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REVIEW/MISE AU POINT

# Posture control, aging, and attention resources: Models and posture-analysis methods

# Contrôle postural, vieillissement et charge attentionnelle : théories et méthodes d'analyse de la posture

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Wavelet transform

**Summary** This paper reviews the literature on balance and cognitive function in normal aging. The first part provides a general background of dual tasking (postural performance under a concurrent cognitive activity) and summarizes the main relevant models capable of explaining the poorer postural performance of older-healthy adults compared to younger-healthy adults: the cross-domain competition model, the nonlinear interaction model, and the task-prioritization model. In the second part, we discuss the main limitations of the traditional-posturographic analyses used in most of the dual-task investigations and explain how these can account for some discrepancies found in the literature. New methods based on the stabilogram-diffusion analysis and the wavelet transform are proposed as better approaches to understand posture control. The advantages of these new methods are illustrated in young adults and elderly people performing a simple postural task (quiet standing) simultaneously with a mental or a spatial task.


**MOTS CLÉS**
Vieillissement ;

**Résumé** Cet article de synthèse est centré sur le contrôle postural et les processus attentionnels au cours du vieillissement. La première partie est une revue générale de la littérature portant sur les données recueillies chez des jeunes adultes et des adultes âgés en utilisant le paradigme expérimental de double tâche. Les principaux modèles, expliquant les modifications

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Méthode des ondelettes

du contrôle postural avec l'âge lorsqu'une tâche cognitive doit être réalisée simultanément, sont présentés : le modèle de compétition ou de partage de la charge attentionnelle, celui de processus interactifs non linéaires entre tâches et celui de la priorité donnée à l'une des tâches (le contrôle de la posture avec l'âge). Dans une seconde partie, sont exposées les principales limitations des techniques et outils traditionnels d'analyse du contrôle de la posture utilisés dans les études en double tâche, qui pourraient rendre compte de résultats en apparence contradictoires rencontrés dans la littérature. De nouvelles approches mathématiques d'investigation de la posture sont présentées ; elles sont basées sur l'analyse de diffusion et la méthode des ondelettes appliquées aux signaux stabilométriques. Les avantages de ces nouveaux outils dans des investigations en double tâche sont illustrés chez de jeunes adultes et des personnes âgées, réalisant simultanément une tâche posturale simple (se tenir debout immobile) et une tâche cognitive de calcul mental ou de représentation spatiale.


## Background and models

### Postural control and cognitive demand

The posture-control system regulates the body's position in space for the purpose of orientation and balance. It is based on the central integration of vestibular, visual, proprioceptive, and tactile information and on an internal representation of the body's orientation in space. The internal model of the body's position is continuously updated on the basis of this multisensory feedback and this internal representation is used to forward motor commands controlling the body's position in space that take into account the environmental constraints [41,46].

Quiet standing is a motor-balance skill of everyday life that is automatically regulated by subcortical nervous structures and spinal-motoneuronal pools [30]. Although this is a rather simple postural task, it is now well established that quiet standing requires cognitive resources [31]. Minimal-attentional resources are needed in younger adults in an undisturbed upright stance, but in more challenging balance conditions (standing on a narrow support, balancing on one foot, walking on a difficult terrain), postural tasks are more cognitively demanding. An increased contribution of cortical structures, involved in motor attention (premotor cortex: [59]) and in the body's internal 3D representation (parietal lobe: [47,54,59,69]), is required when the postural tasks are complex or difficult and/or when the balance abilities of subjects are limited due to normal or pathological ageing.

Other postural behaviours encountered in everyday situations, however, are generally paired with cognitive performances. Indeed, it is the rule, rather than the exception, that individuals perform static- (standing) or dynamic- (walking) postural tasks simultaneously with cognitive tasks. Common real-word observations of people conversing while walking or listening to music while running illustrate this statement. In those situations, the attentional resources must be divided to properly perform both tasks. The question arises, therefore, as to whether dual-task conditions affect postural performance level. One way to answer this question is to compare the baseline-performance level recorded under a single-postural task condition without a concurrent cognitive task to postural performance under dual tasking. Dual-task costs have been reported [33] to result in a general decrease from single-task performance levels presumably because of competition for central processing resources. It has been clearly showed, however, that many variables can affect the performance level observed using the dual-task paradigm. Extrinsic factors depending on the nature of the primary task (such as static- or dynamic-postural tasks) or on the environmental context in which the task is performed (such as postural threat or not) as well as on the real nature of the secondary task (mental arithmetic, visual or spatial tasks) reportedly play a significant role [81]. Intrinsic factors depending on the subjects themselves — such as participants' sensorimotor expertise — have also been shown to affect the dual-task performance level [75]. Furthermore, the interpretation of dual-task data is rendered more difficult when taking into account empirical evidence that both sensorimotor [22,26,40] and cognitive [12,43] functions decline with life span. Undoubtedly, aging must modify the cross-talk between postural and cognitive tasks.

### Dual-task performance with aging

Falls in the old age constitute a serious public health problem because of their frequency (one third of adults, 65 years and over, falls at least one time per year: [60]) and of their dramatic consequences (femoral neck fracture: [70,71]). Post-fall syndrome also results in a combination of anxiety, fear of falling, and decreased mobility in the absence of training or physical activity [49].

Aging of the sensorimotor systems involved in posture control was believed to be the main cause of deterioration in balance abilities and of falls in the elderly [23,79]. A progressive decrease in visual acuity, contrast sensitivity and accommodation found in older adults is associated with increased-body sways during quiet standing [7]. A reduction of both vestibular and joint detection of body motion, reduced sensitivity of the plantar sole, and a diminished contribution of the proprioceptive muscular afferents to spinal reflexivity were reported in many clinical studies aimed at determining the effects of aging on the posture control system. Balance deterioration in old age is further accentuated by a lower muscle force in the antigravitary-extensor muscles [26], but a greater muscle activity during quiet standing [32], and by a diminution in the capacity of brain-