



HAL
open science

A fusimotor role for proprioceptive reweighting in a multisensory context

Anne Kavounoudias, Rochelle Ackerley

► **To cite this version:**

Anne Kavounoudias, Rochelle Ackerley. A fusimotor role for proprioceptive reweighting in a multisensory context. *The Journal of Physiology*, 2021, pp.1-2. hal-03419333

HAL Id: hal-03419333

<https://hal.science/hal-03419333v1>

Submitted on 8 Nov 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

CROSSTALK

Comments on CrossTalk50: There is/is not much to gain from the independent control of human muscle spindles

The control of muscle spindle sensitivity to rehabilitate movements

E. Ribot-Ciscar and J. M. Aimonetti

Aix-Marseille Univ, CNRS, Laboratoire de Neurosciences Cognitives – UMR 7291, Marseille, France

The hypothesis that fusimotor neurons are independently controlled in humans is an idea that we have supported for many years, which includes the demonstration of changes in muscle spindle activity in fully relaxed participants and therefore in the complete absence of alpha activity (for review see Ribot-Ciscar & Ackerley, 2021). The observed effects are subtle, as found under ecological conditions, such as with learning or emotions, which is in opposition to the massive and synchronous recruitment of muscle afferents with reflex protocols.

This capability of humans to specifically control muscle spindle sensitivity is probably responsible, at least partly, for motor improvements induced by proprioceptive training, such as when a participant's hand is passively moved to reproduce a movement trajectory (Wong *et al.* 2012). Therefore, this capability opens perspectives in terms of rehabilitation where any manoeuvre liable to reinforce the role of proprioceptive feedback, by precise adjustments of muscle spindle sensitivity, may be used as movement re-education. As an example, proprioceptive training that consists in focusing attention to vibration-induced kinaesthetic illusions appears a simple means to improve the processing of muscle proprioceptive inputs in Parkinson's disease patients (Ribot-Ciscar *et al.* 2017).

References

Ribot-Ciscar E & Ackerley R (2021). Muscle proprioceptive feedback can be adapted to the behavioral and emotional context in humans. *Curr Opin Physiol* **20**, 46–51.

Ribot-Ciscar E, Aimonetti JM & Azulay JP (2017). Sensory training with vibration-induced kinesthetic illusions improves proprioceptive integration in patients with Parkinson's disease. *J Neurol Sci* **383**, 161–165.

Wong JD, Kistemaker DA, Chin A & Gribble PL (2012). Can proprioceptive training improve motor learning? *J Neurophysiol* **108**, 3313–3321.

Additional information

Competing interests

We declare we have no competing interests.

Why do we have muscle spindles?

Gerald E. Loeb (Professor of Biomedical Engineering)

University of Southern California, Los Angeles, CA 90089, USA

It is unfortunate that both debaters chose to focus on short latency, segmental reflexes. Most of the terminal arborizations of spindle afferents contribute to ascending tracts via brainstem to cortical and cerebellar destinations, where they account for most of posture sense and kinaesthesia (Goodwin *et al.* 1972). Similar to any sense organ, maximizing information over a wide dynamic range of self-generated postures and movements despite a limited range of noisy spike rates is a challenge best met by dynamic adjustment of sensor gain (Loeb, 1984). The numbers of spindle afferents in the muscles of the body correlate well with the psychophysical accuracy of posture and movement perception and the impact of errors on uncertainty of end-effectors (Scott & Loeb, 1994). This is most obvious in axial muscles of the head and neck, which have the highest numbers (Voss, 1971; Amonoo-Kuofi, 1983) of the most elaborated spindles (Richmond & Corneil, 2001) in the body but essentially no segmental stretch reflexes (Richmond & Loeb, 1992). As David Burke points out, the length, mass and slowness of human musculoskeletal systems make short latency stretch reflexes less useful, and hence less prominent, than in cats and monkeys. But knowing where your feet are with respect to your head is even more important when you are tall (Tjell, 2001). Computing posture from multiarticular muscles with task-specific fusimotor programs is complicated, suggesting that it must be learned. Overtrained monkeys achieved similar dynamic range in Ia afferent firing for large movements that stretched or shortened their active or passive parent muscles (Schieber & Thach, 1980). Why did they bother? Can humans afford to ignore this?

References

- Amonoo-Kuofi HS (1983). The density of muscle spindles in the medial, intermediate and lateral columns of human intrinsic post-vertebral muscles. *J Anat* **136**, 509–519.
- Goodwin GM, McCloskey D & Matthews P (1972). The contribution of muscle afferents to kinesthesia shown by vibration induced illusions of movement and by the effects of paralysing joint afferents. *Brain* **95**, 705–748.
- Loeb GE (1984). The control and responses of mammalian muscle spindles during normally executed motor tasks. *Exerc Sport Sci Rev* **12**, 157–204.
- Richmond FJ & Corneil BD (2001). Afferent mechanisms in the upper cervical spine. In *The Cranio-Cervical Syndrome*, ed. Vernon H, pp. 14–30. Butterworth-Heinemann, Oxford.
- Richmond FJ & Loeb GE (1992). Electromyographic studies of neck muscles in the intact cat. II. Reflexes evoked by muscle nerve stimulation. *Exp Brain Res* **88**, 59–66.
- Schieber MH & Thach WT (1980). Alpha-gamma dissociation during slow tracking movements of the monkey's wrist: preliminary evidence from spinal ganglion recording. *Brain Res* **202**, 213–216.
- Scott SH & Loeb GE (1994). The computation of position sense from spindles in mono- and multiarticular muscles. *J Neurosci* **14**, 7529–7540.
- Tjell C (2001). Cervicogenic vertigo: with special emphasis on whiplash-associated disorder. In *The Cranio-Cervical Syndrome*, ed. Vernon H, pp. 231–243. Butterworth-Heinemann, Oxford.
- Voss H (1971). Tabelle der absoluten und relativen muskelspindelzahlen der menschlichen skelettmuskulatur. *Anatomischer Anzeiger* **129**, 562–572.

Additional information

Competing interests

None declared.

Evidence for independent control of fusimotor and skeletomotor neurons is not convincing

Gregory Pearcey and W. Zev Rymer

Northwestern University, USA

Based on microneurographic recordings of spindle afferents from intact human subjects, Dimitriou has proposed that it is advantageous for the central nervous system (CNS) to impose independent control of fusimotor neurons to allow targeted regulation of reflex function. We have two major concerns with this analysis.

Our first concern is that the experiments cited do not directly show that fusimotor activation and skeletomotor neuron activation are decoupled in the muscle that is about to be stretched. In other words, the prevailing view of muscle spindle control (e.g. Edin & Vallbo, 1990), which links fusimotor and skeletomotor activation as part of a consistent coactivation strategy, is not shown to be incorrect. The reduced spindle afferent discharge could easily be part of a generalized reduction in motor activation and not a selective reduction in fusimotor drive.

Second, and more generally, managing fusimotor and skeletomotor activation separately adds to the complexity of motor control, because the CNS would need to track movements, not based simply on voluntary command and afferent feedback, but in full knowledge of what different afferent signals were describing. It is potentially harder to regulate limb motion when key muscle afferent signals may have different meanings (because of varying fusimotor input).

The simplest argument remains that muscle spindles are able to maintain receptor afferent discharge because skeletomotor and fusimotor input work together to facilitate that function. We do not need them to be independently controlled. In this regard we side with David Burke's position.

References

Edin BB & Vallbo AB (1990). Muscle afferent responses to isometric contractions and relaxations in humans. *J Neurophysiol* **63**, 1307–1313.

Additional information

Competing interests

None declared.

A fusimotor role for proprioceptive reweighting in a multisensory context

A. Kavounoudias and R. Ackerley

Aix Marseille Univ, CNRS, LNC (Laboratoire de Neurosciences Cognitives – UMR 7291), Marseille, France

Muscle proprioception is a key sensory modality for perceiving our own body movements, but it is not the only one. Many studies have provided evidence that vision also contributes to kinaesthesia (Blanchard *et al.* 2013). Spatio-temporally congruent visual and proprioceptive cues can optimise and enhance movement perception, which can be predicted

in a Bayesian framework (Van Beers *et al.* 2002; Reuschel *et al.* 2010). Although multisensory integration is generally thought to rely on a weighted combination of different sensory information, the mechanisms underlying this sensory weighting have not yet been fully elucidated and primarily investigated at the highest level of the central nervous system (Klemen & Chambers, 2012). By modulating the sensitivity of muscle spindles, the fusimotor drive is a good candidate to change the relative weight of proprioceptive information by directly facilitating or depressing movement encoding. Ackerley *et al.* (2019) recently found that proprioceptive signals from a passive foot displacement change depending on whether or not the participant sees their foot moving. The relative increase of muscle afferent firing observed in the no vision condition may reflect a proprioceptive weighting increase presumably due to a change in fusimotor drive. Similarly, Jones *et al.* (2001) described a decrease in muscle afferent firing rate during incongruent muscle afferent and visual feedback, which was interpreted as a strategy for resolving bi-sensory conflict. Therefore, the fusimotor drive could play a key sensory role by reweighting proprioceptive information using a direct modulation of muscle mechanoreceptors in ecological and naturalistic multisensory contexts.

References

- Ackerley R, Chancel M, Aimonetti JM, Ribot-Ciscar E & Kavounoudias A (2019). Seeing your foot move changes muscle proprioceptive feedback. *eNeuro* **6**, ENEURO.0341-18.2019.
- Blanchard C, Roll R, Roll J-P & Kavounoudias A (2013). Differential contributions of vision, touch and muscle proprioception to the coding of hand movements. *PLoS One* **8**, e62475
- Jones KE, Wessberg J & Vallbo AB (2001). Directional tuning of human forearm muscle afferents during voluntary wrist movements. *J Physiol* **536**, 635–647
- Klemen J & Chambers CD (2012). Current perspectives and methods in studying neural mechanisms of multisensory interactions. *Neurosci Biobehav Rev* **36**, 111–133
- Reuschel J, Drewing K, Henriques DYP, Rösler F & Fiehler K (2010). Optimal integration of visual and proprioceptive movement information for the perception of trajectory geometry. *Exp Brain Res* **201**, 853–862.
- Van Beers RJ, Wolpert DM & Haggard P (2002). When feeling is more important than seeing in sensorimotor adaptation. *Curr Biol* **12**, 834–837

Additional information

Competing interests

None declared.

Both sides support the resolution

Arthur Prochazka (Professor Emeritus)

University of Alberta, Canada

The resolution of the debate is ‘There is much to gain from the independent control of human muscle spindles’. Opposing the resolution, Dr Burke acknowledges that fusimotor drive in humans is partly independent of alpha motoneuronal activation, but he concludes that ‘there is little evidence that this is a mechanism for changing the gain of stretch reflexes’. Even if he is right in doubting the evidence (e.g. Horslen *et al.* 2018), it is insufficient to refute the resolution. He goes on to say: ‘It is conceivable that selective changes in fusimotor drive play an important role in kinaesthesia.’ ‘An important role’ sounds a lot like ‘there is much to gain’.

Dr Burke also feels that ‘the field has been hampered by the belief that everything functions as in the cat and that we would see this if only we could study humans behaving like cats’. This alludes to the proposal that because it has not been possible to study spindle firing in humans in as wide a range of motor tasks and contexts as in cats and monkeys, this might explain why task- and context-dependent changes in fusimotor effects in humans have seemed relatively weak. It is worth remembering that animal recordings were the first to indicate that alpha-gamma coactivation did not keep spindle afferents firing during muscle shortening and that ensemble spindle firing signalled muscle length changes. These findings were subsequently confirmed in human neurography. In fact, the field might have moved along more quickly had it been possible to study muscle spindle firing in humans behaving like humans.

References

- Horslen BC, Zaback M, Inglis JT, Blouin JS & Carpenter MG (2018). Increased human stretch reflex dynamic sensitivity with height-induced postural threat. *J Physiol* **596**, 5251–5265.

Additional information

Competing interests

None declared.