Benefits of the active control of balance on visual perception and task performance

Cédrick T. Bonnet

Univ. Lille, CNRS, UMR 9193 – SCALab – Sciences Cognitives et Sciences Affectives, F-59000 Lille, France.

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Abstract

This chapter examines whether body position - sitting versus standing - affects cognitive performance in modern sedentary societies. As many adults, particularly desk-based workers, spend over eight hours per day seated, reducing sedentary time has become a major public health concern. Sit-stand desks are increasingly used and have been shown to improve health and long-term productivity. However, it remains unclear whether standing directly enhances short-term task performance or whether observed benefits result only from improved general health. A review of more than 100 studies shows that performance while standing is generally equivalent to sitting, and sometimes superior—especially when reaction time is measured. Alternating between sitting and standing appears more beneficial than prolonged sitting. The author argues that improved performance

in standing is not due to posture itself, but to active postural control. Standing requires continuous balance regulation through postural sway, a nonlinear and adaptive process. This active control may enhance perception and attention for three reasons: (1) sensory systems function best with continuous variability; (2) sway complexity adapts to task and environmental demands; and (3) maintaining balance may promote optimal arousal and selective attention. Experimental studies conducted in the SCALab partially support these hypotheses. Analyses show that sway magnitude and complexity predict better attentional and visual performance when standing, but not when sitting. Overall, actively controlling balance - particularly without fatigue - may enhance cognitive performance, with alternating postures representing an optimal strategy.

Introduction about the body position (sitting vs. standing) in our modern society

In most countries worldwide today, and especially in high-income countries, people spend a lot of time in the seating position. In fact, more than half of the word population spend more than half of the waking day, i.e. more than 8 h/d, in the sitting position (Leitzmann, Jochem, & Schmid, 2018). Desk-based workers even spend between 11.2 and 12.8 h/d in the sitting position (Hadgraft *et al.*, 2016; Parry & Straker, 2013). This large time spent seated is problematic as it leads to various health issues such as physiological issues (e.g. premature death, cancer, diabetes, cardio-vascular diseases, ...), psychological issues (e.g., depression, anxiety, ...), cognitive issues (e.g., problems in attention, working memory, executive functions, ...) with problems at all levels (from microscopic to macroscopic issues)

(Bonnet & Barela, 2021; Bonnet & Cheval, 2023; Ekelund *et al.*, 2016; Levine, 2010, 2015). As a consequence, excessive sitting can lead to reduction of efficiency in work productivity (Chandrasekaran, Pesola, Rao, & Arumugam, 2021; Hendriksen, Bernaards, Steijn, & Hildebrandt, 2016; Munir *et al.*, 2015; Puig-Ribera *et al.*, 2015) in relation to the so many, sometimes chronical, healthy issues.

Solutions have to be implemented worldwide to reduce the time spent seated. The use of sit-stand desks is one of the best solutions for desk-based workers (Bonnet & Cheval, 2023). By definition, sit-stand desks can be used either in the sitting or standing position by simply changing the height of the desk by means of up or down electrical buttons or manual crank. The literature already showed that the use of sit-stand desks is i) well accepted by users (Dutta, Walton, & Pereira, 2015; Leavy & Jancey, 2016), ii) is effective in reducing health issues caused by excessive sitting (Dutta, Koepp, Stovitz, Levine, & Pereira, 2014; Zhu *et al.*, 2018) and iii) is effective in increasing work productivity (Chandrasekaran *et al.*, 2021; Hendriksen *et al.*, 2016; Munir *et al.*, 2015; Puig-Ribera *et al.*, 2015). The question still holds whether task performance, evaluated in short periods of time (e.g. min, hours), can be improved by spending more time in the standing position. In other words, is work productivity (evaluated in months and years of work) more effective with sit-stand desks only because general health is improved or because variations in body position can be beneficial in task performance. The question is especially relevant sit-stand desks are largely sold and used in various countries such as in the USA, Canada, Australia, and North of Europe.

Review of the literature on task performance when sitting vs. standing (before fatigue)

Today, more than 100 research studies in human factors engineering have compared task performance when standing and sitting (for reviews, see (Kar & Hedge, 2016; Karakolis & Callaghan, 2014; Rostami, Razeghi, Daneshmandi, Hassanzadeh, & Choobineh, 2022; Sui, Smith, Fagan, Rollo, & Prapavessis, 2019). In these reviews, investigators analyzed task performance in desk-based activities such as typing, computer mouse use, work-related tasks, memory tasks, visual tasks, reading comprehension, mathematics, executive function tasks, creativity, and psychomotor function. Most of the time, task performance when standing was found to be as good as when sitting (Kar & Hedge, 2016; Karakolis & Callaghan, 2014; Rostami *et al.*, 2022; Sui *et al.*, 2019). Thus, one important information is that the standing position is not associated with poorer performance. These non-significant findings especially were found when task performance was analyzed with discrete variables with "0" for failure and "1" for success. When task performance was analyzed with continuous variables, such as the reaction time to perform the experimental task, published results were more discriminative. In fact, some studies used the modified Stroop task and evidenced better task performance (Rosenbaum, Mama, & Algom, 2017; Smith, Davoli, Knapp, & Abrams, 2019) or equivalent (Caron *et al.*, 2020; Caron *et al.*, 2022) task performance when standing. Other studies used the Attention Network Task (ANT) and analyzed three composite variables, i.e. the alerting, executive, an orienting scores (Abou Khalil, Doré-Mazars, & Legrand, 2023, 2024; Barra, Auclair, Charvillat, Vidal, & Pérennou, 2015). These three studies showed that the overall reaction time or the alerting score was significantly shorter when standing than when sitting (cf. Figure 2 of their publication).

Some investigators also tested whether alternating standing and sitting can lead to better task performance than only sitting. Hasegawa, Inoue, Tsutsue and Kumashiro (2001) evaluated participants performing a repetitive task (single-digit multiplications) over periods of 15, 30, 45 or 90 minutes. These investigators found that changing the body position every 10 to 20 minutes over a 60-minute period was the best alternative to improve task performance (Hasegawa *et al.*, 2001). In a remarkable study, van Steenbergen, Wilderjans, Band and Nieuwenhuis (2024) explored whether the alternating position (six blocks of 20 min) could impact cognitive performance and arousal. Participants performed three tasks (flanker task, switch task and 2-back working memory) in each block, each task lasting 6 minutes. Results showed that when alternating sitting and standing, arousal was significantly enhanced, effort cost was significantly decreased and cognitive outcome was significantly improved. Furthermore, Schwartz, Kapellusch, Baca and Wessner (2019) and Schwartz *et al.* (2018) studied participants either alternating sitting and standing or only sitting during two sessions of 150 minutes. Participants were requested to complete five repeated trials (each lasting 25 minutes) of a test battery comprising three tasks. The results showed a significantly higher concentration and work speed when alternating standing and sitting than when only sitting.

Swaying in the standing position as an effective way to succeed in the task performed

In our research team in France, we do not consider that standing per se can explain better cognitive processes and task performance. For us, the body position is a confounding variable. Instead, we consider that having to actively control equilibrium in the standing position is what matter to explain better cognitive processes and task performance when standing. To be clear, we need to mention that when standing, individuals sway at all time and continuously need to control their equilibrium. Individuals even sway by default in a nonlinear, non-stationary and fractal manner (Riley & Turvey, 2002; Stambolieva, 2011). In our hypothesis, we consider that the active process of adapting postural sway to the task perform matters to explain better cognitive processes and task performance. Carefully, we take into consideration that standing in a stationary position – as when standing in front of a sit-stand desk – is rapidly tiring as it can be tiring only after some minutes. As a consequence, here are our two sub-hypotheses: i) for short period of time (before any fatigue), we expect that individuals should better succeed in cognitive tasks when standing than when sitting; ii) for longer period of time (when physical fatigue is coming into play), we expect that individuals should better succeed in cognitive tasks when frequently alternating sitting and standing to spend as much time as possible in the standing position while avoiding fatigue caused by (excessive) standing.

At least three main reasons could explain why individuals should perform better cognitive tasks when swaying and actively controlling balance in the standing position than when passively seated (again before any physical fatigue). Firstly, for optimal perception, our sensory systems have to be continuously stimulated (Davids, Glazier, Araújo, & Bartlett, 2003; Engbert, 2021; Fabre *et al.*, 2021). In fact, effective visual perception depends on continuous eye movements (Montesano *et al.*, 2018). When fixational eye movements are absent, neural adaptation in the visual cortex renders the system functionally blind (Martinez-Conde *et al.*, 2009). In a completely motionless visual field, that is, without ongoing retinal image refreshment, perception would fade (Engbert, 2021). An important information is that constant sensory input – whether auditory, gustatory, or tactile – is perceived only transiently before fading from awareness. This likely explains why human eyes are never perfectly still (Intoy & Rucci, 2020). Probably for this reason and for vision, micro-movements of the eyes – drifts, tremors, and microsaccades – prevent vision from becoming static (Engbert, 2021; Intoy & Rucci, 2020). In the same vein, both body and brain depend on continuous variability to accurately perceive body position and the spatial relationship between body and environment (Kelty-Stephen, Lee, Carver, Newell, & Mangalam, 2021; Riccio, 1993; Riley & Turvey, 2002). From this perspective, postural sway observed during quiet standing appears beneficial rather than detrimental. This interpretation remains relatively rare in the literature – apart from some studies (Doyon, Hajnal, Surber, Clark, & Kelty-Stephen, 2019; Hajnal, Clark, Doyon, & Kelty-Stephen, 2018; Hajnal *et al.*, 2022; Mangalam, Carver, & Kelty-Stephen, 2020; Mangalam, Chen, McHugh, Singh, & Kelty-Stephen, 2020; Mangalam & Kelty-Stephen, 2020; Masoner *et al.*, 2020; Palatinus, Dixon, & Kelty-Stephen, 2013; Palatinus, Kelty-Stephen, Kinsella-Shaw, Carello, & Turvey, 2014) and the broader ecological framework for perception and action (Gibson, 1966; Riccio, 1993; Stoffregen, Yang, & Bardy, 2005; Stoffregen, Yang, Giveans, Flanagan, & Bardy, 2009). In line with this last line of results, we consider postural sway as a functional and adaptive mechanism to best detect information – or stimuli – from the environment.

Secondly, this is not simply swaying that is important for perception and task performance, but adjusting postural sway to the difficulty of the task performed. As a general insight, our surrounding environment is complex, with various irregular, erratic forms, i.e. fractal forms (Xu, Moore, & Gallant, 1993). A fractal form is a complex geometric structure that exhibits self-similarity across different scales and is often generated by repeating a simple process (iteration) infinitely (Xu *et al.*, 1993). In other words, if you zoom in on a small part of a fractal, it resembles, although still different from, the overall shape. Most of the time, our surrounding environment is extremely complex. According to some investigators, this surrounding complexity could be best perceived only in adjusting the complexity of functioning of our perceptual systems (e.g. Mangalam, Carver, *et al.*, 2020). In other words, the complexity of our perceptual systems should be adjusted to the complexity of the surrounding world, to best match it to allow optimal perception. In many of their studies, the research team by Kelty-Stephan, Mangalam and colleagues are testing these relationships. For example, (Mangalam, Carver, *et al.*, 2020) investigated whether the multifractal characteristic of center-of-pressure (COP) sway was associated with perceptual accuracy during effortful touch. These investigators used vector autoregression (VAR) analysis to capture the body-wide interdependencies among multifractal estimates across trials. Their results revealed that i) multifractality in COP dynamics facilitated multifractal fluctuations in hand movements and that ii) the strength of these exchanges in multifractal fluctuations between the COP and the hand predicted perceptual accuracy. Based on these findings, the authors proposed that accurate perception through effortful touch emerges from the coordinated interactions among different body segments mediated by multifractal fluctuations. In other words, perceptual performance may depend not only on the hand's effortful touch but also on the ongoing dynamic regulation of postural control (Mangalam, Carver, *et al.*, 2020). In conclusion, lucky individuals are to sway in the standing position (Bonnet & Cheval, 2023). The message here is that the nature of postural sway can be easily modulated in the standing position, and is indeed adjusted to the task performed (while it may be too imprisoned in the sitting position).

Thirdly, maintaining an upright posture – and consequently controlling balance through continuous postural adjustments – may facilitate the functioning of attentional resources in goal-directed tasks. This idea is based on Chajut and Algom's attentional hypothesis (Chajut & Algom, 2003). According to these investigators, a moderately high level of mental stress can reduce the overall availability of cognitive resources while simultaneously promoting focus on task-relevant stimuli and filtering out irrelevant information. Moderate stress could foster more selective attention in healthy young adults compared with lower-stress (Chajut & Algom, 2003) or lower-load (Lavie, Hirst, de Fockert, & Viding, 2004) situations. Although Chajut and Algom (2003) did not consider body posture as a factor influencing attentional constraints, it has been suggested that the level of physiological or cognitive stress may be too low in the sitting position, while arousal may reach an optimal level in the standing position (Bonnet & Cheval, 2023; Ebara, Kubo, & Inoue, 2008; Kar & Hedge, 2016; Rosenbaum *et al.*, 2017; Smith *et al.*, 2019). Instead of only considering that the standing position per se could higher selective attention, our research group in France suggests that it is the need to actively control balance in continually regulating postural control that may play a critical role to higher selective attention and task performance.

The three aforementioned explanations discussing active postural control as predictor of task performance are not necessarily mutually exclusive; they can instead be complementary. The literature already showed that postural sway is adjusted both at the magnitude level (e.g. amplitude, velocity) and at the nature level (e.g. complexity) to perform and succeed in various tasks (e.g. fixation of a stationary target, free-viewing of a virtual environment, searching to locate target in a virtual environment) (e.g., Bonnet & Baudry, 2016). In our opinion, the brain actively modulates postural sway all together for controlling equilibrium and for adjusting – fitting – the nature and magnitude of postural sway to the task performed. Individuals would be able to maintain their alertness higher and longer when actively controlling their equilibrium than when passively sitting.

As explained earlier, we need to consider that the standing position becomes rapidly tiring and even sometimes painful (Baker *et al.*, 2018; Coenen *et al.*, 2017; Locks *et al.*, 2018). In fact, one additional hour of standing can lead to pain in the back and lower limbs, muscular fatigue, chronic venous problems (Baker *et al.*, 2018). As a consequence, excessive standing should i) cancel the beneficial effects of swaying and ii) should even cause lower task performance when standing than when sitting. In long-lasting tasks, we thus assume that frequently alternating sitting and standing should favor task performance in contrast to only sitting (or also in contrast to the painful only standing condition) (Bonnet & Cheval, 2023).

Studies performed in the SCALab

Studies performed to test if standing and swaying could benefit task performance (vs. sitting)

In our research team in the SCALab, we are conducting studies to test i) if adaptation of postural sway can be used to higher task performance and ii) if task performance can be higher when standing (and swaying) than when sitting. We published various studies since 2022.

In Bonnet, Singh and Barela (2022), our first objective was to test if task performance to locate Waldo in experimental cartoon images (based on the game “where is Waldo”) could be higher when standing than when sitting. Our second objective was to show that postural sway could play a determinant role in the level of task performance. In studies 1 and 2, 32 and 16 young adults performed three visual tasks (searching to locate targets, free-viewing and fixating a stationary cross) either when standing or when sitting. The tasks were displayed in small images (visual angle: 22°). Task performance, eye, head, upper back, lower back and center of pressure displacements were recorded and analyzed. In both studies, task performance in searching was equivalent (and absolutely not worse) when standing than when sitting. Postural sway was smaller in magnitude during the search task (vs. other tasks) when standing but not when sitting. Hence, only when standing, postural control was adjusted to perform the challenging search task. Only in study 2, when exploring images, and searching to locate the targets, head rotation was significantly greater when sitting than when standing. We explained that when sitting, variability in body movement may be lacking to facilitate visual task performance, thus requiring compensatory movements. In this study, results indirectly suggested that the magnitude of body movement could be too limited when sitting to facilitate task performance in a goal-directed visual task.

In Bonnet, Kechabia, Magnani, Polastri, & Rodrigues (2024), our objective was to test if postural sway could provide beneficial effects on goal-directed visual task performance. Twenty-four healthy, young adults performed the incongruent and reversed incongruent modified Stroop tasks in four body position conditions (standing against a vertical surface, and standing freely either in a wide, standard or narrow stance). COP sway, head sway, eye movements, visual attention, and task performance were recorded. We used partial correlation analyses to test relations between body sway and task performance while controlling for the level of visual attention. These partial correlation analyses showed significant positive associations between task performance and some COP and head sway variables. Therefore, higher magnitude of COP and head sway was suggested to be related to higher level of task performance in this modified Stroop task. Bonnet *et al.* (2024) thus showed that the magnitude of postural sway could have an influence on task performance. In fact, partial correlation analyses showed that i) task performance was worse when participants did not need to control their equilibrium – exactly as when sitting on a chair – and that ii) task performance was higher when participants could sway freely in narrow stance.

In Hua *et al.* (2025), our objective was to test if body position (sitting vs. standing) could influence task performance in various visual tasks (reading and understanding a text; answering questionnaires about this text; performing an Attention Network Task (ANT)) and if the presence of postural sway could influence task performance. Seventeen young adults performed three ANT (5 min 35 per ANT) sequentially in both standing and sitting positions: reading a text, answering a questionnaire and performing ANTs. We measured body kinematics from the head, upper back and lower back during the study. We analyzed the velocity and fractal dimension of body sway, reaction times (shorter reaction time indicating better performance) and alerting scores (higher alerting scores indicating better performance) from the ANT. Our results showed that when standing, the complexity of sway was significantly negatively correlated with ANT reaction times and positively correlated with the scores of alerting from ANT. Hence, consistent with our expectation, ANT performance could be higher when standing because participants could actively adjust their postural sway. In contrast, when sitting, there was no significant correlation between body sway and ANT performance. In our discussion, we suggested that the complexity of body sway in the standing position may increase alertness levels, thus leading to better visual task performance.

Study performed to test if alternating body position could benefit task performance (vs. only sitting)

In Cherigui, Guillaume, Rodrigues and Bonnet (2025), we mainly tested if alternating body position (successively sitting and standing) could higher task performance in contrast to only sitting. We also tested if alternating body position could higher task performance especially when participants were standing. Twenty-four participants performed the ANT six times either in alternating sitting and standing or in only sitting. We analyzed the reaction time in the ANT measured by the keyboard and the proportion of blinks measured by our Pupil-labs eye tracker. The proportion of blinks was significantly lower when alternating sitting and standing than when only sitting. We then analyzed significant differences in our dependent variables between the three tasks performed when standing and the three tasks performed when sitting. These analyses were performed either in the same block of 6 trials (within-condition) or in contrast to the other block (between-condition). In both between- and within-condition analyses, the reaction times were significantly shorter when standing than when sitting. Overall therefore, young individuals were more effective (i.e. a shorter reaction time) and had greater visual attention (i.e. less frequent proportion of blinking) when alternating sitting and standing than when only sitting.

Methodological benefits of our international collaboration (CAPES-COFECUB project)

The new use of the linear mixed model

In the literature reports, various studies already used linear mixed models to show that characteristics of postural sway (both linear and nonlinear) to predict task performance in affordance tasks (Doyon *et al.*, 2019; Hajnal *et al.*, 2018, 2022; Mangalam, Carver, *et al.*, 2020; Mangalam, Chen, *et al.*, 2020; Mangalam & Kelty-Stephen, 2020; Masoner *et al.*, 2020; Palatinus *et al.*, 2013, 2014). In 2024, our research team decided to learn how to use the linear mixed model and this work was performed by Dr. De Andrade Silva (Brazilian researchers) who came to France as a post-doctoral fellow in the CAPES-COFECUB project. Dr. De Andrade Silva successfully understood the methodology to use this linear mixed model, he prepared R codes to use it and he even defined and explained this model to SCALab members in a statistical technical course (on October 24th 2024).

First results brought by the linear mixed model

In Butin *et al.* (in preparation), our objective was to test if it was body position or postural sway which could predict change in task performance in ANT. Twenty-four participants were positioned in front of a sit-stand desk and performed three successive ANTs in three body positions: i) in sitting quietly, ii) in free standing and touching the two key boards on the desk with their two preferred fingers and iii) in restrained standing in pushing both forearm on the desk to touch the two key boards with their two preferred fingers. We tested differences in general reaction time and in the three sub-scores of the ANT (alerting network, orienting network and executive control). We expected task performance to be significantly higher than when standing quietly in both other conditions. We also expected task performance to be exactly equivalent when sitting and when standing in the restrained condition because participants did not need to control their posture in both latter conditions. Our results initially showed that task performance was not affected by any type of body position. We then used the linear mixed model to test if the body position and/or characteristics of body sway could predict task performance in the ANT. The model showed that body position was not a relevant variable. It also showed that body sway at the head ($p<0.05$), lower back ($p<0.05$) and almost at the upper back ($p=0.06$) could predict task performance only in the restrained standing condition. A repeated measure ANOVA and post-hoc additionally showed that participants swayed significantly less in the restrained standing condition than when standing quietly but still swayed significantly more in this restrained standing condition than in the sitting condition. Overall, we invalidated our main hypothesis that only postural sway when standing quietly could predict task performance. However, our results were not completely contrary to our initial hypothesis. In fact, participants really swayed in the restrained condition, they swayed more than originally expected and could still actively modulate their equilibrium. May be that results validated our initial hypothesis only in this restrained condition because the restriction eliminated irrelevant variability of postural sway and facilitated the discrimination of relations between characteristics of postural sway and task performance. May be that in including more participants, we could have validated our initial hypothesis with postural sway when standing quietly. In line with this last assumption, the model was almost significant when standing quietly at the lower back level ($p = 0.07$), upper back level (0.13) and head level (0.14).

In a more recent study performed in the context of the CAPES-COFECUB project (in preparation), our objective was to test if postural sway when standing could predict task performance in a visual search task. Twenty-four participants were either sitting on a chair or standing on a force platform in front of a large screen (dimensions: left-right: 62°; up-down: 38°). The images used were virtual rooms (e.g. kitchen, living room, bedrooms) in various houses composed or few vs. a lot of objects. The experimental tasks were either searching to locate as many target objects as possible (experimental search task), to randomly look at the image without any specific goal (free-viewing control task) or to fixate a stationary target displayed at the center of the screen (basic fixation task). Analyses of results of this study are still not performed but will be computed end of 2025 – beginning of 2026. We will be interested to know if task performance can be predicted by characteristics of postural sway in such an ecological search task. We will also be interested to know how characteristics of postural sway can be changed by the task performed (fixation, free-viewing, searching) and body position (sitting vs. standing).

Interpretation

For recall, in our research team, we consider that the active process of controlling and adapting postural sway to the task perform matters to explain better cognitive processes and task performance. For short period of time (before any fatigue), we expect that individuals would better succeed in cognitive tasks when standing than when sitting because they can adjust their sway when standing. More exactly, we expect that changes in postural sway should predict success in cognitive tasks only when standing. For longer period of time (when only standing can be tiring), we expect that individuals would better succeed in cognitive tasks when frequently alternating sitting and standing instead of only sitting. Exactly as for short periods of time, we expect that changes in postural sway should predict success in cognitive tasks only when standing. Published studies in our research team partially validated these hypotheses, and at least did not invalidate them.

Could active postural control and active adaptation of postural sway explain better performance when standing?

In two studies (Bonnet *et al.*, 2024; Hua *et al.*, 2025), we used – Pearson's and partial – correlation analyses to show possible relations between characteristics of postural sway and the level of task performance. In Bonnet *et al.* (2024), participants were only standing and Partial correlation analyses showed significant positive associations between task performance and some COP and head sway variables, after controlling for the level of visual attention. In (Hua *et al.*, 2025), we found a significant negative correlation between the complexity of postural sway and ANT reaction times (as an important insight, the lower the reaction time the better the performance) and a significant positive correlation between the complexity of postural sway and the score of alerting. In contrast, while sitting, there was no significant correlation between body sway and ANT performance. The results in both studies showed that there was a positive relation between an increase in the quantity and/or complexity of postural sway and higher task performance (Bonnet *et al.*, 2024; Hua *et al.*, 2025). In an earlier study in Bonnet *et al.* (2022), we did not perform any correlation analyses but showed that young participants significantly increased their head rotation from a free-viewing control task to a search goal-directed task when seated but not when standing. We suggested that when seated, participants needed to increase this variability – by means of head rotation – to compensate for the lack of useful variability required to facilitate visual task performance. For us, the increased head rotation in the seated position in Bonnet *et al.* (2022) was a functional sign of adaptability. At least, it could not be a sign of instability as individuals were already stable in the seated position. Furthermore, in the sitting position, there was no reason for participants to get less stable from free-viewing to searching. Butin *et al.* (in preparation) is our first study to test whether active adjustment of postural sway could predict – by means of the linear mixed model – task performance in an attentional task (ANT). In this study, the model was almost significant when standing quietkly at the level of the back marker (p=0.07). Furthermore, linear characteristics of postural sway (dependent variables: path length and ellipse area) predicted task performance when participants were standing in the restrained condition. These results partially validated our initial hypothesis as participants still swayed significantly more in this restrained condition than when seated, thus showing that they still actively adjusted their equilibrium to the task performed.

In our Introduction, we already explained three reasons why active postural control and active adaptation of postural sway in the standing position could predict task performance. These reasons are summarized here again for recall. Firstly, all our perceptual systems detect random stimuli, i.e. nonlinear, non-stationary and fractal stimuli but do not detect constant stimuli. In the visual system, the eyes need to move to best perceive (Montesano *et al.*, 2018) and the absence of stimulation in the eyes make them functionally blind (Martinez-Conde, Macknik, Troncoso, & Hubel, 2009). Accordingly, eyes move continuously with drifts, tremors, microsaccades and saccades. Furthermore, eyes also move randomly because the head and body sway in a random manner, i.e. with nonlinear, non-stationary and fractal properties. In our opinion, randomly swaying in the standing position is an efficient functional manner to best help all our perceptual systems to best perceive stimuli our surrounding environment. Secondly, the adjustment of postural sway to the difficulty of the task performed also matters. As our surrounding environmental is more or less complex, with various irregular, erratic forms, i.e. fractal forms, our perceptual systems have to function in complex ways to best perceive it. More exactly, the more complex our surrounding environmental is and the more complex the functioning of our perceptual systems should be. Remarkably, some investigators already showed that the complexity of postural sway was adjusted to the complexity of the perceptual task performed (Masoner *et al.*, 2020). In our opinion, the complexity of body movement may not be adjusted enough while seated as the body is too much constrained. Thirdly, based on (Chajut & Algom, 2003)'s theory, the fact of having to control balance and adjust postural sway when standing may higher the level of selective attention. The constrained imposed on the body system by actively maintaining balance may be great enough when standing but may be too low when passively seated. Overall, individuals could more easily detect relevant stimuli and avoid focusing on irrelevant stimuli when standing than when sitting (Bonnet & Cheval, 2023; Ebara *et al.*, 2008; Kar & Hedge, 2016; Rosenbaum *et al.*, 2017; Smith *et al.*, 2019).

Is task performance better when standing (before fatigue) or not?

In two of our studies (Cherigui *et al.*, 2025; Hua *et al.*, 2025), we showed that young participants get significantly shorter reaction time in the ANT when standing than when sitting. In other studies, we could not find any significant difference, in reaction time or in task performance (success vs. failure) between the standing and sitting conditions (Bonnet *et al.*, 2024, 2022; Butin *et al.*, in preparation). These results are in line with the literature reports as some studies showed significantly shorter reaction time when standing than when sitting (Abou Khalil *et al.*, 2023, 2024; Barra *et al.*, 2015; Rosenbaum *et al.*, 2017; Smith *et al.*, 2019) or equivalent ones between the two body positions (Caron *et al.*, 2022, 2020; for reviews cf. Kar & Hedge, 2016; Karakolis & Callaghan, 2014). We are aware of a few studies in which participants performed worse when standing than when sitting. However, in all these studies, there were biases as participants were not standing in the standard position but either on one foot (Remaud, Boyas, Caron, & Bilodeau, 2012) or one foot forward the other (Kerr, Condon, & McDonald, 1985; Remaud *et al.*, 2012).

Is task performance better when alternating than when only sitting?

In Cherigui *et al.* (2025), we tested and found that task performance, indirectly evaluated in visual attention to perform the ANT, was significantly better when alternating sitting and standing than when only sitting. In fact, we found that the proportion of blinks was significantly lower in the alternating condition than in the only sitting condition. In other words, the standing position was effective in reducing visual attention. Our results are in line with van Steenbergen *et al.* (2024) who tested participants in three tasks (flanker task, switch task and 2-back working memory; 20 min in total). Participants performed these tasks either in alternating between sitting and standing or in only sitting. van Steenbergen *et al.* (2024) also showed that arousal was significantly enhanced in the alternating condition than in the sitting only condition in the flanker task. So far, we are not aware of any published study showing worse task performance of cognitive processes when alternating between sitting and standing than when only sitting.

Future work to test the hypotheses that task performance can be better when standing

As it should be clear in this book chapter, we assumed that task performance could be higher when actively controlling postural sway in the standing position than when passively sitting. The fact of disentangling which of the standing position and the active control of equilibrium could better explain and predict task performance is possible in two ways. Firstly, we have to use linear mixed model considering both body position (sitting vs. standing) and postural sway as predicting factors in showing that only the variables of postural sway can predict task performance. Secondly, we have to vary the active control of equilibrium in requesting participants to stand either naturally or completely restrained (e.g. standing against a vertical wall). Then, we have to disentangle which of our three aforementioned sub-hypotheses (see introduction for more details) is most relevant to best predict task performance in the standing position. In this vein, various investigators already showed that the two first hypotheses are complementary and closely related (Doyon *et al.*, 2019; Hajnal *et al.*, 2018, 2022; Mangalam, Carver, *et al.*, 2020; Mangalam, Chen, *et al.*, 2020; Mangalam & Kelty-Stephen, 2020; Masoner *et al.*, 2020; Palatinus *et al.*, 2013, 2014). In fact, all these studies showed that postural sway is very complex and that this complexity is adjusted to best perceive and best perform perceptual affordance tasks. Future studies still have to test and disentangle if it is only active postural control or more efficient selective attention that may matter to best perceive and best perform goal-directed tasks. We assume that both active postural control and more efficient selective attention are closely related and come together. Future studies will need to test this new assumption.

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