeya’s results but their training periods (about 8’) were shorter. An immediate effect of VFB training is observed although statistical tests for the whole population are not significant. The analysis method used allows a more accurate explanation of the modifications on postural control induced by VFB training in the very short-term. It seems that VFB training principally affects the CG\(_v\) corrective mechanisms, supposedly by more efficiently bringing back their CG\(_v\) to a preferred zone. The second short effect of FBV training is an increase of CP-CG\(_v\) motions, i.e. the initial accelerations communicated to the CG.

To analyse only the post-T1 results has been determined since a progressive deterioration of postural stability is generally observed for 3 to 4 minutes after training, i.e. on post-T2, post-T3, post-T4, post-T5 (Farenc et al., 2001a). The reason for this degradation of postural balance could probably be explained by an attention fatigue due to the train of VFB and post-T1 events. In analysing the investigations conducted in this field, it should be noted that the sessions of VFB training are generally programmed for much longer periods, from 10 days to 9 weeks. The effects of VFB training observed in these protocols appear naturally more pronounced, signifying that, in the long term, some additional effects can intervene. Another feature concerns the value (2) of the gain used in this study. This latter parameter is known to induce various effects in both spatial co-ordinates of transition points and H\(ll\) values (Farenc et al., 2001b). Consequently, one may suppose that this kind of protocol programmed over a longer period of several weeks with an increased VFB gain could favour further facilitation of postural rehabilitation in patients demonstrating difficulties in controlling their CG motions.

**REFERENCES**