Supplemental Material for

NEPS*scaling*: Providing Plausible Values for Users of the National Educational Panel Study

Further Functionality of NEPS*scaling* Shiny App

To import background data for the estimation, a click on the field “Manage background data” on the top left of the starting page (also called the “Manage” tab) expands the import, remove and inspect options for the background data (Figure S1). By clicking on the “Browse…” button, the file explorer pops up and the background data can be selected. After setting the scale level of the background variables, the data is displayed in the “Manage” tab (Figure S2).

Furthermore, the background data can be inspected, i.e., there are options to select variables and filter columns available after expanding the “Manage background data” field’s “Inspect background data” button (see Figure S3). Please note that these configurations do not affect the variable selection for the plausible values estimation.

Figure S1

Import of background data

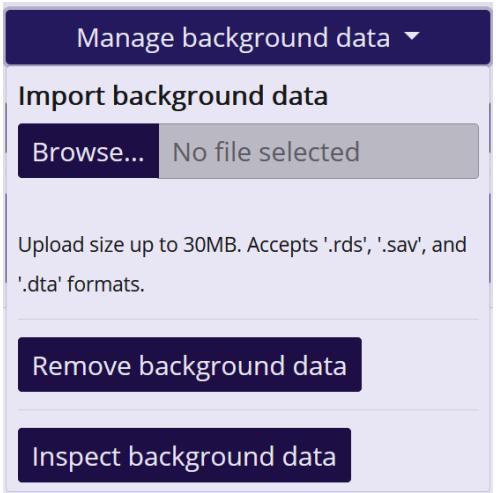


Figure S2

Display of background data after setting the scale level

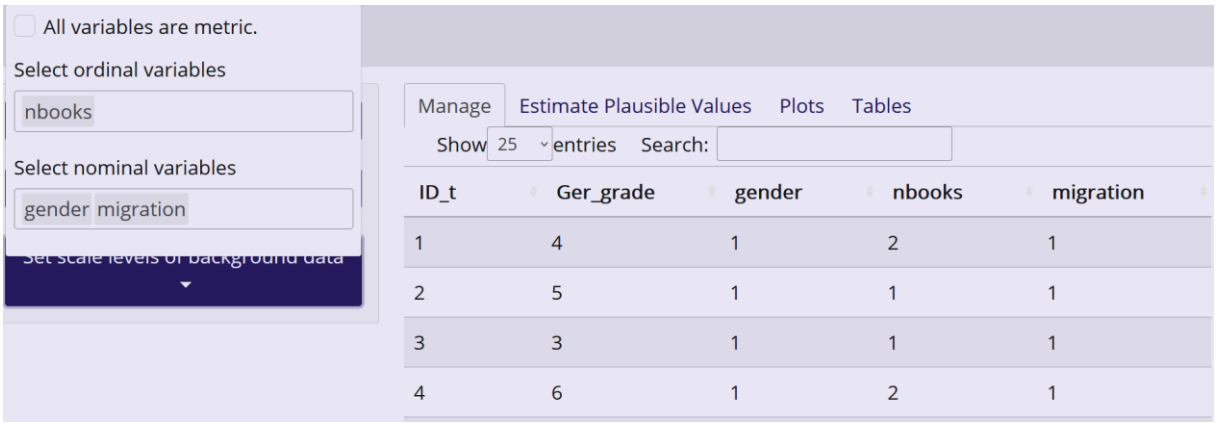
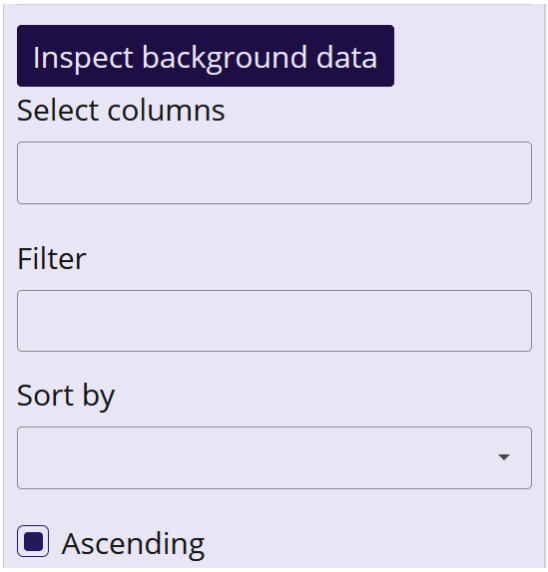


Figure S3

Ways of inspecting the background data



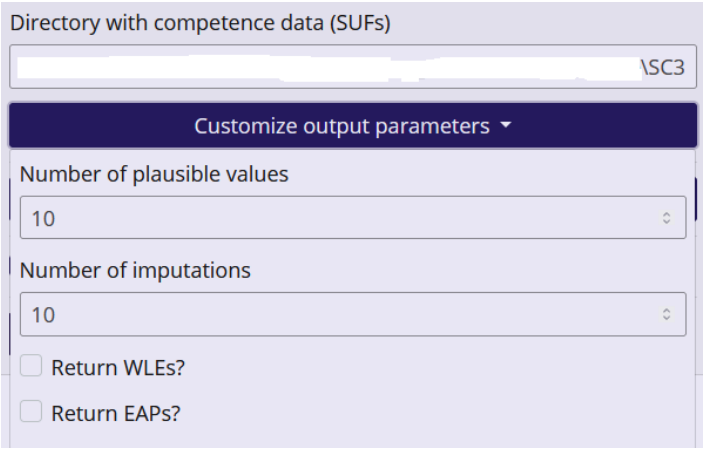
Note. Any variable selection or subject filtering is not permanent. Exclusion of variables for the plausible values estimation is part of the input arguments for the estimation.

Before estimating plausible values, the output of the estimation algorithm can be tweaked. After expanding the field “Customize output parameters” in the middle left of the “Estimate Plausible Values” tab (Figure S4), one can change the number of imputations and plausible values (both default to 10) and whether point estimates of the competences (weighted likelihood estimates, WLEs, and expected a posteriori estimates, EAPs) should be returned next to the set of plausible values.

The field “Customize model parameters” includes the option to exclude background variables from the plausible values estimation (i.e., they are used only for imputation). The variables can be chosen from a drop down selection of the available variables (Figure S5).

Figure S4

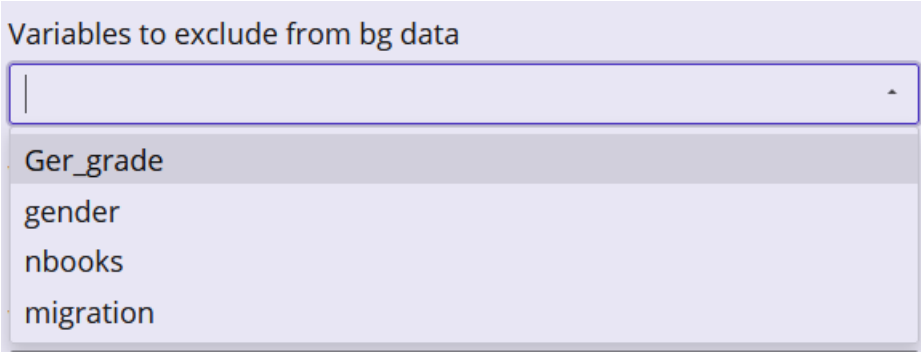
Customization of the output object



Note. The pre-defined numbers of imputations and plausible values are the current standard in large-scale assessment studies and should be considered as a minimum number.

Figure S5

Exclusion of variables from the background data during plausible values estimation



Note. This field is part of the "customize model parameters" button. It refers to either the background data in cross-sectional estimation or the background data of the first wave in longitudinal estimation. For later waves, separate fields appear after selecting longitudinal estimation.

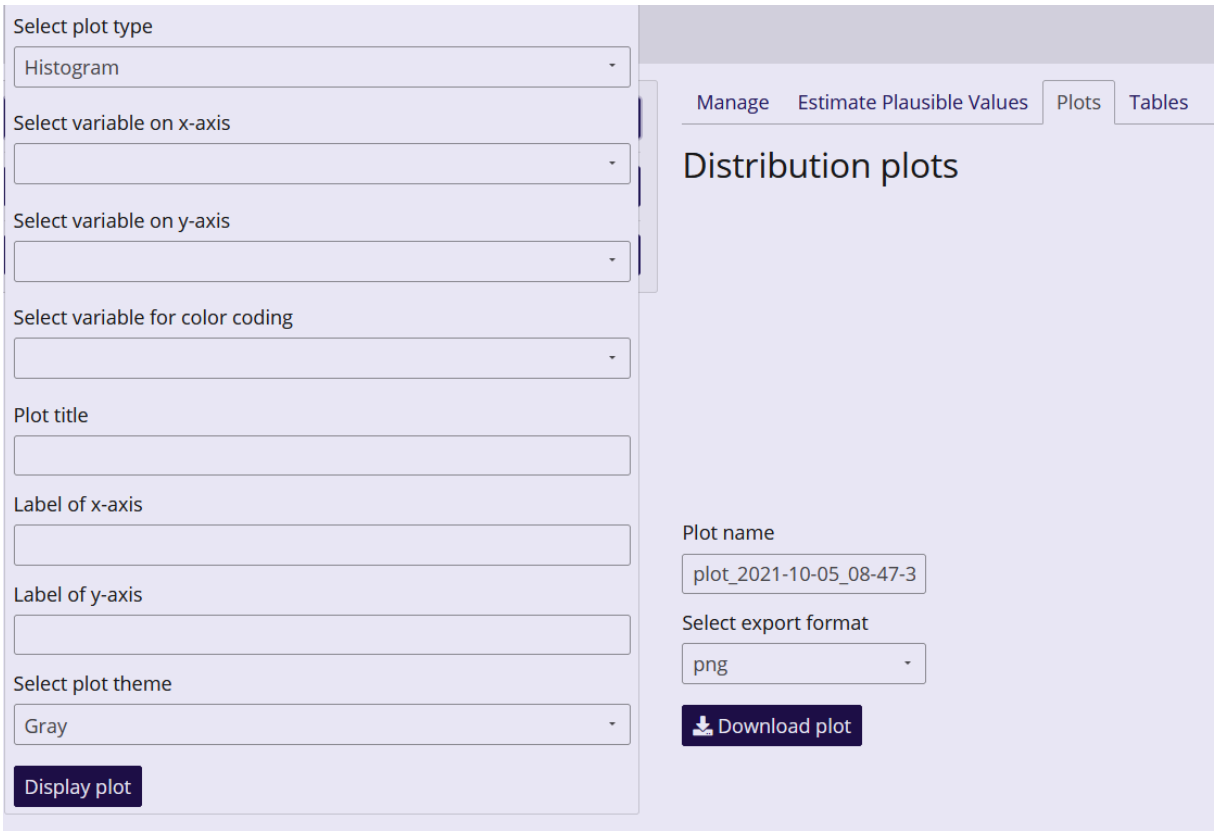
After the estimation, the imputed data and plausible values can be inspected visually in the "Plots" tab (Figure S6). There are options to display the imputed data and plausible values with histograms, scatter plots and kernel density plots (Figures S7 and S8). The variable to plot on the x-axis and, in case of the scatter plot, the variable to plot against on the y-axis can be chosen from drop down menus. Furthermore, the data can be color coded by group memberships of the participants (see Figure S8).

Figure S6

Overview of the Plots tab

Figure S7

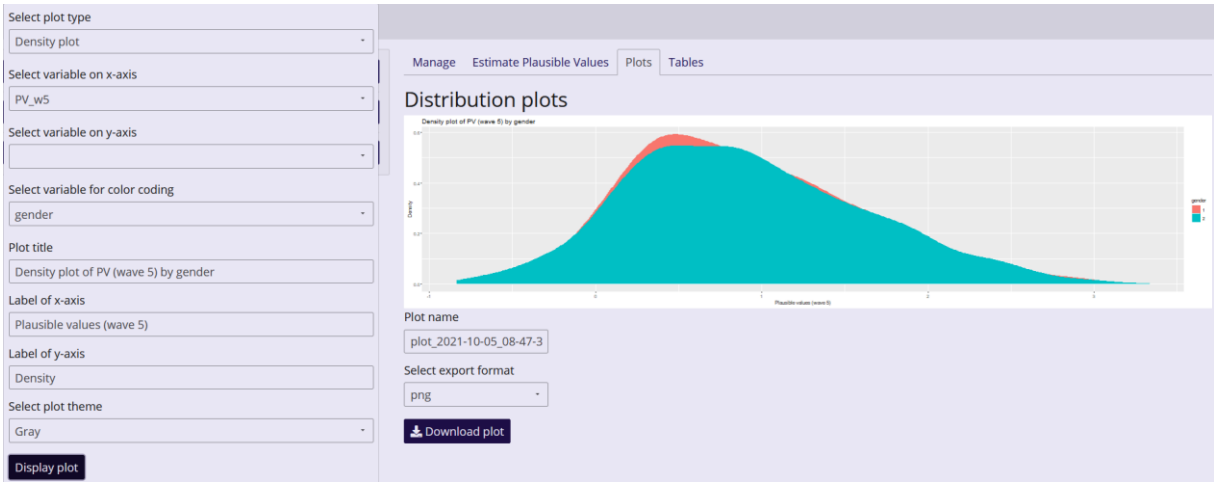
Options for plotting the imputed data and estimated plausible values



Note. Histograms, scatter plots and kernel density plots are available for the imputed background data and the plausible values, aggregated to one single data set. *Color coding* refers to group-wise plots, e.g., grouped by gender.

Figure S8

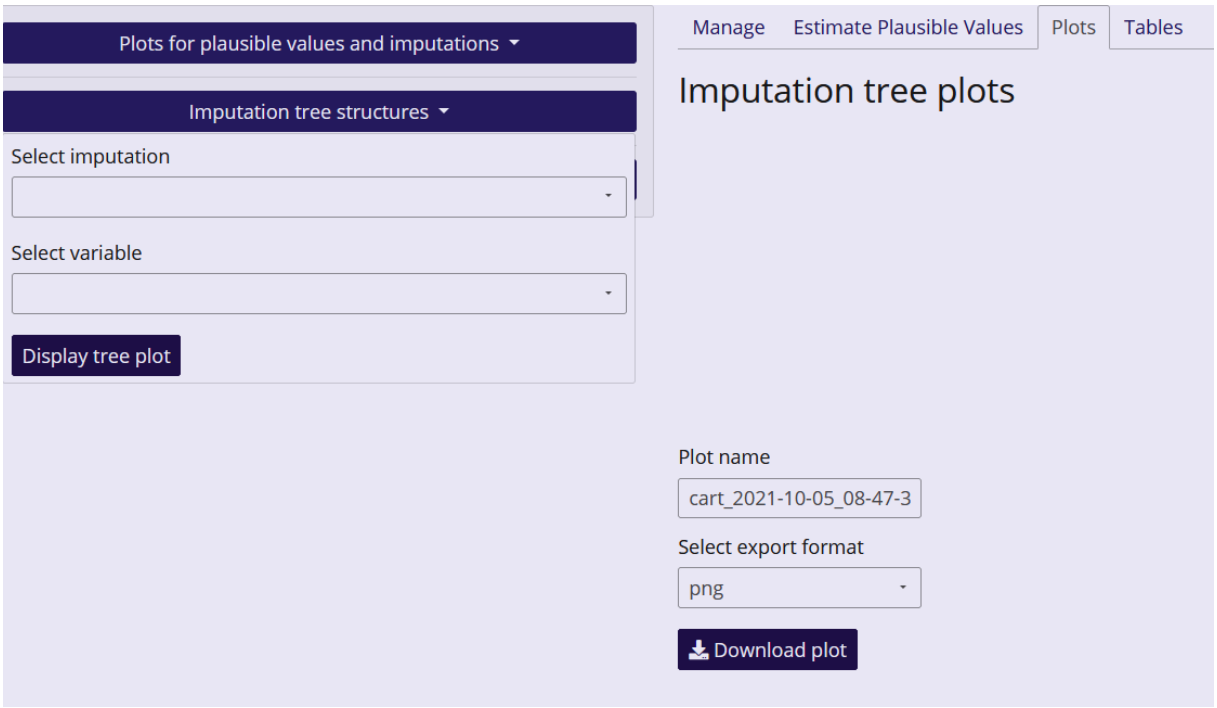
Example for kernel density plot of plausible value by gender



Moreover, the imputation process can be inspected as well (fields “Imputation tree structures” and “Variable importance plots for imputations” in the “Plots” tab; Figure S6). Both plots need the same inputs as can be seen in Figures S9 and S10, that is, the imputation and the imputed variable which can be selected from drop down menus in both cases. However, the tree structure may become very complex especially if many variables are included in the model. In those cases, the tree structure may not be displayed by NEPSshiny. It can still be inspected in its written representation using the function *get_imputation_tree(pv_obj, imputation, variable)* in R. The variable importance plots are not affected by the tree’s complexity.

Figure S9

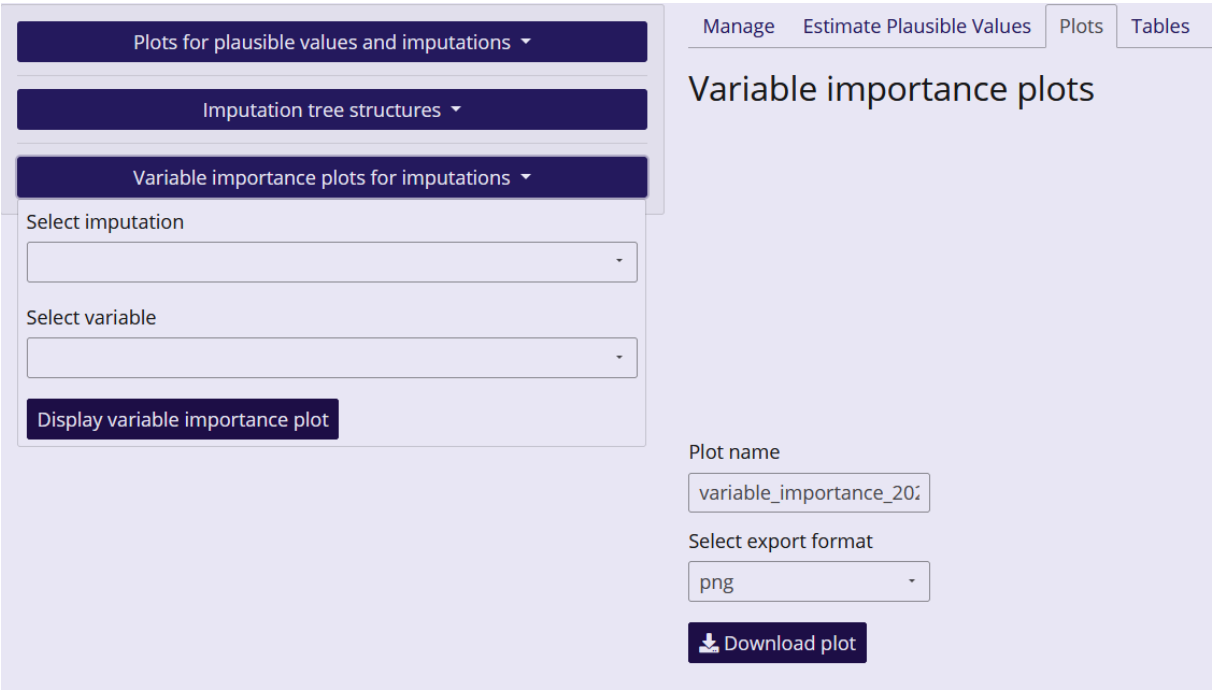
Imputation tree plot



Note. For each variable per imputation, the classification or regression tree used for filling in the missing values can be displayed, as long as the tree is not too complex.

Figure S10

Variable importance plot

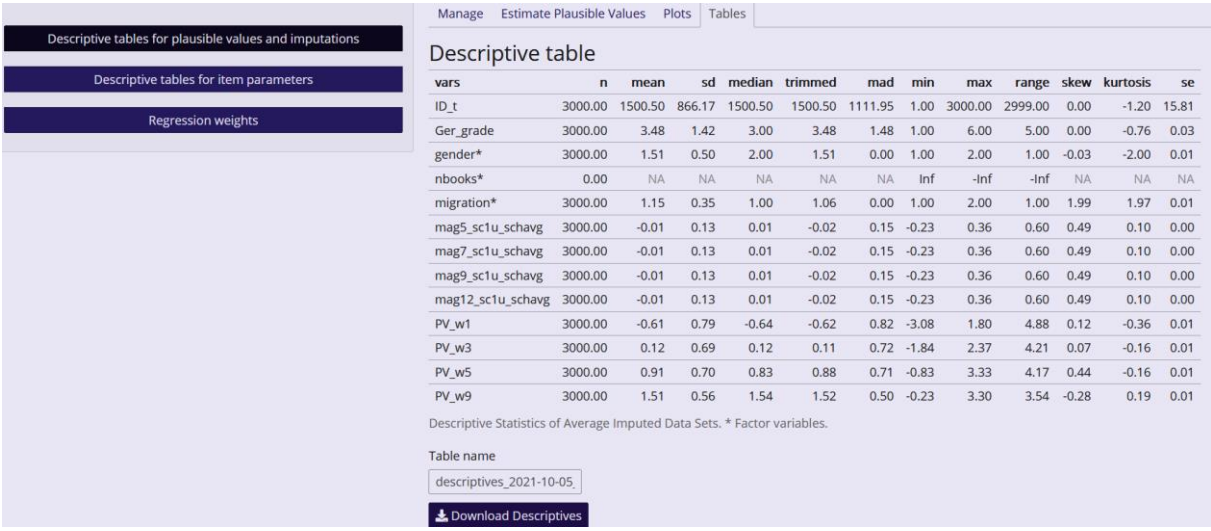


Note. For each variable per imputation, the importance of the predictor variables in the imputation can be plotted as bar plots.

The imputed data sets can, furthermore, be inspected in tabular form. By clicking the button "Descriptive tables for plausible values and imputations" in the "Tables" tabs, descriptive statistics (e.g., mean, standard deviation and range) of the aggregated imputed data sets, including the estimated plausible values, are calculated and displayed (Figure S11).

Figure S11

Descriptive table of imputed data sets



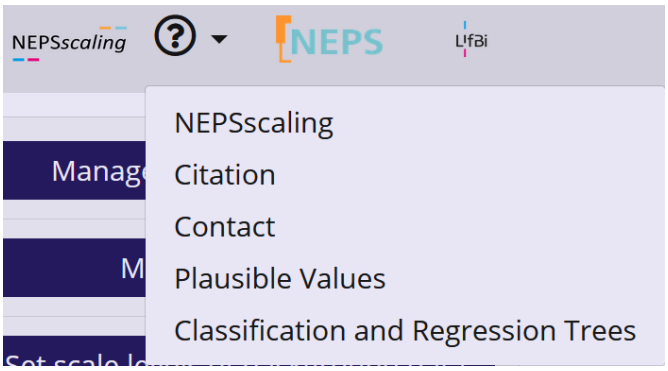
vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
ID_t	3000.00	1500.50	866.17	1500.50	1500.50	1111.95	1.00	3000.00	2999.00	0.00	-1.20	15.81
Ger_grade	3000.00	3.48	1.42	3.00	3.48	1.48	1.00	6.00	5.00	0.00	-0.76	0.03
gender*	3000.00	1.51	0.50	2.00	1.51	0.00	1.00	2.00	1.00	-0.03	-2.00	0.01
nbooks*	0.00	NA	NA	NA	NA	NA	Inf	-Inf	-Inf	NA	NA	NA
migration*	3000.00	1.15	0.35	1.00	1.06	0.00	1.00	2.00	1.00	1.99	1.97	0.01
mag5_sc1u_schavg	3000.00	-0.01	0.13	0.01	-0.02	0.15	-0.23	0.36	0.60	0.49	0.10	0.00
mag7_sc1u_schavg	3000.00	-0.01	0.13	0.01	-0.02	0.15	-0.23	0.36	0.60	0.49	0.10	0.00
mag9_sc1u_schavg	3000.00	-0.01	0.13	0.01	-0.02	0.15	-0.23	0.36	0.60	0.49	0.10	0.00
mag12_sc1u_schavg	3000.00	-0.01	0.13	0.01	-0.02	0.15	-0.23	0.36	0.60	0.49	0.10	0.00
PV_w1	3000.00	-0.61	0.79	-0.64	-0.62	0.82	-3.08	1.80	4.88	0.12	-0.36	0.01
PV_w3	3000.00	0.12	0.69	0.12	0.11	0.72	-1.84	2.37	4.21	0.07	-0.16	0.01
PV_w5	3000.00	0.91	0.70	0.83	0.88	0.71	-0.83	3.33	4.17	0.44	-0.16	0.01
PV_w9	3000.00	1.51	0.56	1.54	1.52	0.50	-0.23	3.30	3.54	-0.28	0.19	0.01

Note. The descriptive table is created for the aggregated completed data sets, including the estimated plausible values.

Finally, help and support information is available when clicking on the question mark at the top left of the Shiny app (see Figure S12). It links to a short summary of the purpose of NEPS*scaling* (option “NEPSscaling”; see also Figure S13), citation (option “Citation”; see Figure S14) and contact information in case of further questions (option “Contact”; see also Figure S15) as well as an overview of the theory behind plausible values (option “Plausible Values”; see also Figure S16) and classification and regression trees (“Classification and Regression Trees”; see also Figure S17) that are used for multiple imputation in NEPS*scaling*.

Figure S12

Help and support button in the main bar of the app



Note. A click on the question mark button opens a list of short explanations about the underlying concepts as well as further information (sources).

Figure S13

*Short summary of NEPS*scaling

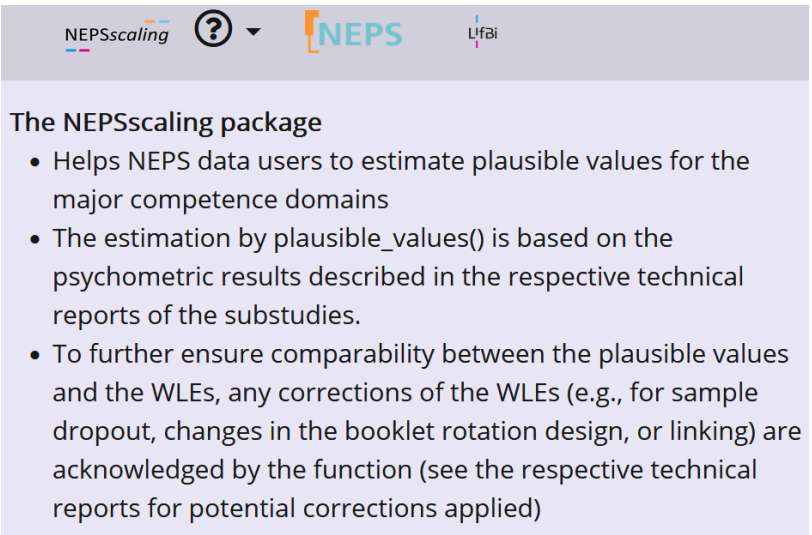


Figure S14

*Correct citation of the NEPS*scaling *package*

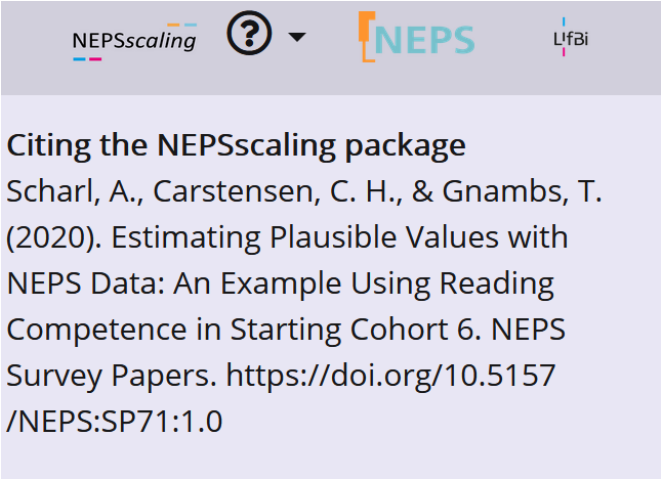
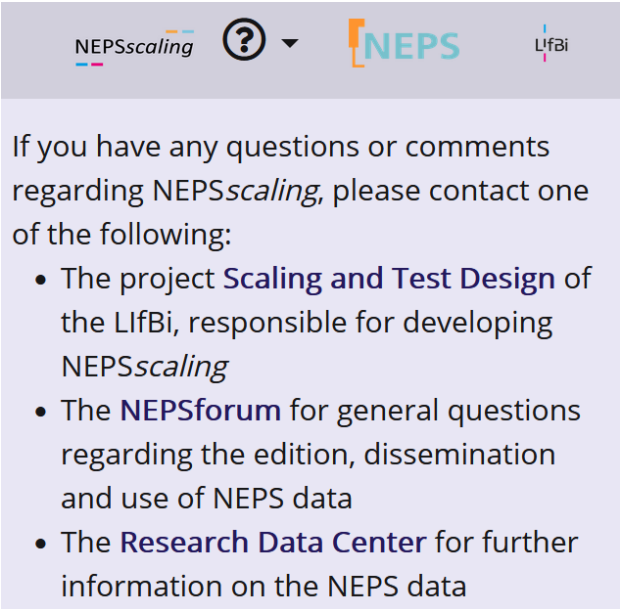


Figure S15

*Contact information of NEPS*scaling *team*



Note. The phrases in bold type contain hyperlinks of the described contacts.

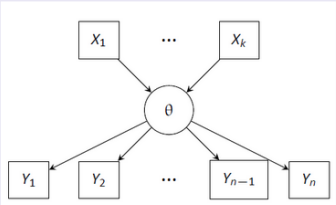
Figure S16

Short summary of plausible values technique with recommended reading

NEPSscaling NEPS Ufai

Plausible Values

- Estimators for latent constructs such as competencies
- Set of random draws out of individual respondent's latent competence distribution
- Derived from competence test and respondent characteristics (e.g., gender, socio-economic status)
- Uncertainty in random draws reflects uncertainty in competence estimation
- Background variables should at least contain all variables used for later analysis
- Unbiased on a population level, but biased on the individual level because of respondent information (i.e., group-level information)
- Special case of multiple imputation: statistical analyses with plausible values have to be performed accordingly



Recommended Reading

1. Scharl, A., Carstensen, C.H., & Gnambs, T. (2020). Estimating Plausible Values with NEPS Data: An Example Using Reading Competence in Starting Cohort 6 (NEPS Survey Paper No. 71). Bamberg: Leibniz Institute for Educational Trajectories, National Educational Panel Study. doi:10.5157/NEPS:SP71:1.0
2. von Davier, M., Gonzalez, E., & Mislevy, R. (2009). What are plausible values and why are

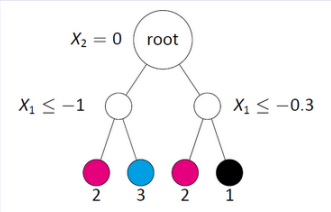
Figure S17

Short summary of used imputation algorithm with recommended reading

NEPS*scaling* NEPS Lifai

Classification and Regression Trees

- Background variables for plausible values cannot contain missingness, but non-response is pervasive in large scale assessments and surveys
- Multiple imputation as an approach to fill in randomly missing data without introducing further bias
- Decision trees (e.g., classification and regression trees, CART) can be used to identify a set of plausible responses for the missing data
- Variable with missingness is recursively split into subsets; each subset has to be more homogenous than the superset
- Splits are made according to a value on a predictor variable (e.g., being female, being older than X years) until a node purity criterion is reached
- Prediction for missing values are drawn by following the tree's branches to its nodes and choosing a value from the node following an algorithm
- CART is a non-parametric approach and automatically incorporates non-linear relationships in the predicted and predictor variables



Recommended Reading

1. Scharl, A., Carstensen, C.H., & Gnambs, T. (2020). Estimating Plausible Values with NEPS