Arithmetic deficits in Parkinson's Disease? A registered report

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Submitted by Hannah Dorothea Loenneker 29 Jun 2021 19:23

Abstract

Elderly people and patients with neurodegenerative diseases such as Parkinson's Disease (PD) immensely rely on arithmetic skills to lead an independent life. Activities such as medication management, financial transactions or using public transport require intact abilities to manipulate numbers with different arithmetic operations. However, research on cognitive deficits in PD has been focusing on domain-general functions such as executive functions, attention or working memory so far – largely neglecting potential domain-specific aspects of numerical cognition (e.g., carry or problem size effect). These aspects should be addressed, as PD-immanent deterioration of domain-specific numerical areas and domain-general functions suggests mechanisms of both primary and secondary (mediated by other cognitive deficits) arithmetic deficits, respectively. The current study will systematically investigate arithmetic performance and effects in PD patients differing in cognitive impairment for the first time, targeting domain-specific cognitive representations of arithmetic as well as the influence of domain-general factors. Besides healthy controls (HC), PD patients with normal cognition (PD-NC) and PD patients with mild cognitive impairment (PD-MCI) will be compared in arithmetic performance in the four basic operations (addition, subtraction, multiplication, division). Discriminant analysis will be employed to assess whether performance in arithmetic tasks can differentiate between a healthy control group and both PD groups. The study results will help us to understand the underlying mechanisms of arithmetic deficits faced by PD patients in daily life.

Keywords: Parkinson's disease, mild cognitive impairment, arithmetic operation, calculation, place × value system

Round #3

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by Zoltan Dienes, 03 Dec 2021 12:22
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minor revision

Sorry, just a couple of minor things.

This may have been clear to me before but it is not now. Why is your robustness analysis relevant to your proposed analysis? Make sure you state the model of H1 you will use (saying "uninformed" does not specify as there a number of "uninformed" models of H1). I presume you mean a Cauchy centred on zero with scale factor = 0.7 in d units. Your simulations use different centring and scale factors. What would you get if you used your proposed model? H0 is typically a spike at 0. Why not use this in your robustness analysis? Indicate the standardized effect size of the previous study you base your reasoning on, to give some justifcation for why 0.7 may be relevant. (Bear in mind there are really no "uninformed" models of H1; every model is a conjecture about the probable effect sizes in a scientific context, so a

default is just a suggestion you should check for adequately representing the plausibility of different effect sizes in your context.) Apologies if I missed an explanation somewhere!

We do agree that there are no "uninformed" priors in a scientific context where comparable studies have been conducted before. Therefore, first of all we changed the wording here:

"For all Bayesian analyses, ~~uninformed~~ Cauchy priors centred on zero with a scale factor of 1 in d units will be used based on findings of Zamarian et al. (2006)~~, as the current study is the first of its kind and we cannot infer priors from available literature~~, and models will be compared to the null model."

We changed the robustness check as you suggested:

> "We estimate the robustness of the BF analysis based on Zamarian's (2006) results on the Graded Difficulty Arithmetic Test (i.e., mixed arithmetic tasks), comparing PD-NC (M = 10.2, SD = 4.3, n = 15) and HC (M = 15.5, SD = 4.6, n = 28), $t(41)$= -3.70, $p < .001$ ($M_{difference}$ = -5.3, SD_{pooled} = 4.49, SE_{pooled} = 1.41). We assessed the robustness using the online Bayes factor calculator (Tattan-Birch et al., 2021). As this difference of mean accuracies reflects an effect size of d = 1.18, we will use a scale factor of 1 for the prior Cauchy distribution. We defined the likelihood based on a student t distribution with the parameters from Zamarian's results ($M_{difference}$ = -5.3, SE_{pooled} = 1.41, df = 41), assuming a Cauchy distribution (location = 0, scale = 1) ~~with the same parameters~~ for the model of the alternative hypothesis ~~and a Cauchy distribution with a location parameter of 0 for the model of the null hypothesis, both~~, one-sided with a lower limit. Results on possible ranges of the scale factor~~s and mean differences~~ producing BFs indicating conclusive evidence are reported in Table 3. ~~These results are only available for ACC, but not for RT data. However, many of these tests operationalize the constructs differently (e.g., the GDAE assesses all basic arithmetic operations at once instead of testing the four operations separately as in our study). Even if the name is the same (complex calculation), it is possible that effects depend on the exact stimuli (e.g., with or without carry/borrowing, which we manipulated). Furthermore, the study was conducted in PD-NC, but not PD-MCI patients.~~ However, the study by Zamarian (2006), that we base our effect size estimates on, differs in important aspects from our planned study: (1) they report accuracies instead of RT (we use both separately), (2) they compare a healthy control group with a PD group without cognitive impairments (we additionally compare this group with a patient group with cognitive impairments), and (3) they use a task-based instead of our effect-based approach. While findings from Zamarian et al. (2006) provide a first hint in which region the expected effect sizes and priors could be, we are quite far-off a direct replication: Hence, our effect sizes could differ considerably from Zamarian et al. (2006). Considerations regarding effect sizes in Q3b cannot be inferred from the literature, as we are not aware of a study comparing PD-NC with PD-MCI patients in mental arithmetic.

Table 3. Robustness considerations of scale factors for Bayesian analysis.

Model for alternative hypothesis		
Location	Scale	BF_{10}
0	1	55.64
0	0.5	14.14
0	0.25	3.02
0	0.24	2.84
0	0.1	1.41

> Table 3 indicates that we can expect fairly robust results as long as ~~the location parameters are not substantially smaller, or the scale parameters are not substantially larger than in the work by Zamarian et al. (2006).~~ the effect size of our group difference does not drop below $d = 0.25$. Since the current study implies both comparisons with a PD-NC and a more advanced PD-MCI group as opposed to a single PD-NC sample in Zamarian's study, we might even expect larger effects. However, we want to be careful with this prediction as target tasks, control variables, and items within tasks differ and may modulate effects. After data acquisition, robustness of the BF across different scale factors will be assessed with a robustness plot in JASP."

And while there is a chance a small matter. In the design table for your third section, hypothesis column: b) "It is not clear whether..." is not a hypothesis; rephrase as a hypothesis that could be refuted by the data.

We changed the wording regarding our hypothesis 3 in the design table accordingly:

> "a) The weighted linear combination of the four basic arithmetic tasks ~~predicts~~ can be used to differentiate whether a patient belongs to the group with or without mild cognitive impairments.
> b) The weighted linear combination of the four basic arithmetic tasks can be used to differentiate between HC and PD-NC (who show a comparable cognitive status). ~~It is unclear whether the HC and PD-NC groups differ in arithmetic, despite them showing comparable results regarding global cognition.~~"

This has also been changed in the manuscript.