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## Redefining neurocognitive assessment: The essential integration of sensory evaluation

We read with interest the recommendations of [Leroi et al. \(2019\)](#) and SENSE-Cog Expert Reference Group of healthcare professionals for the Recognition and Management of Hearing and Vision Impairment in People with Dementia. This group of experts recommends the implementation of flexible and individualized assessments to identify and address concurrent deficits in sensory and cognitive functioning ([Leroi et al., 2019](#)). It is also highlighted the lack of standardized, sensitive clinical assessment tools, and evidence-based interventions for addressing simultaneous hearing, vision, and neurocognitive impairment ([Leroi et al., 2019](#)). Although sensation can be considered a neurocognitive function ([Luria, 1963](#)), [Leroi et al. \(2019\)](#) presented it as a concurrent function with neurocognition, rather than as an intertwined part of it. Other previous studies have followed a similar approach. For instance, research has indicated that sensory impairment appears to increase the risk of Major Neurocognitive Disorders ([Brenowitz et al., 2019](#); [Hwang et al., 2020](#)). Furthermore, [Leroi et al. \(2019\)](#) focused primarily on peripheral assessment of hearing and vision, overlooking both peripheral and central evaluations of other senses.

Therefore, while we fully support the recommendations provided, we propose expanding them by redefining neurocognitive assessment protocols to: (1) incorporate sensory evaluation beginning in middle age; (2) assess sensory function at both peripheral and central levels; (3) include all senses in the evaluation process; and (4) include tasks targeting multisensory integration.

Integrating tests specifically focused on sensory function into neurocognitive assessment protocols for middle-aged and older adults is paramount, as the effects of sensory decline may become more noticeable from this age onwards ([Humes, 2015](#)) and is interdependent with other neurocognitive functions ([Littlejohn et al., 2022](#); [Luria, 1963](#); [Wolski et al., 2019](#)). The assessment of sensory functioning can be undertaken at different levels of complexity, ranging from basic peripheral sensory processes (e.g., involving audiometry or optometric tests) to central sensory-perceptual processes that are more complex and involve higher cognitive processing ([Musiek & Baran, 2018](#); [Powell et al., 2022](#)). The failure of central processes is usually manifested as *agnosia* phenomena, which may have an apperceptive form, related to impaired recognition stemming from deficits in the early stages of perception, or an associative type, related to impaired recognition due to semantic deficits despite unscathed perception ([Kumar & Wroten, 2023](#); [Luzzi et al., 2007](#)). Most studies have focused on assessing the peripheral level focusing on sensory acuity for a single sensory modality or dual sensory loss ([Joo et al., 2022](#); [Lad et al., 2022](#); [Reed et al., 2022](#)), neglecting the cumulative effects of multiple sensory-perceptual deficits on central processes, including their impact on other neurocognitive functions.

Moreover, the incorporation of multisensory integration measures into neurocognitive assessment can also be advocated, as most of the activities of daily living depend on multiple senses, and data from multisensory information could also benefit treatment planning (see [Pinto et al., 2021](#)).

Neuropsychologists rely on data from physicians and other specialized health professionals regarding sensory acuity or are limited to using self-reports, informant reports, and clinical observation during consultations to gather information on sensory deficits. However, sensory-perceptual functioning can be a core domain of neuropsychological evaluation, and suitable protocols could be based on previous works, such as the results of factor analysis of the Luria-Nebraska Neuropsychological Assessment Battery ([Von Seggern, 1987](#)). According to such analysis, the visual assessment includes the following factors: visual perception; visuospatial ability; and speed of visuospatial perception. The tactile assessment includes: elementary cutaneous sensation – localization, discrimination of differences in intensity, two-point discrimination, the direction of the stimulation, recognizing and naming of geometric symbols traced on hand or of common objects placed on the hand; and integration of complex stimuli – complex measures of stereognosis, the naming of objects placed on the hand, and speed of naming the objects. Based on the abovementioned arguments, the following protocol for the assessment of sensation at a central level can be recommended: (a) visual perception, for example, using tasks of colour and superimposed images discrimination (see *Programa Integrado de Exploración Neuropsicológica - Test Barcelona- 2*; TB-2; [Peña-Casanova, 2019](#)); (b) tactile perception, for example, administering tasks of graphesthesia, morphognosis, and stereognosis (see TB-2; [Peña-Casanova, 2019](#)); (c) auditory perception of everyday songs (e.g., a bell song; see TB-2; [Peña-Casanova, 2019](#)); (d) olfactory perception of common smells (see *Sniffin' Stick Screening 12 test*; [Hummel et al., 1997](#)); and (e) multisensory integration of visual and auditory stimuli using, for example, a detection task (see [Murray et al., 2018](#)). Given that sensory assessment has long been overlooked, research is still needed to validate such assessment as a crucial component of neuropsychological evaluation protocols, showing its incremental validity and clinical utility in comparison to standard practices. Furthermore, although key psychometric properties of the suggested instruments have been studied, it is also important to examine such properties for the complete protocol across different age groups and clinical populations. Together with longitudinal developmental studies to reveal aging effects on performance, these lines of research will enable the identification of cut-off scores for the sensory measures. These cut-off scores, which are necessary to differentiate between normal age-related changes and

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pathological decline, would inform decisions regarding appropriate neurocognitive tests for assessing other functions, such as attention or memory. For instance, if a person demonstrates deficits in auditory acuity that affect audiovisual integration, the decision might be to prioritize visual attention and memory tests. Conversely, if auditory deficits do not impact audiovisual integration, both auditory and visual tests could be administered, as multisensory performance may indicate a good sensory reserve (see Pinto et al., 2023). Additionally, establishing cut-off scores to distinguish between normal and pathological sensory changes is essential for the clinical interpretation of the individual's performance in the neuropsychological assessments and for planning sensory rehabilitation targets. Specifically, a comprehensive sensory evaluation would inform the inclusion of multisensory integration tasks, at varying difficulty levels, in neurocognitive training programmes, either for clinical population, or to improve sensory reserve in cognitively healthy individuals (see Pinto et al., 2021; Pinto et al., 2022).

Summing up, we emphasize the importance of formally considering the sensory-perceptual assessment within neuropsychological evaluation, given the influence of the former on other neurocognitive functions, and suggest an assessment protocol for this purpose. Despite the potential of expanding neurocognitive assessment protocols to include sensory measures, there are some practical challenges to its implementation that must be acknowledged, such as time constraints in clinical settings, cost implications, additional training requirements for practitioners, and the potential to increase mental fatigue during the neuropsychological assessment. Therefore, whenever time or resources are limited, at least a self-report acuity assessment and a multisensory integration task should be administered, because performance on neuropsychological tests is mostly dependent on them. Future studies on the sensitivity of neurocognitive assessment protocols that incorporate the proposed sensory-perceptual domains could aim to identify which sensory functions exhibit greater interdependency and influence in other neurocognitive functions.

#### CRedit authorship contribution statement

**Joana O. Pinto:** Writing – original draft, Conceptualization. **Artemisa R. Dores:** Writing – review & editing. **Bruno Peixoto:** Writing – review & editing. **Fernando Barbosa:** Writing – review & editing.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### References

- Brenowitz, W. D., Kaup, A. R., Lin, F. R., & Yaffe, K. (2019). Multiple sensory impairment is associated with increased risk of dementia among black and white older adults. *The Journal of Gerontology. Series A, Biological Sciences and Medical Sciences*, 74(6), 890–896. <https://doi.org/10.1093/geron/gly264>
- Humes, L. E. (2015). Age-related changes in cognitive and sensory processing: Focus on middle-aged adults. *American Journal of Audiology*, 24(2), 94–97. [https://doi.org/10.1044/2015\\_AJA-14-0063](https://doi.org/10.1044/2015_AJA-14-0063)
- Hummel, T., Sekinger, B., Wolf, S. R., Pauli, E., & Kobal, G. (1997). 'Sniffin' sticks': olfactory performance assessed by the combined testing of odor identification, odor discrimination and olfactory threshold. *Chemical Senses*, 22, 39–52. <https://doi.org/10.1093/chemse/22.1.39>
- Hwang, P. H., Longstreth, W. T., Jr, Brenowitz, W. D., Thielke, S. M., Lopez, O. L., Francis, C. E., et al. (2020). Dual sensory impairment in older adults and risk of dementia from the GEM Study. *Alzheimer's & Dementia*, 12(1), e12054. <https://doi.org/10.1002/dad2.12054>

- Joo, H. J., Joo, J. H., Kim, S. H., Kwon, J., & Park, E. C. (2022). The impact of self-reported sensory impairment on cognitive function using the Korean longitudinal study of aging survey data. *Scientific Reports*, 12(1), 17907. <https://doi.org/10.1038/s41598-022-22840-7>
- Kumar, A., & Wroten, M. (2023). *Agnosia*. StatPearls Publishing.
- Lad, M., Sedley, W., & Griffiths, T. D. (2022). Sensory loss and risk of dementia. *The Neuroscientist: A Review Journal Bringing Neurobiology, Neurology and Psychiatry*, 00(0), 1–13. <https://doi.org/10.1177/10738584221126090>
- Leroi, I., Himmelsbach, L., Wolski, L., Littlejohn, J., Jury, F., Parker, A., & SENSE-Cog Expert Reference Group. (2019). Assessing and managing concurrent hearing, vision and cognitive impairments in older people: an international perspective from healthcare professionals. *Age and Ageing*, 48(4), 580–587. <https://doi.org/10.1093/ageing/afy183>
- Littlejohn, J., Bowen, M., Constantinidou, F., Dawes, P., Dickinson, C., Heyn, P., et al. (2022). International practice recommendations for the recognition and management of hearing and vision impairment in people with dementia. *Gerontology*, 68(2), 121–135. <https://doi.org/10.1159/000515892>
- Luria, A. R. (1963). *Restoration of function after brain injury*. MacMillan.
- Luzzi, S., Snowden, J. S., Neary, D., Coccia, M., Provinciali, L., & Ralph, M. A. L. (2007). Distinct patterns of olfactory impairment in Alzheimer's disease, semantic dementia, frontotemporal dementia, and corticobasal degeneration. *Neuropsychologia*, 45(8), 1823–1831. <https://doi.org/10.1016/j.neuropsychologia.2006.12.008>
- Murray, M. M., Eardley, A. F., Edginton, T., Oyekan, R., Smyth, E., & Matusz, P. J. (2018). Sensory dominance and multisensory integration as screening tools in aging. *Scientific Reports*, 8(8901), 1–11. <https://doi.org/10.1038/s41598-018-27288-2>
- Musiek, F., & Baran, J. (2018). *The auditory system: anatomy, physiology, and clinical correlates* (2nd Edn.). Plural Publishing.
- Peña-Casanova, J. (2019). *Programa integrado de exploración neuropsicológica Test Barcelona - 2. Test Barcelona Services SL*.
- Pinto, J. O., Vieira De Melo, B. B., Dores, A. R., Peixoto, B., Geraldo, A., & Barbosa, F. (2021). Narrative review of the multisensory integration tasks used with older adults: inclusion of multisensory integration tasks into neuropsychological assessment. *Expert Review of Neurotherapeutics*, 21(6), 657–674. <https://doi.org/10.1080/14737175.2021.1914592>
- Pinto, J. O., Dores, A. R., Peixoto, B., Vieira de Melo, B. B., & Barbosa, F. (2022). Critical review of multisensory integration programs and proposal of a theoretical framework for its combination with neurocognitive training. *Expert Review of Neurotherapeutics*, 22(7), 557–566. <https://doi.org/10.1080/14737175.2022.2092401>
- Pinto, J. O., Peixoto, B., Dores, A. R., & Barbosa, F. (2023). A model of sensory, emotional, and cognitive reserve. *Applied Neuropsychology: Adult*, 0(0), 1–3. <https://doi.org/10.1080/23279095.2023.2291480>
- Powell, D. S., Oh, E. S., Reed, N. S., Lin, F. R., & Deal, J. A. (2022). Hearing loss and cognition: what we know and where we need to go. *Frontiers in Aging Neuroscience*, 13, Article 769405. <https://doi.org/10.3389/fnagi.2021.769405>
- Reed, N. S., & Oh, E. S. (2022). New insights into sensory impairment and dementia risk. *JAMA Network Open*, 5(5), Article e2210740. <https://doi.org/10.1001/jama-networkopen.2022.10740>. -e2210740.
- Von Seggern, H. B. (1987). *Factor analysis of the clinical scales on the Luria-Nebraska neuropsychological battery, form II [Unpublished doctoral dissertation]*. North Texas State University.
- Wolski, L., Leroi, I., Regan, J., Dawes, P., Charalambous, A. P., Thodi, C., et al. (2019). The need for improved cognitive, hearing and vision assessments for older people with cognitive impairment: a qualitative study. *BMC Geriatrics*, 19(1), 328. <https://doi.org/10.1186/s12877-019-1336-3>

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