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Author: Cédrick T. Bonnet Stéphane Baudry

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A functional synergistic model to explain postural control during precise visual tasks

Cédrick T. Bonnet[1,*]

Stéphane Baudry[2]

[1]Cognitive Science and Affective Science Laboratory (SCALab), Universities of Lille, CNRS, France.

[2]Laboratory of Applied Biology and Neurophysiology, Université Libre de Bruxelles, FNRS, Belgium.

Running head: functional vision-posture synergy under precise visual tasks

Highlights

In the manuscript, "A functional synergistic model to explain postural control during precise visual tasks", by Cédrick T. Bonnet and Stéphane Baudry, the highlights are:

- Postural control is improved in precise visual tasks, not deteriorated (our recent review)
- Proposition of a functional synergistic model (with visual and postural processes)
- Description of this new model with its strengths, limits and potential cortical bases
- Discussion of differences between this new model and existing ones
- Short review of the first experimental validation of the synergistic model

* Corresponding author at: Cédrick Bonnet, SCALab UMR 9193, Faculté de Médecine, Pôle recherche, 5e étage, 1 place de Verdun, 59045 Lille cedex, France. Tel.: +33 320 626813. Fax: +33 320 623457. E-mail address: cedrick.bonnet@chru-lille.fr

Abstract

In everyday life, individuals sometimes have to perform precise, or challenging, visual tasks in upright standing. Upright, one problem to perform precise saccades and fixations is that the body oscillates continuously in a mainly unpredictable way. Current cognitive models assume that the central nervous system should divide its attention to perform these ‘dual tasks’ because of limited attentional resources (keeping balance and performing the precise visual task). The problem with the concept of duality is that individuals (need to) succeed in precise visual tasks upright and should not be more unstable and inefficient – because of a division of attention – in these tasks. In our opinion, the central nervous system should work adaptively in a way that enables success in these tasks. Hence, instead of assuming ‘duality’ in cognitive processes, we suggest that i) a ‘synergy’ – or unification – between visual and postural processes may be required to succeed in precise visual tasks. Success in precise visual tasks upright would also require ii) the synergy to be based on two feedforward processes with the visual process being the leader; iii) individuals to reduce their postural sway to facilitate successful synergies; iiii) additional cognitive resources to link visual and postural processes. We discuss some literature findings consistent with these assumptions and summarize a recent validation of the synergistic model. In summary, both models of duality and synergy could be complementary and the present manuscript shows how they could be included in a higher-order, two directional, cognitive model of postural control.

Keywords: postural control; precise visual tasks; cognitive models; young adults; dual-task; synergistic-task

1. 'Duality' in existing cognitive models of postural control

During upright standing, individuals continuously sway and their sway broadly depends on physical constraints, environmental constraints and on the goal of the task being performed [1]. It is generally assumed that the amplitude of postural sway needs to be controlled and kept relatively small because greater body sway amplitude is considered as a threat to keep balance [2]. An increase in postural sway during dual-task situations (keeping balance and performing a secondary task such as an arithmetic mental task) is commonly interpreted as an overreaching of the maximal attentional capacity of the central nervous system (CNS). In this context, the greater the attentional demand of one or both tasks, the greater the level of interference, resulting in alterations of one of the two tasks or in both tasks [3]. This assumption led to different cognitive models to explain postural control in dual-task situations (limited attentional resources, U-shaped non-linear interaction, adaptive resource-sharing). One main difference between the three dualistic models is the level of task difficulty above which the maximal attentional capacity should be overwhelmed in dual-task situations. The model of limited attentional resources assumes that the two tasks performed simultaneously, even relatively simple ones may overreach the CNS's cognitive capacity. In the more recent U-shaped nonlinear interaction model, easy dual tasks may improve postural control [4] and difficult dual tasks may deteriorate it [5]. In the adaptive resource sharing model, the performance of a dual task may alter postural control and/or the task performance if the secondary task is purely cognitive (e.g. only counting in one's head). The performance of challenging visual tasks may also lead to worse postural control and/or task performance but only if the postural and/or the visual task is very difficult [3]. In brief, in all dualistic models, there should be a competition of attentional resources between the two tasks being performed, if they are hard enough.

Although individuals continuously sway when keeping upright standing, healthy individuals are not unstable in quiet stance, i.e. in the situation in which they stand and do no task. Indeed, their postural sway is bounded in a small area that is much smaller that the limits of stability [5]. In quiet stance, they do no need to over constrain their postural sway and can let their body sway within a ‘safety region’ or ‘region of tolerance’ [5]. Furthermore, increasing postural constraint is costly, and preference should be given to the minimum-effort principle [3,5].

In everyday life, individuals continuously perform visual explorations of their environment. They can look at their environment with no specific goal. In this situation, the fact of swaying upright is not detrimental because no precision is required to detect certain things and each gaze shift is, in some ways, successful. However, in many other situations, individuals have to perform precise gaze shifts to identify things, to locate or find objects. Precise visual tasks are challenging tasks that require gaze shifts on very specific locations. In these situations, saccades and fixations have to be goal-directed toward the target with minimum corrections in eyes position. A real inconvenient for precise visual exploration is that individuals sway at all time in a mainly unpredictable way [7]. Hence, independent processing of the two tasks (division of attentional resources) should be counter-productive, as it renders the success in precise visual tasks more difficult. Instead, the CNS needs to find a way to facilitate successful performance. Indeed, in real life, individuals are able to perform precise visual tasks upright without falling over, without stepping, without having to fail and try again. Even better, healthy, young adults sway significantly less when they perform precise visual tasks than when they perform control visual tasks as shown recently in our review of the literature [8]. This general finding was valid in any type of precise visual task, both relatively easy and very hard, hence showing that the concept of duality is not convenient for this population in this context (see [8]).

The present article examines the hypothesis of synergistic processing (instead of dualistic processing) of precise visual task and balance control. Our goal was to generate a new model explaining how individuals can succeed in precise visual tasks performed upright. This view was based on the literature reports showing that postural control was not worse but instead better when individuals performed precise visual tasks [8]. We had to assume that a synergy between the visual and postural systems may be required to succeed in precise visual tasks (Figure 1A). Hence, instead of being obliged to divide its attentional resources to perform two separated cognitive processes – as assumed in dualist models – the CNS may need to unify both cognitive processes to succeed in precise visual tasks – as assumed in our synergistic model. This vision-posture synergy would be required in precise, or challenging, visual tasks but not in control, more basic, visual tasks (Figure 1A). In our discussion, the stationary-gaze task is considered as a control visual task, as generally assumed in the literature reports. Additionally, random-looking tasks (the task of freely looking at a white target or even at furnished images) are also considered as control, basic, visual tasks because individuals have no specific goal to perform, they have no constrain, they simply look at the white panel or images as they like. Our analyses concerned only healthy, young adults and visual tasks that do not require head motion, i.e. visual tasks with a visual angle lower than 15° [9]. The present manuscript serves to explain the main features of the synergistic model, to show how to test this model and to show that it is novel.

Insert Figure 1A, B and C about here

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2. Main features of the synergistic model

2.1. Precise visual tasks may require a synergy between visual and postural behaviours

The independent control of visual and postural behaviours would/could result in failure or at least continuous needs to correct gaze shifts depending on direction and amplitude of the postural sways. Hence, the first key proposition is that precise visual tasks should require oculomotor and postural behaviours to be controlled conjointly, in a synergistic way. In our opinion, the CNS would control the synergy between cinematic variables of oculomotor behaviour (displacement of the eyes in up/down and left/right direction) and cinematic variables of postural behaviour (e.g. center of pressure and/or body segment displacement in the anteroposterior and mediolateral axes). The synergy would concern angular variables of oculomotor behaviour (calculated in degrees) and linear variables of postural sway (calculated in centimeters) on similar characteristics of body motion (e.g. range, standard deviation, path length of motion). The better the synergy between these behaviours, the easier it may be for the CNS to succeed in precise visual tasks. Hence, the CNS should engage a stronger synergy between the visual and postural systems when the precise visual task becomes harder (Figure 1A and 1B).

The results by [10] indirectly showed that the existence of synergies between visual and postural control is a relevant hypothesis. In their study, two individuals coordinated their postural sway when they stood in front of each other, one having to hold a circle and the other having to hold a pointer through the circle without touching it. Cross recurrence quantification analyses showed that the smaller the circle, the greater participants coordinated their hand and torso body motions to each other. The coordination concerned similarities of time-series over time. This example of interpersonal synergy [11] is interesting because participants could see each other. This interpersonal synergy would not have existed if participants had kept their eyes closed. Hence, interpersonal synergy may not have existed if there was no intrapersonal synergy between the visual and postural systems.

2.2. Two dependent feedforward processes

The second key proposition is that precise oculomotor behaviours in upright stance should require linked vision and posture feedforward processes. Otherwise, the success in precise oculomotor behaviours would not be possible without any oculomotor re-adjustment. Oculomotor behaviours should be planed and run in relation to the feedforward balance control [12] so that anticipation of the consequence of postural sway can serve to gain precision in the control of saccades. The feedforward control of oculomotor behaviour should lead the feedforward control of postural sway because the target to be reached is what matters to succeed in the task, not the stability of the posture per se. Hence, our assumption is that the performance in precise visual tasks may require a bidirectional feedforward command with postural and visual control mutually modulated with respect to each other but led by the visual system. The supposition of this bidirectional vision-posture motor plan is original because it was not assumed to exist in this way, even recently [13].

2.3. A reduction of postural sway should be valuable (when possible)

The third key proposition is that when precise visual tasks are performed, postural sway may have to be lower than in a control visual task requiring similar eyes and/or body motion (e.g. in a random-looking task). Indeed, the head's stability is important because it facilitates the CNS to pick-up information of the world [14]. The visual system is very sensitive to body motion and/or motion of the visible environment and "the amount of sway reflects the level of instability that the visual system can tolerate while performing the given fixation task" ([3], p. 29). If the natural level of body sway may be acceptable in quiet stance, it may impede the performance of the precise visual tasks, therefore explaining why it should be reduced in precise visual tasks.

A second reason to predict reduced postural sway in precise visual tasks – compared to a control random-looking task – is that the synergy between visual and postural behaviours should be facilitated if the amount of postural sway is reduced. Even if some mistakes can occur in the planning and run of saccades toward very specific target, the mistakes would be attenuated if postural sway is reduced. In this situation, corrections would be facilitated – the corrected saccades would be smaller – and new imprecisions would be minimized. Remarkably, the literature reports are in line with this assumption [8]. Indeed, in the nine selected manuscripts for their review (see [8]), the results unanimously showed that healthy, young participants swayed significantly less under precise visual tasks than under the control visual task. These reductions in body sway were found at different level of the body (head, neck, lower-back, center of pressure), in different axes (anteroposterior, mediolateral) and in different types of visual paradigms [8]. Hence, these results all comforted the third proposition of the synergistic model suggesting that individuals may reduce their postural sway in order to facilitate a successful synergy between visual and postural behaviours.

Important is to note that the reduction of postural sway in any precise visual task (compared to an adequate control visual task) is not a main hypothesis of the synergistic model. The reduction of postural sway in precise visual task is not sufficient, by itself, to validate the synergistic model. This model cannot be validated or invalidated with analyses of postural control per se, but with correlation or cross-correlation analyses between postural and visual variables (see also [15]). The reduction of postural sway in precise visual tasks could only be a way to facilitate successful relationships between the visual and postural systems. The main hypothesis of the model stands on diverging relationships between visual and postural variables in precise and control visual tasks (see also [15]).

2.4. The synergy should involve additional cognitive resources

The fourth key proposition is that precise visual tasks should require higher cognitive workload than other control tasks (both random-looking and stationary-gaze tasks). Indeed, precise visual tasks should require the CNS to perform more complicated visual behaviours (goal-directed instead of stimulus-bounded; more voluntary instead of automatic), to perform subtle postural control (to reduce postural sway compared to the random-looking task, as shown in 2.3) and supposedly to link visual and postural behaviours to each another. There is no doubt that the top-down strategy is more cognitively demanding than the bottom-up strategy [16,17]. In the top-down strategy, eye motions are directed by the goal of the current task and not by image properties, fixations concern task-relevant objects [16,17]. This cognitively demanding top-down strategy should be performed in precise visual tasks. In the bottom-up strategy, the eyes simply move on the most salient image properties (e.g. bright, colorful, contrasty, detail-containing, flashing, moving…). This is more like a reflex strategy, of lower-order, supposedly performed in random-looking tasks.

In contrast to limitations in attentional resources in dualistic models, the increase in cognitive workload to link the visual and postural systems should be understood in the positive sense, i.e. as a functional adaptation of the CNS to enable the performance and success in precise visual tasks. The synergistic model assumes that the CNS may engage more attentional resources in some difficult tasks than in other simpler control tasks. The increase in the cognitive workload should be perceived as a pre-requisite for performance as the greater the difficulty of the precise visual task, the greater the requirement of cooperation between the postural and visual variables (Figure 1B). Although the constraint imposed to the CNS by precise visual tasks should involve more attentional resources than in quiet stance, the increase in attentional resources is possible by an increase in the motivation for (or commitment to) successful task performance.

2.5. Postural control in random-looking and stationary-gaze tasks

The synergistic model of postural control does not assume that there should be the same type of synergistic vision-posture relations in easy, control, visual tasks than in precise visual tasks. Otherwise, the model would be of no value. Below, we discuss the hypothesis for both types of control visual tasks, the random-looking and stationary-gaze tasks.

In random-looking tasks, individuals can look at an image in the way they like, with no goal. Saccades can run randomly on the image, with no need of precision. Hence, in these tasks, all saccades and fixations can be stimuli-bounded, automatically controlled. In these random-looking tasks, postural control may not need to be tightened because it is safe (in healthy, young adults, see [6]). Therefore, both visual and postural control processes may function independently of each other in their respective role (Figure 1C). Accordingly, [13] suggested that random viewing tasks should not require any adjustment of postural control relative to the visual stimuli while intentional tracking (precise) tasks should do so. Carefully, the synergistic model does not assume that visual information is not used to improve postural control in random-viewing tasks, but that the control of oculomotor behaviours does not need to be planed and run in relation to the control of upright stance in such tasks. In other words, even if both visual and postural processes are assumed to be independent of each other, the synergistic model does not contest that some visual information can be used to control upright stance. For example, visual information could be used automatically by the postural control system, e.g. simply in keeping constant the level of optic flow. When there is more visual information, optic flow can be more easily detected and postural sway therefore reduced [7]. However, in these situations, the visual information would be used in feedback, not in a feedforward way. Likewise, stationary-gaze tasks, usually used as control tasks in the literature report, may not require visual and postural control processes to be performed in synergy. Indeed, the vestibulo-ocular reflex can automatically keep the eyes on a stationary target, regardless of the amplitude of spontaneous sway. Both visual and postural control systems may also work independently of each other in such stationary-gaze tasks.

Taken as a whole, the synergistic model assumes that in random-looking tasks, there should be either no significant vision-posture relations (Figure 1C) or eventually significant relations that are not functionally-related. If they can be found significant, these relations should be instability-related, e.g. showing an increase in postural sway related to in an increase in the gaze shift amplitude; these relations should be positive. These relations would simply show a consequence of greater eyes and/or body motions to perform the random-looking task. They should also not need any increase in cognitive workload to exist. All these aspects are key assumptions, already discussed and shown in [15].

2.6. Suggested processes in both random-looking and searching tasks

As suggested above, random visual explorations of the environment can constitute control task for the synergistic model. This model assumes that in such tasks, both visual and postural systems would run separately because there would be no necessity for the CNS to link the visual and postural systems. On one hand, the visual inspection may be merely automatic and performed by the parietal eye-field to modulate the activity of the superior colliculus to trigger and control reflexive saccades [18]. In these tasks, there would be no need to gain precision in saccades because the parietal eye-field is sensitive to the position of an object in relation to the eyes [19]. On the other hand, the control of upright stance may also be mainly bottom-up in random-looking tasks [20].

In precise visual tasks, the frontal cortex may have an important role to establish the vision-posture synergy, i.e. to link the visual and postural systems. Indeed, it modulates the activation of the parietal eye-field that guides reflexive saccades [18], performs selective allocation of attention [21] and commands voluntary saccades via the frontal eye-field [19], all aspects being relevant to guide specific visual explorations in the top-down strategy. The frontal cortex is specifically involved in the goal-directed (top-down) strategy of visual exploration required in precise visual tasks [22]. Moreover, recent studies also showed that the frontal cortex is involved in postural control [23-25]. The frontal cortex may be particularly involved in challenging postural control tasks [25].

3. Evidence supporting the synergistic model of postural control

Recently, a study with healthy, young adults was performed to assess the validity of the synergistic model [15]. Images were projected in a circle that induced a small visual angle (22°). In the precise visual task, participants had to search a personage in a crowd of people (searching task). In the control task, they simply had to randomly look at an image (random-looking task). As expected by the synergistic model, the results firstly showed that the searching task required significantly higher cognitive workload (evaluated by a questionnaire, the NASA-TLX, [26]) than the random-looking task. The results did not show that visual-postural relations would be significant only in the searching task and *ns* in the free-viewing task. Instead, the results showed that all visual-postural relations were negative in the searching task and that all relations were positive in the free-viewing task. These trends were expected based on subtle hypotheses of the synergistic model (see [15]). Indeed, on one hand, the negative relations in the searching task seemed functionally-related based on the claim that a decrease in postural sway in hard task is generally assumed as a sign of better stability [2]. On the other hand, the positive relations in the free-viewing task seemed instability-related because an increase in postural sway in hard visual task is generally assumed as a sign of postural instability [2,7]. Thirdly, and also validating the synergistic model, the negative relations in the searching task seemed to involve greater attentional resources. Indeed, these relations were not significant anymore when the influence of the cognitive workload was controlled in partial correlations. Instead, the positive relations in the free-viewing task did not involve any increase in cognitive workload as these relations did not change whether or not the influence of the cognitive workload was controlled. Fourthly, participants swayed significantly less (in anteroposterior and mediolateral axes, and in linear and angular orientations) in the searching task than in the random-looking task at different levels of the body (head, neck, lower-back). These results are promising and showed that the synergistic model is robust. They showed that in precise visual tasks, the CNS may control angular oculomotor behaviour in relation to linear postural sway.

4. Is a synergistic model of postural control really novel?

So far in the literature reports, no model seemed to suggest the possibility of a synergy between postural and visual systems to perform some visual tasks upright (in our assumption, precise visual tasks). Indeed, in studies concerned with visual processing, only strategies adopted by the visual system (for our concern bottom-up and top-down strategies, strategies for fixation, from global to precise vision) are investigated with almost not mention that individuals sway upright [16]. In postural control studies, oculomotor behaviours are not systematically measured and when they are measured, oculomotor and postural variables are not interrelated with correlation or regression analyses [8]. The review of [8] showed that in postural control studies, investigators are simply interested in postural control per se.

In the literature reports, some published models were already interested in the coordination and/or synergy between the eye, head and body motions (e.g. [27]). However these models showed the way individuals coordinated their different segments to succeed in the task, not the way upright stance was controlled in relation to these coordinated body motions. Also, these published models of eye-head-upper body coordination only used angular variables [27]. In contrast in the synergistic model, postural sway is analyzed with linear variables (in centimeters), most particularly measured in the anteroposterior (forward-backward) and mediolateral (left-right) axes and eyes motion is analyzed with angular variables (in degrees) and also with some additional quantitative characteristics (e.g. number of saccades; cf. [15]).

5. Are the notions of duality and synergy incompatible or could they be combined in a unified, higher-order model of postural control?

The notions of synergy and duality may be complementary. However, the hypothesis of duality or synergy should be used carefully depending on the situation.

The hypothesis of synergy should be used when precise visual tasks are performed. The synergistic model may also be testable in other conditions requiring precise sensory interaction with the environment (active auditory tasks, active haptic tasks) in contrast to the corresponding control sensory task. Indeed, in challenging sensory tasks, precise detection of sensory information should require a significant synergy between sensory and postural variables (as shown in Figure 1A and B for the visual system). However, in purely mental paradigms (task only involving mental activities, e.g. counting backward in one's head), individuals may not need to modulate their postural sway in reference to a sensory information because the task performance does not rely on any sensory information [3]. In these purely cognitive tasks, the CNS may keep postural control and task performance separated (as shown in Figure 1C for the visual system) and eventually conflicting if one or the two tasks is difficult enough. In this case, there may be a competition between the two tasks to prioritize one of them because of limited capacity of the CNS to share cognitive resources.

The suggestion that postural control could diverge in situations with/without sensory interaction with the environment was already suggested by previous authors. For example, [3] suggested that in double tasks with no sensory interaction with the environment, upright posture may be controlled for a large part through an automatic control, based on feedbacks. In these situations, higher cognitive workload would merely serve to perform the requested second task, not to strengthen postural control, per se. In double tasks with sensory interactions with the environment, postural control may be strengthened to facilitate the success in the visual task [3]. The synergistic model is different than Mitra's [3] adaptive resource sharing model because it concerns relations between postural and oculomotor controls and not postural control, per se. [3] explained that both facilitatory and automatic controls could work together, while we assume that there should be one model preferred to the other depending on the situation. The choice of one type of control should prevent the use of the other type of control. Also, instead of assuming as [3] that more difficult precise visual tasks should increase automatism, we assume that the greater the difficulty of one or both tasks, the stronger the synergy between visual and postural processes. In other words, the greater the difficulty of one or both tasks, the greater the cognitive workload to perform and succeed in both tasks. However, we agree with [3] that visual and/or postural performances could be worse in very difficult situations than in more simple conditions because there is a limit above which individuals cannot succeed anymore. The visual task can be too hard, the postural task can be too hard and/or the strength of the synergy cannot indefinitely increase.

In healthy, young adults, the hypothesis of duality may be designed to describe the task performance per se. Indeed, investigators may assume better task performance in single task (e.g. computation in one's head in a sited condition) than in double task (same computation in upright stance). Hence, and consistent with the limitation of attentional resources, the synergistic model assumes that i) the visual task performance may be better when sited than when upright, not worse, and that ii) the harder the visual task, the greater the difference in task performance in both conditions (sited vs. upright).

6. Limitations of the present discussion and perspectives

In the present manuscript, only precise visual tasks that did not require any head or body rotation were studied (visual angle lower than 15°; [9]). In other visual tasks (visual angle greater than 15°), the synergistic model of postural control may still be tested. It would assume the existence of significant functional synergistic relations between the visual and postural systems in precise visual task as in [15] (with tasks performed on 22°), even if the head, shoulders and lower-back need to rotate. In random-looking tasks, the synergistic model would expect instability-related synergies as in [15]. Postural sway may still be lower in precise visual tasks than in random-looking tasks if and only if individuals perform similar amplitude of body motion in both tasks. However, individuals should sway significantly more in both visual tasks than in any other stationary-gaze tasks because of large visual explorations requiring the body, and therefore the center of mass, to move [28]. Further research should examine these assumptions. Investigators should keep in mind that the synergistic model of postural control cannot be tested in the contrast between precise sensory tasks and stationary control tasks but between precise sensory tasks and random sensory tasks. Indeed, and for example, relations between oculomotor and postural behaviors in the stationary-gaze task cannot be tested as the eyes do not move in such a task.

In the present manuscript, no discussion concerned the influence of age or disease on the synergistic relations between visual and postural systems in precise visual tasks. The synergistic model assumes that there should be less significant functional relations between visual and postural systems in older adults and/or patients than in healthy, young adults (in precise visual tasks). Age-related and disease-related impairments in vision-posture synergy may be due to a lack of available attentional resources, e.g. in the anterior lobe of the cerebellum [29], or to lower brain connectivity (e.g. in patients with traumatic brain injury;

[30]). [29] recently explained that these older individuals may need higher cognitive workload to perform motor tasks similarly as young adults. Therefore, these individuals would have lower opportunity to contrast their cognitive resources between random-looking and precise visual tasks than healthy, young individuals. If the vision-posture synergy was weaker in older adults and/or patients, both feedforward processes would work in more isolated ways, hence explaining a weaker predictive postural control, as shown by slowness and higher variability in body motions [29]. As a result, these individuals would need to re-adjust their body motions based on feedback corrections, as also suggested by [29]. Further research should examine these possibilities as well.

7. Summary and conclusion

In the present manuscript, we suggested a new cognitive model of postural control and not a sub-hypothesis that could be linked to any existing cognitive model. Indeed, it is not possible to address a synergistic hypothesis in line with a dualistic hypothesis, both hypotheses being incompatible. The synergistic model is based on the powerful and functional capabilities of the CNS to control and adjust upright stance to the task performed; it is not based on its limitations.

The synergistic model provides a new approach to understand postural control, it emphasizes the positive, functional nature of the CNS to perform both postural and visual behaviours in a unified way. It suggests that healthy, young adults could succeed in precise visual tasks during upright standing: i) if there is a synergy between visual and postural behaviours; ii) if the vision-posture synergy is based on two feedforward processes led by the visual feedforward process; iii) if postural control is improved to facilitate successful synergies; and iiii) if attentional resources are higher in precise visual tasks than in control visual tasks. The synergistic model suggests that visual and postural controls performed upright may not be fully understood in isolated ways. It suggests that closing the gap between visual and postural control field of research may enable better understanding on how individuals can succeed in precise visual tasks when upright.

The relevance between synergistic and dualistic models may only depend on the tested paradigms (presence of absence of precise sensory interactions with the environment). These ideas all together provide the basis for a higher-order updated cognitive model of postural control, integrating both duality and synergy in contrasted life conditions (with or without sensory interaction with the environment).

Conflict of interest

In the manuscript "A functional synergistic model to explain postural control during precise visual tasks", by Cédrick T. Bonnet and Stéphane Baudry, there is no conflict of interest.

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Figure 1. Schematic representation of the synergistic model of postural control. In precise visual tasks, it is assumed that the central nervous system (CNS) should link visual and postural behaviours (full line between both systems) to succeed in the task (Figures A and B). The harder the requirement on precise visual saccades and fixations, the stronger the synergy between visual and postural behaviours (full line between both systems heavier in Figure 1B than in Figure 1A). In random-looking (control) visual tasks, the CNS should not engage more cognitive resources to link visual and postural behaviours (as shown by the dashed line between the visual and postural systems in Figure 1C). The model assumes that these behaviours should function merely independently of each other in such tasks.

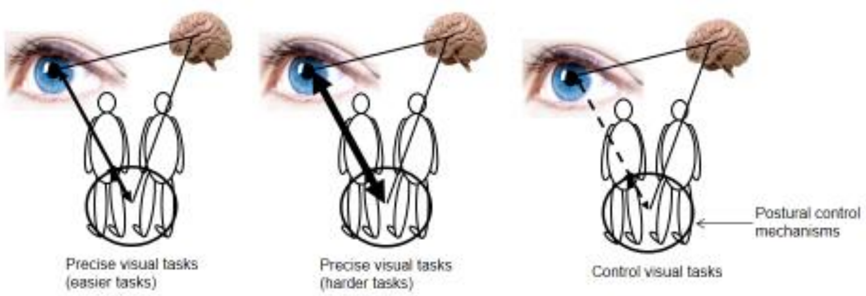

Figure 1