Yes, there is a neural dissociation between language and reasoning.

Martin M Monti, Lawrence M Parsons, Daniel N Osherson

UCLA Department of Psychology, Los Angeles CA 90402, USA

The University of Sheffield, Department of Psychology, Sheffield S10 2TN, UK

Princeton University, Department of Psychology, Princeton NJ 08540, USA

Corresponding author: Monti, M. M. (monti@psych.ucla.edu).

In their commentary, Tzourio-Mazoyer and Zago (henceforth, TMZ) caution against the conclusion, presented in Monti et al (2012), that there exists a dissociation between algebraic and linguistic reasoning. In what follows we briefly summarize our experimental design and then show that TMZ's concerns spring from an inaccurate reading of our methods.

In [1] we visually presented participants with two sets of arguments (i.e., pairs of sentences). One set featured 'linguistic' arguments, as in: "X gave Y to Z." and "Z was given to Y by X.", while the other featured 'algebraic' arguments, as in: "X plus Y is smaller than Z." and "Z minus Y is greater than X." Participants saw each argument twice, once to judge whether the sentences in a given pair were logically equivalent (equivalence/reasoning task) and once to assess whether the two sentences were both grammatically correct (grammar task). The subtraction of grammar trials from equivalence trials uncovered extensive activations in left inferior frontal gyrus (IFG) and posterior temporal cortex (among others) for linguistic arguments *but not* for algebraic arguments (as confirmed with an independent ROI analysis, [1]).

#1.**“[…] it appears from Figure 3 [1] that IFGop and IFGtri are indeed activated during all tasks.”**

In this comment, TMZ fail to consider that our stimuli are verbal in nature and need to be read and comprehended before any manipulation can occur. As stated in our introduction: “It is uncontroversial that language mechanisms are required to encode the two statements of an argument. We tested the more substantive claim that language accompanies reasoning *beyond the point of encoding* in both the linguistic and algebraic domains” ([1] p.2, emphasis added). Therefore, the fact that *as compared to looking at a fixation cross* algebraic trials exhibit greater than zero activation in linguistic regions does not allow one to conclude that language is required for algebraic reasoning. For, one cannot tell whether the linguistic activation is due to reading and encoding verbally presented statements or whether it is also required for manipulating algebraic variables and operators. To eliminate this confound we assessed whether algebraic reasoning elicited any more linguistic activity than is necessary for reading and comprehending individual sentences in the absence of any reasoning (i.e., the grammar task). As shown by our results, “algebraic operations did not recruit any more language resources than did simple reading” ([1] p. 8), implying that “beyond initial reading and comprehension of stimuli, the neural substrate of language does not intervene in algebraic reasoning” (*ibid.,* p. 6). This result is consistent with the finding that some aphasic (agrammatic) patients are able to comprehend the syntactic structure of algebraic expressions (presented in algebraic symbols) despite being unable to comprehend the syntax of language [5].

#2 “One difficulty stems from differences in the syntactic complexity of the sentences used for linguistic and algebraic tasks.”

This comment does not recognize that the main contrasts (as well as the ROI analysis) upon which our results are predicated are based on the comparison of *the very same arguments* when evaluated for grammaticality versus equivalence. Of course, as TMZ note, “the grammatical evaluation of sentences […] involves semantic and syntactic processes”. But crucially, even if processing the individual sentences of linguistic arguments required greater grammatical effort, this would equally affect grammar and equivalence judgments (because the same sentences are used) and would thus be cancelled by the subtraction of the two tasks.

#3 " [I]In the introduction of the present paper [1], the authors focus on the inferior frontal gyrus (IFG) [i]t is thus the involvement of inferior frontal areas [ ] that appears to be under investigation, rather than the involvement of any perisylvian language areas."

As evident in our text and figures (in [1] and in our previous work [2,3,4]), we always report full brain results and show activity for several regions traditionally associated with language processing (including, for example, IFG, superior and middle posterior temporal gyri and angular gyrus) [see 2 for greater discussion]. Our text focuses on the IFG because of our interest in testing the "proposal that the left inferior frontal gyrus (IFG) acts 'supramodally' to forge complex hierarchical dependencies for nonlinguistic domains" [6,7].

In sum, we stand by our conclusion that our data point at a "neural dissociation between the syntax-like operations of algebra and those of natural language" [1, p.8].

[1] Monti, M.M. *et al.* (2012) Thought beyond language: neural dissociation of algebra and natural language. *Psychol. Sci.*

[2] Monti, M. M., Parsons, L. M., & Osherson, D. N. (2009). The boundaries of language and thought in deductive inference. *Proceedings of the National Academy of Sciences, USA*, *106*, 12554–12559.

[3] Monti, M.M. and Osherson, D.N. (2012) Logic, language and the brain. *Brain Res.* 1428, 33-42

[4] Monti, M.M., Osherson, D. N., Martinez, M. J., & Parsons, L. M. (2007). Functional neuroanatomy of deductive inference: A language-independent distributed network. *NeuroImage*, *37*, 1005–1016.

[5] Varley, R. A., Klessinger, N. C., Romanowski, C. A. J., & Siegal, M. (2005). Agrammatic but numerate. *Proceedings of the National Academy of Sciences, USA*, *102*, 3519–3524.

[6] Fadiga, L. *et al*. (2009) Broca's area in language, action, and music. *Ann. N. Y. Acad. Sci.* 1169, 448-458.

[7] Tettamanti, M., & Weniger, D. (2006). Broca's area: A supramodal hierarchical processor? *Cortex*, *42*, 491–494.