

EFFECT OF AGE ON DETECTING A LOSS OF BALANCE IN A SEATED WHOLE-BODY BALANCING TASK

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INTRODUCTION

Falls in the elderly are associated with considerable morbidity and mortality. All unintentional falls are attributable to a 'loss of balance' (LOB). However, a precise definition of a LOB is lacking. It has earlier been proposed that a LOB is required for the central nervous system to trigger a compensatory response to prevent the ensuing fall (Ahmed, 2002). The LOB is posited as a *loss of effective control*, detectable, both internally and externally, as a control error signal anomaly (CEA).

A model-reference adaptive controller and failure-detection algorithm were used to represent central nervous system decision-making based on input and output signals obtained during a challenging whole-body planar balancing task. Control error was defined as the residual generated when the actual system output is compared to the predicted output of a simple model of the system. A CEA is hypothesized to occur when the error exceeds a threshold three standard deviations (3σ) beyond the mean baseline signal. The quality of the signals involved is inherently dependent on the accuracy of the afferent signals which is known to decline with the neuropathic changes associated with aging. This deterioration could result in an inability to detect a CEA and respond appropriately.

Our goal was to (a) detect CEA in both healthy young (YA) and older (OA) subjects performing a challenging seated balancing task, and (b) compare the performance of the

3σ detection algorithm in predicting any impending compensatory response. We tested the null hypothesis (H1) that there would be no age effect on the successful detection of CEA using a 3σ threshold criterion on the controller error signal. The secondary (null) hypothesis (H2) was tested that age would not affect the performance of the 3σ threshold in predicting the occurrence of any compensatory reaction by 100 ms.

METHODS

Twenty YA (10 females) and 20 OA (10 females) volunteers were tested (ages were 18-25 and 65-80 years, respectively). Seated subjects were asked to balance a custom high-backed chair for as long as possible over its rear legs, P (Fig. 1). Each performed five trials with eyes open. The ground reaction force under the dominant foot, which constituted the sole input to the system, was measured using a two-axis load cell. The position of three LEDs on the head and two on the chair were tracked using an Optotrak 3020 system. The error signal formed from the difference between the expected system



Figure 1: Experimental Setup

output due to the given force input and the actual output, chair acceleration was calculated. CEA was defined to have occurred once the error signal crossed a

threshold level set at three standard deviations (3Σ) above the mean value in a 2-second-wide moving window, **b**, which lagged the current time instant, **t**, by 100 msec (Fig 2: The threshold calculation begins at ‘**Start**’, initially using data in **a** as baseline data. Points ‘**F**’ on the chair must strike the ground within **c**, a two-second post-CEA interval.) The occurrence of a natural righting response, a large acceleration of the head in flexion (relative to the chair), was defined as a compensatory response, and evidence of CEA perception. Reaction time (RT) was defined as the latency of this response and could occur no earlier than 100 ms after CEA.

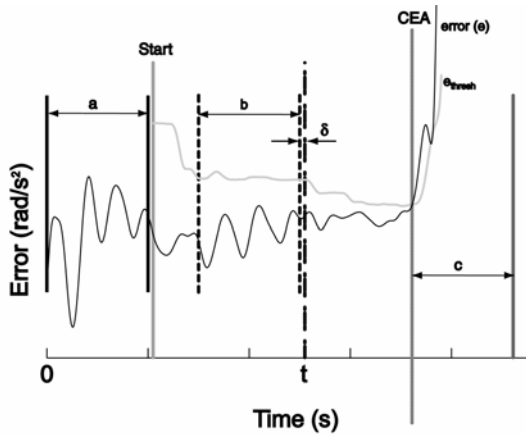


Figure 2: Sample time history of the control error signal (black) along with the moving threshold (gray) from one trial

RESULTS

The primary hypothesis (H1) was supported in that the 3Σ algorithm successfully detected CEA in 91.6% of the 99 YA trials and in 91.9% of the 95 OA trials (no significant age difference: χ^2 : $p > 0.995$). The secondary hypothesis was rejected in that a compensatory reaction was successfully predicted using the 3Σ algorithm in 92.7% of the 82 YA trials with reactions, and in 67.5% of 80 OA trials with reactions (age effect significant: χ^2 : $p < 0.005$). Applying a lower threshold (2Σ) to the H2 trials in

which 3Σ was unsuccessful did successfully predict reactions in a further 2% of YA trials and 10% of OA trials. However, a sensitivity analysis in both YA and OA demonstrated that the optimal threshold level was 3Σ ; lower levels resulted in more false positives, while higher levels resulted in delayed CEA detection times (Fig. 3).

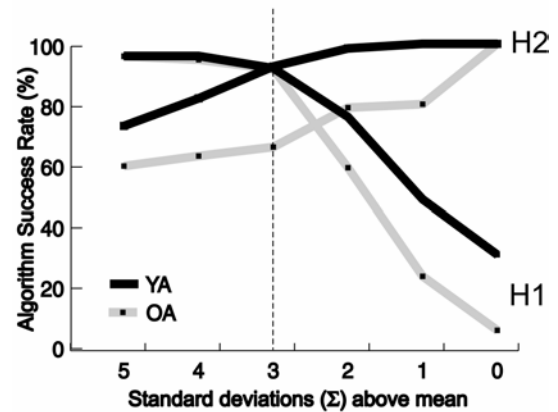


Figure 3: Sensitivity analysis results

DISCUSSION

The results suggest that a CEA is detectable by an external observer in both YA and OA. There are, however, age-related changes in a healthy subject’s ability to internally detect a CEA. The 3Σ threshold did not predict a reaction in OA as accurately as in YA. Two OA in particular seemed to respond to a lower threshold, or perhaps another signal due to decreased sensor accuracy (manifested as a lower error threshold for CEA detection in OA), and/or a more conservative strategy. CEA detection provides a novel approach to understanding and quantifying the effect of aging on postural control.

REFERENCES

Ahmed, A.A., Ashton-Miller, J.A..(2002) WCB & Gait & Posture, *accepted*.

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