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PIAAC-L: the longitudinal follow-up to PIAAC in Germany

Silke Martin*, Débora B. Maehler**, Anouk Zabal*** and Beatrice Rammstedt****

Abstract: This paper describes the main features of PIAAC-L, the German longitudinal follow-up to PIAAC (Programme for the International Assessment of Adult Competencies), and presents the PIAAC-L data. PIAAC-L was a collaborative study by three large-scale surveys in Germany, PIAAC, the National Educational Panel Study (NEPS), and the German Socio-Economic Panel (SOEP). Respondents from the German PIAAC sample (2011/2012) and the adult members of their households were interviewed over three waves (2014, 2015, 2016). PIAAC-L combined design features and instruments from PIAAC, NEPS, and the SOEP and included a re-assessment of basic cognitive skills. Literacy and numeracy were measured with instruments from PIAAC and NEPS and the assessment was extended to include cohabiting spouses/partners of PIAAC respondents. Interviewer-administered person and household questionnaires covered a broad range of content. The PIAAC-L data, which are available to researchers for secondary analyses, allow to explore cognitive skills over time and factors related to their acquisition and maintenance. In the German context, the study is of interest because it combined expertise and content from three national large-scale surveys.

Keywords: PIAAC-L; PIAAC Germany; Large-scale Assessment; Cognitive Skills; Longitudinal Study; Data Usage

PIAAC-L: die Nachfolgestudie von PIAAC in Deutschland

Zusammenfassung: Dieser Beitrag beschreibt die Grundzüge von PIAAC-L, der Nachfolgestudie von PIAAC (*Programme for the International Assessment of Adult Competencies*) in Deutschland und stellt die PIAAC-L-Daten vor. PIAAC-L war eine gemeinschaftliche Studie von drei groß angelegten Erhebungen in Deutschland, PIAAC, dem Nationalen Bildungspanel (NEPS) und dem Sozio-oekonomischen Panel (SOEP). Die Befragungspersonen der deutschen PIAAC-Stichprobe (2011/2012) und die erwachsenen Mitglieder ihrer Haushalte wurden über drei

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Wellen (2014, 2015, 2016) befragt. PIAAC-L kombinierte Designmerkmale und Instrumente aus PIAAC, NEPS und dem SOEP und beinhaltete eine erneute Messung von grundlegenden Kompetenzen. Die Lesekompetenz und die Alltagsmathematische Kompetenz wurden mit Instrumenten aus PIAAC und NEPS gemessen. Die Messung wurde auf mit den PIAAC-Befragungspersonen zusammenlebende (Ehe)partnerinnen und -partner ausgeweitet. Die Interviewer-administrierten Personen- und Haushaltsfragebögen deckten ein breites Spektrum an Inhalten ab. Die PIAAC-L-Daten, die Forscherinnen und Forschern für Sekundäranalysen zur Verfügung stehen, erlauben es, grundlegende Kompetenzen im Zeitverlauf und Faktoren, die mit ihrem Erwerb und Erhalt zusammenhängen, zu untersuchen. Im Hinblick auf den deutschen Kontext ist die Studie von Interesse, da sie Expertise und Inhalte aus drei nationalen Großerhebungen kombiniert.

Stichworte: PIAAC-L; PIAAC Deutschland; Large-Scale Assessment; Kompetenzen; Längsschnittstudie, Datennutzung

1 Introduction

High-quality data from cross-sectional and longitudinal surveys form the basis for evidence-based research in various fields, for example, in the educational, social, and economic sciences. When these data are made available for secondary analyses from data archives and research data centers, they are an excellent resource for re-researchers from various disciplines.

In 2008, the Organisation for Economic Co-operation and Development (OECD) launched the first cycle of PIAAC, the Programme for the International Assessment of Adult Competencies. The goal was to generate data that can be used for cross-national comparative analyses and international benchmarking of three adult cognitive skill domains—literacy, numeracy, and problem solving in technology-rich environments. These cognitive skills are considered essential to successful participation in modern society and are regarded as the foundation for developing many other, more specific, competencies (OECD 2013). PIAAC is a cross-sectional study that is repeated at ten-year intervals. Thirty-eight countries, including Germany, participated in the data collection of the first cycle of PIAAC in 2011/2012. In 2014, GESIS – Leibniz Institute for the Social Sciences, LIfBi – Leibniz Institute for Educational Trajectories, and the German Institute for Economic Research (DIW Berlin) started PIAAC-Longitudinal (PIAAC-L).¹ Respondents from the *German* PIAAC sample were followed up and re-interviewed at three points in time: 2014, 2015, and 2016 (Rammstedt et al. 2017).

The longitudinal study PIAAC-L intended to collect more information on German PIAAC respondents. Key aims included a re-assessment of basic cognitive skills

¹ The study was funded by the Federal Ministry of Education and Research.

(literacy, numeracy), a broadening of the breadth and depth of background information compared to that collected in PIAAC, as well as an extension of the design to include information on the entire household and to assess cognitive skills of spouses/partners. The added value of PIAAC-L includes: First, the longitudinal design and the re-assessment of cognitive skills allow researchers to go beyond the cross-sectional international PIAAC findings and study the acquisition, maintenance, and outcomes of cognitive skills more comprehensively. Although a few other countries that participated in the first cycle of PIAAC have followed up on their PIAAC respondents, Germany is the only one that has carried out a re-assessment of literacy and numeracy using PIAAC instruments. Second, in contrast to PIAAC, PIAAC-L also assessed the cognitive skills

of cohabiting spouses/partners, thereby allowing within-couple comparisons of competencies and offering insights into assortative mating. Third, PIAAC-L extended the scope of PIAAC by including additional content and questionnaire constructs, for example, by collecting background information on lifelong learning, health, and skill mismatch. This enables the investigation of the relationship between cognitive skills and related factors. Fourth, the international PIAAC design was extended to include the entire household and the collection of detailed information at the household level. And finally, PIAAC-L combined expertise, instruments, and design features from three national large-scale surveys: PIAAC Germany, the National Educational Panel Study (NEPS), and the German Socio-Economic Panel (SOEP).² The PIAAC-L assessment design with the administration of different cognitive assessment instruments developed by PIAAC and NEPS allows to compare different approaches to the assessment and operationalization of cognitive skills and thus contributes to comparability in research and to linking international results to the national framework. Similarly, measuring background information using different operationalizations implemented by the three surveys for the same constructs provides opportunities for methodological research from which all three surveys can benefit.

The PIAAC-L study provides information on the level and distribution of cognitive skills. It allows academic scholars to examine various research questions, also across different subpopulations (e.g., low-skilled persons, couples, or persons with different employment conditions). Correlates of cognitive skills measured by PIAAC-L include, for example, health, personality, income, family background, further education, and employment history. Several sociological topics that emerge in the context of today's societal challenges could be explored with PIAAC-L data. Section 6 presents three such topics: (a) monitoring the match between workers' skills and workplace skill requirements to identify *skill mismatch* in the modern labor market; (b) *lifelong learning* as a key element in responding to aging societies and rapid environmental changes and monitoring effects of training on skills maintenance

² PIAAC: www.gesis.org/piaac/piaac-home/; NEPS: www.neps-data.de/; SOEP: www.diw.de/en/soep.

and development; and (c) *family-related issues* such as gender equality, assortative mating, and within-couple comparisons of cognitive skills.

This paper elaborates on key aspects of the study and presents the PIAAC-L data as a resource for research in the social sciences in general, and in educational research in particular. It is structured as follows: Section 2 summarizes the design, sampling, data collection, and data quality of PIAAC-L. The survey instruments used in the study are described in Section 3. Section 4 deals with the employed data anonymization and documentation procedures. Section 5 provides details of the data files and the conditions of access to the PIAAC-L scientific use file (SUF). Finally, Section 6 outlines the analytical potential, strengths, and limitations of the study.

2 Design, sampling, data collection, nonresponse, and weighting

2.1 The PIAAC-L design

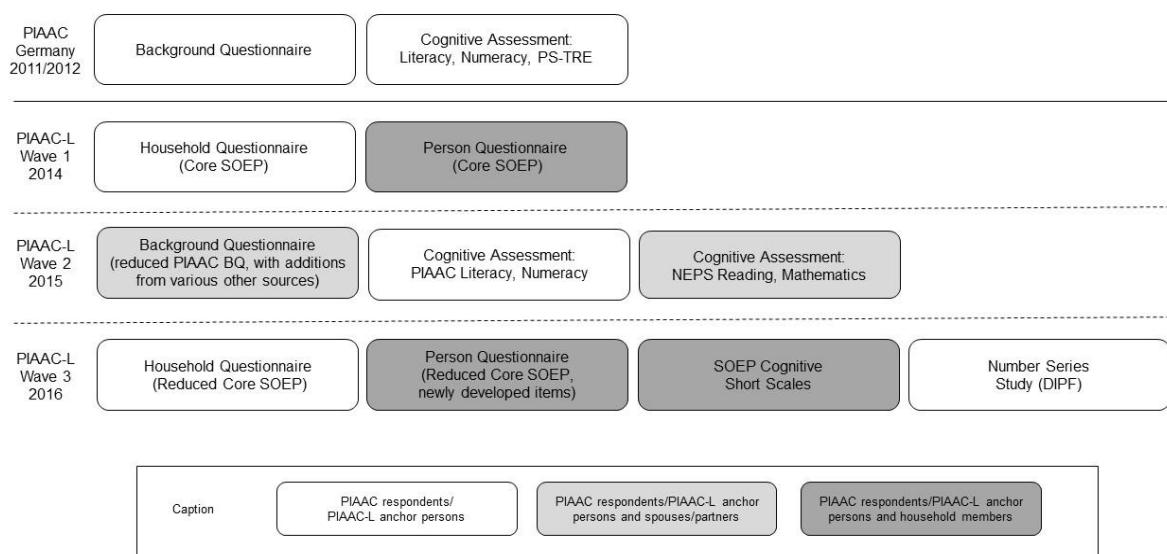
PIAAC-L was not a classical longitudinal study designed from scratch. Rather, it re-used an existing sample for scientific purposes and combined content and methodological expertise from PIAAC, NEPS, and the SOEP. German PIAAC respondents who agreed to be re-contacted for a PIAAC-related follow-up study were the *central survey units*. They are referred to as *anchor persons* and were re-interviewed over three annual waves of data collection (2014, 2015, 2016). The key design features of PIAAC-L were as follows (see also Figure 1):

1. Collection of background information of considerable depth and breadth on the anchor person (in all three waves) and of context information from interviews with household members aged 18 years and older (in Waves 1 and 3; adaptation of the SOEP design).³
2. Measurement of certain background variables using (different) operationalizations for the same constructs (in all three waves).
3. Repeated assessment of the anchor persons' cognitive skills using PIAAC instruments for measuring literacy and numeracy and/or NEPS instruments for measuring reading competence and mathematical competence (Wave 2).
4. Provision of a basis for linking cognitive assessments in international and national education surveys using the PIAAC and NEPS instruments (Wave 2).
5. Collection of background information on partnerships by interviewing anchor persons' spouses/partners. Assessment of reading and mathematical competences of spouses/partners using NEPS instruments (Wave 2).
6. Assessment of general intellectual ability with short general cognitive tests used in the SOEP (anchor persons, household members) and assessment of numeri-

³ In contrast to the SOEP, a household's eligibility depended exclusively on the anchor person's participation.

cal reasoning skills with a set of number series tasks (only anchor persons; Wave 3).

Figure 1: PIAAC-L design by waves, instruments, and respondent types



Note. BQ = background questionnaire. DIPF = German Institute for International Educational Research. PS-TRE = problem solving in technology-rich environments.

2.2 Sampling

Given the PIAAC-L design, the selection of anchor persons had taken place beforehand for PIAAC. In accordance with the international PIAAC sample design standards, each PIAAC-participating country selected a probability-based sample of adults aged 16 to 65 years who were resident in the country and living in private households (OECD 2013). The sample size requirement was a minimum of 5,000 completed cases. Germany implemented a registry-based, two-stage stratified and clustered sampling design (Zabal et al. 2014). The first stage involved a random selection of municipalities with a probability proportional to their size. At the second stage, the local registry offices in the selected municipalities randomly sampled persons from the target population. The German gross sample consisted of 10,240 persons. Data collection took place between August 2011 and March 2012. The achieved response rate, computed according to international PIAAC specifications, was 55%, resulting in a net sample of 5,465 cases (OECD 2013). A total of 5,320 persons completed a full PIAAC interview and were asked for their consent to be re-contacted for a follow-up survey. In total, 5,225 of these PIAAC respondents agreed to be re-contacted and were followed up as anchor persons in the first PIAAC-L wave in 2014.

2.3 Fieldwork, completed cases, and retention rates

In the three waves of interviewer-administered data collection, PIAAC-L implemented many of the fieldwork standards and measures from PIAAC (Zabal et al. 2014), supplemented with best practices from the SOEP and NEPS. As the survey organization (TNS Infratest) did not change between PIAAC and PIAAC-L, many interviewers who had already carried out PIAAC were recruited for data collection in PIAAC-L (in Wave 1: 84% of the PIAAC interviewers). In-person interviewer trainings prepared the interviewers for their work in PIAAC-L. Advance letters were sent to the anchor persons to announce the interviewer’s visit. Anchor persons and their household members received monetary incentives for their participation. As in PIAAC, the monetary incentive offered upon completion of the (quite long) Wave 2 interview with the PIAAC and/or NEPS cognitive assessment, was higher than for the other face-to-face interviews. The interviewers’ work was thoroughly monitored and validated. Table 1 summarizes key facts about the three PIAAC-L waves (and PIAAC).

As mentioned above, 5,225 respondents from the PIAAC net sample ($n = 5,465$) were eligible and followed-up in PIAAC-L. Figure 2 shows the number of completed interviews per wave for anchor persons, spouses/partners, and other household members. Table 2 summarizes simple fieldwork retention rates, which were computed for each wave by dividing completed cases by the gross sample.

Figure 2: Number of completed cases per wave

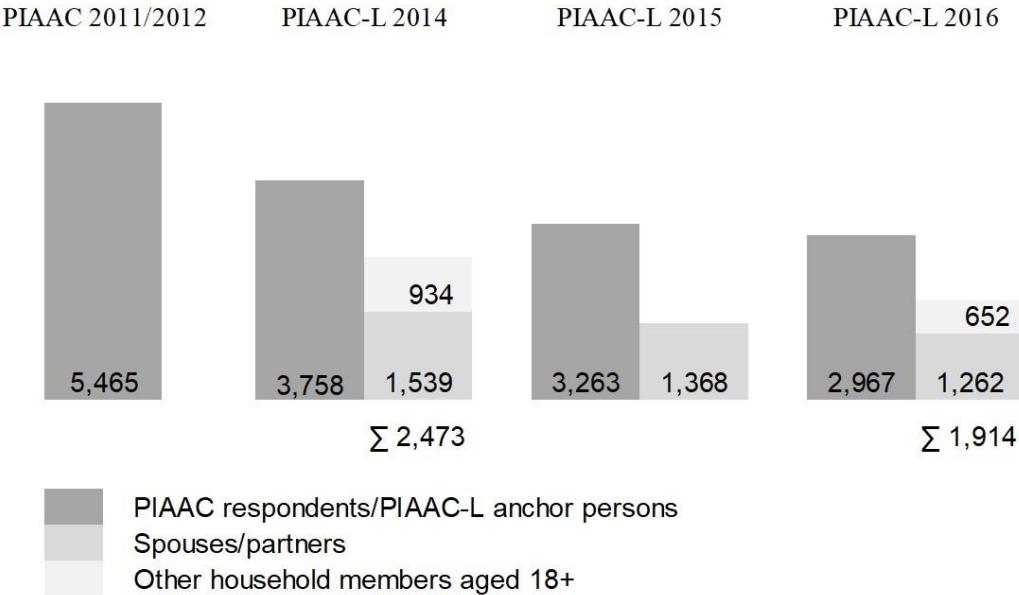


Table 1: Key facts about PIAAC and PIAAC-L

Key Facts	PIAAC	PIAAC-L Wave 1	PIAAC-L Wave 2	PIAAC-L Wave 3
Design	F2F, BQ (CAPI) and cognitive assessment (default CBA, PBA option, self-administered, untimed)	F2F, SOEP core household and person questionnaires (CAPI)	F2F, background questionnaire (CAPI) and cognitive assessment: PIAAC (default CBA, PBA option, self-administered, untimed) NEPS (PBA; self-administered, timed)	F2F, SOEP core household and person questionnaires plus extensions (CAPI) SOEP cognitive short scale (CBA, interviewer- and self-administered) Number Series Study (CBA, self-administered)
Target persons	Age 16–65 years, in private HHS	Anchor persons and their HH members aged 18+ years	Anchor persons and their spouses/partners in same HH	Anchor persons and their HH members 18+ years
Survey organization	TNS Infratest ^a	TNS Infratest ^a	TNS Infratest ^a	TNS Infratest ^a
Data collection period	08/2011–03/2012	02–08/2014	03–09/2015	03–07/2016
No. of interviewers	129	138	117	117
Interviewer training	Five-day in-person training	Half-day in-person training for interviewers without PIAAC experience	Three-day in-person training	Half-day in-person training
Interview duration (approx. Ø, in min.)	BQ (40), cognitive skills assessment (60)	HH interview (15); person interview (45)	Person interview (90–100)	HH interview (10); person interview (45)
Fieldwork measures	Comprehensive measures, incl. advance mailing, information material; targeted refusal conversion; address search	Advance letter, basic refusal conversion (particular focus on gaining the cooperation of anchor persons)		
Monetary incentive (postpaid)	€50	€25 (HH + anchor person interview); €10 (HH person interview)	€40	€30 (HH + anchor person interview); €20 (HH person interview)

Monitoring and Implementation of international quality control standards^b international quality control and data adjudication; National in-depth monitoring of fieldwork, incl. interviewers' performance, quality control back-checks, review of survey data; Benchmarking to Microcensus data

General monitoring of fieldwork incl. interviewers' performance, quality control back-checks, review of survey data, longitudinal consistency checks

Note: ^a = Name changed to Kantar Public in 2016. ^b = Technical Standards and Guidelines (OECD 2014). BQ = background questionnaire. CAPI = computer-assisted personal interview. CBA = computer-based assessment. F2F = face-to-face. HH = household. min = minutes. PBA = paper-based assessment.

Overall, 3,758 anchor persons participated in Wave 1, which represented an unadjusted participation rate of 69% compared with the original PIAAC net sample of 5,465 respondents, or 72% compared with the PIAAC respondents who agreed to be re-contacted for a follow-up survey ($n = 5,225$). The number of participating anchor persons decreased over Waves 2 and 3, leaving 54% of the PIAAC net sample in Wave 3. The decrease in the number of participating household members from Wave 1 to Wave 3 was due mainly to anchor persons dropping out of the study.

The loss of anchor persons was highest in Wave 1 after the transition from PIAAC to PIAAC-L. From a PIAAC respondent's perspective, PIAAC-L was a new survey under different conditions, and the period between PIAAC and the PIAAC-L Wave 1 was longer than between each of the PIAAC-L waves. Simple fieldwork retention rates in Waves 2 and 3 reached values above 84%. Retention rates for spouses/partners were stable at around 65%, but were lower for other household members, at around 50% (Martin et al. 2018; Zabal et al. 2016, 2017).

Table 2: PIAAC-L fieldwork retention rates per wave

Survey Units	PIAAC-L Wave 1			PIAAC-L Wave 2			PIAAC-L Wave 3		
	Gross	Net	%	Gross	Net	%	Gross	Net	%
Anchor persons	5,225	3,758	71.9	3,758	3,263	86.8	3,510	2,967	84.5
Spouses/partners	2,371	1,539	64.9	2,103	1,368	65.0	1,954	1,262	64.6
Other household members aged 18+	1,843	934	50.7	n/a	n/a	n/a	1,210	652	53.9

Note: A non-monotonic design in Wave 3 allowed to re-contact some anchor persons who were temporary non-participants in Wave 2. n/a = not applicable.

2.4 Nonresponse, bias, and weighting

Attrition is a common concern for every panel survey (e.g., Roßmann/Gummer 2016), and PIAAC-L was affected by the loss of anchor persons. For the German PIAAC sample (baseline for the PIAAC-L anchor person sample), nonresponse bias analyses showed a low bias in the outcome statistics for age, citizenship, and educational attainment (Helmschrott/Martin 2014; Zabal et al. 2014). The number of participating anchor persons further decreased over the three waves of PIAAC-L. Martin et al. (2021) showed that PIAAC respondents with low literacy skills had a higher probability of refusal in PIAAC-L Wave 1 than did respondents with high literacy skills. Comparisons of distributions from PIAAC-L with benchmark data from the German Microcensus showed bias for age (e.g., overrepresentation of persons younger than 25 years) and educational attainment (e.g., under-representation of persons with a low level of education). Table A1 in the Appendix summarizes related results.

Weights were produced in each wave to address selectivity from attrition. Separate technical weighting reports documenting the weighting activities in detail are available (Bartsch et al. 2017; Burkhardt/Bartsch 2017; Burkhardt et al. 2018). The following brief information is drawn from these reports.

Because only the anchor persons had participated in PIAAC, final PIAAC weights were available only for anchor persons and served as base weights in PIAAC-L. In PIAAC-L, no sampling took place to select other household members. Therefore, no selection probabilities and no base weights could be calculated for these persons. Thus, PIAAC-L provides weights only for anchor persons.

Nonresponse and poststratification weighting factors were computed for each wave. First, nonresponse weighting factors were derived from the inverse of the product of the staying probabilities obtained from separate logistic regression models. In all waves, at least two models were used to adjust for noncontact and nonresponse. Wave 1 also included two other models to adjust for different nonresponse causes during the transition from PIAAC to PIAAC-L. In Wave 1, explanatory variables were derived from PIAAC; in Waves 2 and 3, they were derived from the previous waves.

Second, the nonresponse weighting factor of the current wave was combined with the cross-sectional weight of the previous wave. Third, some key variables (sex, age, education, region, household size, municipality size) were benchmarked to Microcensus data using poststratification and raking procedures. This calibration step resulted in poststratification factors.

For cross-sectional analyses with anchor person data in 2014, 2015, or 2016, the corresponding poststratification weighting factors (variables `hrf_14`, `hrf_15`, and `hrf_16`) should be used. For longitudinal analyses, the nonresponse weighting factors (variables `bleib_14`, `bleib_15`, and `bleib_16`) should be used. Table 3 shows how to combine the weighting factors for different longitudinal analyses (GESIS – Leibniz Institute for the Social Sciences et al. 2017a).

Table 3: Multiplicative combination of weighting factors for longitudinal analyses

Analysis with data from ...	PIAAC weighting factor	PIAAC-L nonresponse weighting factors			PIAAC-L poststratification weighting factors	
	SPFWT0	bleib_14	bleib_15	bleib_16	hrf_14	hrf_15
(1) PIAAC & PIAAC-L 2014	x	x				
(2) PIAAC & PIAAC-L 2015 or PIAAC & PIAAC-L 2014/2015	x	x	x			
(3) PIAAC & PIAAC-L 2016 or PIAAC & PIAAC-L 2014/2016 or PIAAC & PIAAC-L 2015/2016 or PIAAC & PIAAC-L 2014/2015/2016	x	x	x	x		
(4) PIAAC-L 2014/2015			x		x	
(5) PIAAC-L 2014/2016 or PIAAC-L 2014/2015/2016			x	x	x	
(6) PIAAC-L 2015/2016				x		x

Note: SPFWT0, bleib_14, bleib_15, bleib_16, hrf_14, and hrf_15 are variable names of the weighting factors in the PIAAC and PIAAC-L SUFs. The numbers 14, 15, and 16 in the variable names refer to the corresponding PIAAC-L wave.

3 Measurement instruments

3.1 Background information

The three waves of PIAAC-L collected varied and rich background information. Table 4 summarizes the main constructs and central information collected for the anchor person.⁴ The core PIAAC content is included as reference in the first column.

Wave 1 was dedicated to obtaining background information in a way similar to the SOEP but with minor adjustments (Zabal et al. 2016). The focus was on collecting information of greater depth and breadth on the anchor persons and their households—first and foremost detailed information on work and income, a differentiated measurement of education within the national framework, and background information on the household constellation and resources. Key sources for the per-

⁴ Other eligible adults living in the anchor person's household (Waves 1 and 3: adult household members; Wave 2: spouses/partners) were administered similar but somewhat adapted person questionnaires.

son questionnaires in Wave 1 were the 2014 SOEP core biography and individual questionnaires (DIW Berlin/SOEP 2014b, 2014c).

Because the PIAAC cognitive assessment was re-administered in Wave 2, the background questionnaire for that wave replicated key questions from PIAAC to allow for a direct comparison with the PIAAC data (Zabal et al. 2017). A wide variety of other methodologically interesting elements were added. For example, the NEPS skills use module was implemented as an alternative to the module used in PIAAC. Also, a self-assessment of literacy and numeracy was included.

Wave 3 was similar to Wave 1 (Martin et al. 2018), with a (shortened) version of the SOEP-based person and biography questionnaires from 2015 (DIW Berlin/SOEP 2015b, 2015c). The person questionnaire was enhanced with additional new questions and modules and included questions from earlier SOEP instruments (DIW Berlin/SOEP 2014b, 2014c),⁵ from the Adult Education Survey 2010,⁶ and from PIAAC. The PIAAC Leibniz Network (PIAAC LN)⁷ developed questions on adult education and training, job changes, and skill mismatch, which were tested in the person questionnaire administered in Wave 3. Wherever possible, item selection and development for the questionnaires focused on constructs and indicators relevant in the context of the key cognitive skills assessed.

Some constructs were measured repeatedly to ensure that the most up-to-date information was available. For example, each wave included an update on education to obtain data on new qualifications and on more recent continuing education and training activities. The same holds for recent critical life events. Some constructs, such as education, work, and income, were measured somewhat differently in the PIAAC-based waves (PIAAC and Wave 2) than in the SOEP-based waves (Waves 1 and 3), thus providing opportunities for methodological research.

Detailed information on the questionnaire content is available in the PIAAC-L questionnaires and codebooks, which provide a comprehensive list of all questions and variables (published on the PIAAC Research Data Center website).⁸

⁵ SOEP 2008: https://www.diw.de/documents/dokumentenarchiv/17/diw_01.c.85359.de/personen_2008.pdf.

⁶ <https://dbk.gesis.org/dbksearch/SDesc2.asp?DB=D&no=5074&tab=3&dab=1&dac=4>.

⁷ <https://www.gesis.org/en/piaac/projects/piaac-leibniz-network>.

⁸ <https://www.gesis.org/en/piaac/rdc/data/piaac-longitudinal>.

Table 4: Overview of main constructs and central background variables measured in PIAAC and PIAAC-L (for anchor persons)

PIAAC	PIAAC-L Wave 1	PIAAC-L Wave 2	PIAAC-L Wave 3
General Information	General Information	General Information	General Information
Year and country of birth, citizenship, immigration	Year and country of birth, citizenship, immigration	Citizenship Life events, update	Update life events and household Kindergarten
Household size	Living and household situation	Friends	
Number of books at home (at age 16)	Life events Childhood (e.g., home situation, school grades)	Household possessions, number of books at home (at age 16/today)	
Family	Family	Family	Family
Children (e.g., number, age)	Marital/civil status, relationships Siblings (e.g., number, year of birth, sex) Children (e.g., number, year of birth, sex)	Relationships, distribution of tasks, and activities with spouse/partner Update children	Update current situation
Parental information	Parental information		
Country of birth	Year and country of birth, death, citizenship		
Education and occupation	Education and occupation		
	Biographical calendar (15–65y): Education and employment		

Education, detailed

Formal education (highest school and professional qualification)

Current formal education

Continuing education and training

Work, detailed

Employment status

Current/last occupation and industry

Job search

Current/last job (e.g., company size, contract, working hours)

Years paid work, number of employers (past 5 years)

Income

Earnings

Education, detailed

Formal education (general and vocational education), qualifications

Current education

Continuing vocational education and training

Work, detailed

Employment status

Current/first/last occupation and industry

Job changes

Sector, company size

Contract conditions, working hours

Income and benefits (current/last year), detailed

Earnings, bonuses, benefits, income sources

Time use on typical weekday (current)**Education**

Formal education (highest school and professional qualification)

Current formal education

Work

Employment status

Current (or in last year) occupation and industry

Looking for work

Income

Earnings

Household income

Leisure activities**Education**

Update formal education and current education

Extended module on continuing education and training: continuing vocational; continuing general; future interest; informal learning

Work status and situation, update

Extended job changes

Update income and benefits**Time use on typical weekday and weekend (current)**

Health General health	Health SOEP SF-12 short version Physical measures, disability, doctor/hospital visits, behavior (e.g., smoking)	Health SOEP SF-12 short version Behavior (e.g., alcohol consumption, exercise)	Health General health, doctor visits Sleep
Attitudes Learning strategies Political efficacy, social trust Cultural engagement	Well-being, personality, attitudes Life satisfaction, satisfaction with life domains Big Five, locus of control, risk propensity, trust, grit Attitude to lifelong learning Political inclination, voting	Well-being Life satisfaction, satisfaction with life domains	Well-being, personality Life satisfaction, satisfaction with life domains Big Five, locus of control
Languages Mother tongue	Cultural identity Attachment to country of origin, identification as German	Languages Mother tongue Foreign languages, incl. level of proficiency in German for non-native speakers	Cultural identity Attachment to country of origin, identification as German Identification with country of origin (migrants); identification with German culture (non-migrants)
Skill mismatch		Self-assessed literacy and numeracy module	Short self-assessed literacy and mathematical skills; skill mismatch

Skill use at work and in everyday life

Time use, problem solving
Literacy and numeracy
ICT/computer use

Skill use at work, job characteristics

Literacy and numeracy
Autonomy, routine, physical exertion
Computer use at work/in everyday life, computer activities

Note. PIAAC-L technical reports provide in-depth information on the constructs and items and their sources (Martin et al. 2018; Zabal et al. 2016, 2017); codebooks document the data (available at <https://www.gesis.org/en/piaac/rdc/data/piaac-longitudinal>).

3.2 Information on the household

In addition to the information obtained on the anchor person (Table 4), detailed information on the anchor person's household was obtained in Waves 1 and 3 based on the current SOEP household questionnaires (DIW Berlin/SOEP 2014a, 2015a). The household questionnaires were administered in each household, preferably to the anchor person. Figure 3 summarizes the major areas covered by these questionnaires.

Figure 3: Main areas of information collected at household level

- Residential/living conditions
 - Type of dwelling, size, number of rooms
 - Amenities and facilities
- Condition of housing unit (modernization/renovation)
 - Neighborhood characteristics and infrastructure
 - Time period in current residence
 - Ownership/tenancy or rental, costs (including costs for specific utilities, maintenance, etc.)
- Household income and wealth
 - Household income and detailed sources
 - Social benefits and other state assistance (e.g., child benefit)
 - Savings
 - Loans
- Household members
 - Children (e.g., ages, school attendance, childcare incl. related costs, extra-curricular activities)
 - Other household members, including persons in need of help/care

3.3 Cognitive assessments

The measurement of cognitive skills was one of the central goals of PIAAC-L. Table 5 summarizes the cognitive skills that were measured in PIAAC and in Waves 2 and 3. Wave 2 in 2015 included a comprehensive cognitive assessment using established instruments from PIAAC and NEPS (Zabal et al. 2017). The assessment was administered in the same way as in the original survey. Respondents worked on the cognitive items in a self-administration mode.

Respondents who worked on PIAAC items could spend as much time as they wanted on the tasks. The assessment was administered in a computer-based mode by default. Optional paper-based instruments were available to respondents who lacked computer experience. The NEPS assessments were timed (limitation of 2 minutes for reading speed and 28 minutes for the reading or mathematics block) and were offered only in a paper-based mode. For anchor persons, a complex ran-

domized assessment design with eight conditions was implemented.⁹ Some anchor persons worked only on PIAAC items, some only on NEPS items, and others on a combination of PIAAC and NEPS items (Figure 4).

Table 5: Overview of cognitive skills measured in PIAAC and PIAAC-L

PIAAC	PIAAC-L Wave 2	PIAAC-L Wave 3
Literacy, components	PIAAC literacy	SOEP short scales
Numeracy	PIAAC numeracy	
Problem solving in technology-rich environments	NEPS reading speed	DIPF number series tasks
	NEPS reading competence	
	NEPS mathematical competence	

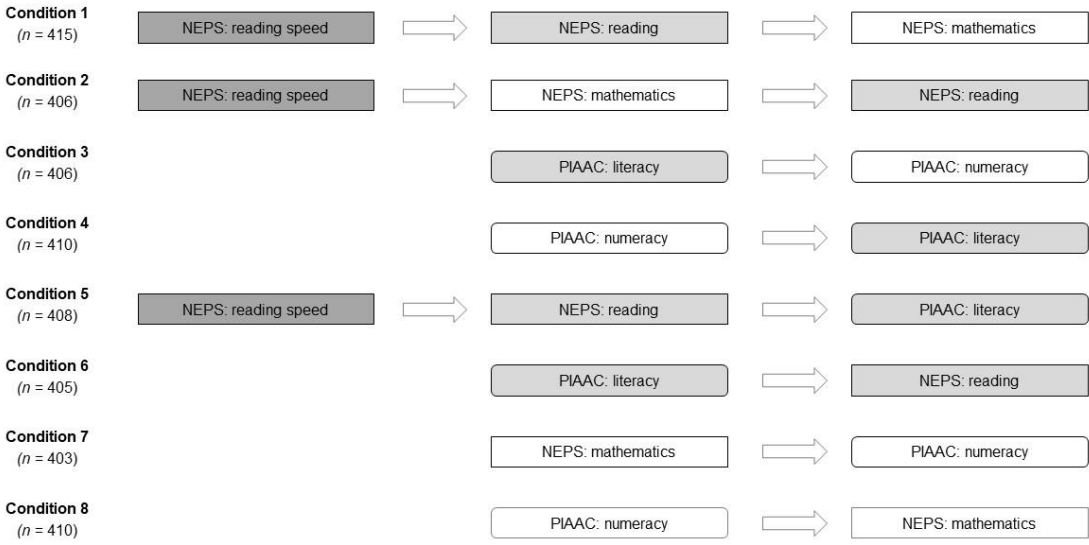
Note: DIPF = German Institute for International Educational Research

PIAAC and NEPS measure similar cognitive domains. Literacy (PIAAC) and reading competence (NEPS) focus on reading and understanding written texts in everyday situations. This is regarded as a foundation skill for lifelong learning and participation in society. Because of the computer-based administration of the cognitive assessment in PIAAC, the conceptual framework and measurement instrument for literacy could include digital reading, an important and necessary extension to the literacy concept. For detailed information on the PIAAC literacy framework and the framework for assessing reading competence in NEPS, see Jones et al. (2009) and Gehrler et al. (2013), respectively.

The PIAAC concept of numeracy and the NEPS concept of mathematical competence are both centered on using mathematical information in typical situations encountered by adults in everyday life. Although the conceptual frameworks and measurement instruments are similar, they are somewhat less closely related than in the case of literacy and reading competence (for detailed information on the frameworks, see Ehmke et al. 2009 and Gal et al. 2009, respectively).

⁹The assessment design for spouses/partners included only two conditions with NEPS instruments. About half of the spouses/partners received first reading and then mathematics; for the other half, the order was reversed.

Figure 4: Assessment design (anchor persons)



In Wave 3, two short scales assessing general intellectual ability and a vocabulary test were administered: an *animal naming task* measuring word fluency, a *symbol-digit test* measuring perceptual speed, and a *multiple-choice vocabulary intelligence test* (Richter et al. 2017). The animal naming task and the symbol-digit test were designed to take 90 seconds on average, and the multiple-choice vocabulary intelligence test 5 minutes on average. These three tests had previously been implemented in the SOEP. A subgroup of anchor persons ($n = 910$) also completed a set of number series tasks assessing numerical reasoning, which is a measure of general cognitive ability.¹⁰ These tasks were administered within the framework of the Number Series Study, an add-on module to PIAAC-L under the responsibility of the German Institute for International Educational Research (DIPF; Engelhardt/Goldhammer 2018).

4 Data anonymization and documentation

An elaborate data confidentiality strategy was developed for PIAAC-L. It was based on the approach implemented for the German PIAAC SUF, with some important adaptations due to the particularities of the PIAAC-L design, such as accounting for the longitudinal approach or the extension to the household level (Zabal et al. 2016). The PIAAC-L confidentiality strategy also considered the different approaches to data privacy of the three institutes involved in PIAAC-L. The variables in every data set were screened, and the risk assessment was discussed among the

¹⁰ All anchor persons who had worked on both PIAAC literacy and numeracy items (computer-based) were included. To increase the sample size, some anchor persons who had worked on only one PIAAC domain (computer-based items) were also selected for participation in the Number Series Study.

three institutes. Data protection officers were consulted in the case of key or difficult decisions. In general, disclosure risk was weighed against the scientific benefits. Variables that were regarded as risky with respect to potential re-identification of participants were suppressed or coarsened. For example, in the SUF, regional information was restricted, information such as the interview date and month of birth was suppressed, and country and language information were coarsened (variable suppressions and coarsening are documented in the codebooks). Another element of the confidentiality strategy was the development of a data usage contract specifically for the PIAAC-L data (data usage agreement, see Section 5).

Technical reports (in English) provide information on the methodology, design, and implementation of PIAAC-L and on weighting (Bartsch et al. 2017; Burkhardt/Bartsch 2017; Burkhardt et al. 2018; Martin et al. 2018; Zabal et al. 2016, 2017). Fieldwork reports (in German) by the survey organization provide details of the data collection for each wave (Steinacker et al. 2016; Steinacker/Wolfert 2017; Steinacker et al. 2017). Users can download person and household questionnaires (in German) and codebooks for all data files (in English) from the PIAAC Research Data Center website.¹¹

5 PIAAC-L SUF and data access

The PIAAC-L SUF combines data from three waves and for different survey units (households, persons). It consists of 12 separate data files: three for Wave 1 (_14), two for Wave 2 (_15), five for Wave 3 (_16), and two “cross-wave” data files (*Calendar* and *Registry*). Table A2 in the Appendix gives an overview of the data files and informs about units and contents.

Cognitive assessment data are spread across several data files. In Wave 1, the cognitive assessment data from PIAAC for literacy, numeracy, and problem solving in technology-rich environments were re-scaled using background data from PIAAC and the newly collected background information from Wave 1. The data file *Persons_14* contains 10 re-scaled plausible values (PVs) for each of these PIAAC domains.

The data file *Persons_15* has four different sets of cognitive assessment data. Based on the PIAAC cognitive assessment data, 10 PVs for literacy and 10 PVs for numeracy were scaled longitudinally with background data from PIAAC and data from Waves 1 and 2 of PIAAC-L. Based on the Wave 2 cognitive assessment using PIAAC instruments, 10 PVs for literacy and 10 PVs for numeracy were scaled longitudinally with background data from PIAAC and data from Waves 1 and 2 of PIAAC-L. Weighted maximum likelihood estimates are available for NEPS reading and mathematical competence and are based on the Wave 2 cognitive assessment using NEPS instruments. Also, weighted maximum likelihood estimates for PIAAC literacy and numeracy were estimated. The document *Notes to the User* provides information on

¹¹ <https://www.gesis.org/en/piaac/rdc>.

scaling, PVs, and weighted maximum likelihood estimates in PIAAC-L (GESIS – Leibniz Institute for the Social Sciences et al. 2017a). Data from the short scales assessing cognitive abilities, which were administered in Wave 3 (2016), are stored in the file *Cognit_16*, and data from the Number Series Study are available in the file *NumberSeries_16*.

The files *Calendar* and *Registry* are incremental and combine data from different points in time. The *Calendar* file contains spell data from biographical calendars collected in 2014 and 2016. Respondents reported their activity status (e.g., at school, undergoing vocational training, employed) for each year of age between 15 and 65. The *Registry* file contains sociodemographic information (e.g., sex, year of birth) and general information on the survey history of the respondents (e.g., status in each wave, relationship to the anchor person). The file combines data for all persons who were ever registered for PIAAC-L. Each row in the file represents one person, nested in an anchor-person household. The file is the main source to be used for merging data from different files.

Besides the PVs released in the PIAAC-L SUF, researchers can independently estimate PVs specific to their research question using the open access R package PVPIAACL developed by LIfBi.¹² Users can select a set of research-related PIAAC-L context variables and include them in the built-in population model.

The PIAAC-L SUF is available in SPSS and Stata format for academic research only, subject to signing a data usage agreement (GESIS – Leibniz Institute for the Social Sciences et al. 2017b). The German PIAAC SUF (Rammstedt/Martin et al. 2016) is automatically provided along with the PIAAC-L data. The PIAAC-L data usage agreement covers both data sets.

Although there is no campus file version of the PIAAC-L data for university training purposes, the anonymized and reduced version of the German PIAAC public use file (PUF) may be a useful resource for such purposes. Tools for analyzing PIAAC data that take account of the complex design and replicate weights (for variance estimation)—for example, the web-based International Data Explorer (IDE) and the International Database (IDB) Analyzer—are available and do not require high levels of statistical knowledge. The German PIAAC PUF (and the PUFs of other countries) and information on the IDE and IDB are available from the OECD website.¹³ A textbook with a focus on the analysis of PIAAC(-L) data can provide support to researchers and students with different levels of expertise (Maehler/Rammstedt 2020).

¹² <https://github.com/jcgaasch/PVPIAACL>.

¹³ <https://www.oecd.org/skills/piaac/data/>.

6 Analytical potential, strengths, and limitations

6.1 Analytical potential

The PIAAC-L data contain information that allows the investigation of current societal issues, including research on topics such as social inequality, skill mismatch, economic returns to education, family-related issues, participation in further education, and the relationship between health and cognitive skills. To date, researchers from different disciplines have used these data to address a variety of research questions (Maehler et al. 2020). For example, some recent publications based on PIAAC-L data have investigated the influence of job-related training on skill development (Reder et al. 2020), the relationship between cognitive skills and personality (e.g., Rammstedt/Danner et al. 2016), and methodological topics (Gauly et al. 2020; Martin et al. 2021). The large sample size allows researchers to study different subpopulations, for example, persons with low literacy levels, couples, or persons with different employment conditions. Below, we present three selected research topics that could be addressed with the PIAAC-L data and may be of interest for sociologists: skill mismatch, lifelong learning, and family-related issues.

Skill mismatch is one challenge of modern labor markets (Heisig/Solga 2015). In recent years, the relationship between individual worker skills and workplace skill requirements across country systems (e.g., in terms of stratified educational systems) and groups (e.g., low-skilled or immigrant workers) has been widely discussed in the scientific community. The focus has been on the measurement (subjective self-rated measures vs. objective test-based measures) of skill mismatch and on the resulting policy implications (e.g., Flisi et al. 2017; Pellizzari/Fichen 2017; Perry et al. 2014; van der Velden/Bijlsma 2019). PIAAC-L has expanded the indicators used to measure and investigate skill (mis)match. It thus allows researchers to use different methods (e.g., the realized matches approach or the job analysis method), examine different outcomes (e.g., wage differences, job satisfaction), and analyze cohort effects (e.g., whether older cohorts are at higher risk of being mismatched).

Digitalization and automation have led to rapid changes in work contexts. At the same time, the life span of active adults is getting longer. Jobs may change or disappear as some job tasks are automated. As a result, the skills acquired through initial education and training may no longer be sufficient to remain employable and participate in society (Autor 2015). Against this background, research has focused on the determinants and structures of *lifelong learning*. Lifelong learning is seen as a key factor in maintaining and developing skills to meet the changing demands in today's societies. There seems to be a consensus in the literature that further training opportunities are unequally distributed, with higher participation opportunities for those who have already attained higher initial education and training (e.g., Blossfeld et al. 2014; Ehlert 2020). Recent analyses have further revealed that the comparability of statistics on participation in adult education and training (AET) in the literature is limited, and that the measurement of participation in AET in existing large-scale sur-

veys varies considerably (Widany et al. 2019). As PIAAC-L used measurement instruments from various surveys in this area, its data can be used to better understand findings from cross-national comparative research. PIAAC-L also focused on measuring informal learning, which allows researchers to explore the role of these activities in labor market participation. Besides capturing individual factors (e.g., motivation to learn) and household context information, the PIAAC-L data also provide information on skills and job requirements as central contextual information for further education and training.

PIAAC-L also offers a range of background information at the individual and household level that can be used to examine *family-related issues*. In recent decades, changes in family structure and gender roles have been widely discussed in the sociology of the family (Naldini 2017). The impact of these changes has been studied with different approaches, focusing, for example, on work-family balance (due to changes in family models and the increase in the number of women in paid work) or mechanisms of partner selection. Furthermore, the implications of the reversal of the gender gap in education for the composition of marriage markets, assortative mating, gender equality, and marital outcomes have also been a focus of research in the sociology of the family (e.g., Blossfeld/Timm 2003; Esteve et al. 2016). As PIAAC-L also assessed the cognitive skills of the spouses/partners of anchor persons, these data provide an innovative level of comparison. Together with the background information collected on the current employment and the employment history of anchor persons and their spouses/partners, and the information on their households, an in-depth exploration of these issues is possible.

6.2 Strengths and limitations

In PIAAC-L, PIAAC instruments were used to re-assess literacy and numeracy, and the assessment design was set up in the same way as in PIAAC. As PIAAC-L is the only PIAAC follow-up study to have conducted such a re-assessment, this link to the international comparative PIAAC study is a unique feature of PIAAC-L. PIAAC-L provides researchers with an opportunity to go beyond the findings from analyses with German PIAAC data and to investigate in more depth the development, maintenance, or loss of cognitive skills over time by including additional explanatory factors. In the absence of a repeated cognitive assessment in other PIAAC-participating countries, some researchers use synthetic cohorts as an alternative to repeated measurements for trend analyses at the population level (e.g., Desjardins 2019; Flisi et al. 2019). However, this approach is viewed critically, especially due to the differences in survey design and methodology (e.g., Vézina/Bélanger 2020).

Another strength of PIAAC-L is the link between PIAAC and NEPS. A significant proportion of anchor persons completed both PIAAC and NEPS instruments (under the same test conditions; see Figure 4 above). The conceptual definition of

the cognitive skills from both studies overlap at least to a certain extent (for a brief description of the conceptualizations, see Table A3 in the Appendix). Empirically, PIAAC literacy and NEPS reading competence and PIAAC numeracy and NEPS mathematical competence are highly correlated ($r = .87$; $r = .90$, respectively; Carstensen et al. 2017: 13). Thus, PIAAC-L has been and continues to be a resource that links international and national educational research focusing on the adult population.

PIAAC-L also has certain limitations. Like many other surveys in the social sciences, it was affected by bias over time due to the attrition of persons with specific characteristics (e.g., persons with lower levels of education). Hence, analyses with the data require the use of weighting factors. Moreover, the study did not follow a traditional panel design but rather combined design features and integrated instruments from three large-scale surveys in Germany, each with a different focus. On the one hand, this construction introduced the desired variety of content; on the other hand, it hampered the continuous measurement of data across waves.

Although PIAAC-L data offer many analytical opportunities, their complex structure with several data files and different survey units can make them difficult to process. Longitudinal analyses and the use of multiple imputed PVs require a high level of analytical skills. Moreover, in Wave 3, it was not possible to estimate PVs with a model that included all background data collected over the three waves because the number of variables exceeded the maximum value that could be processed in the background model. This limitation in the scaling procedure can be resolved post hoc. Researchers can estimate their own PVs adapted to specific research questions (using the R tool PVPIAACL). However, this approach requires some psychometric knowledge and programming skills in the statistical software package R. A high level of psychometric knowledge is also necessary to investigate methodological research questions, including scale-equivalence testing between the NEPS and PIAAC assessment instruments. In general, data users may find it useful to familiarize themselves with the data and their structure by consulting the data documentation and technical reports. Attending data analysis workshops to learn how to handle the data correctly may be helpful for data users without experience in analyzing longitudinal data with a complex design.

The re-assessment of cognitive skills is an added value of PIAAC-L, but there were only two measurement points for literacy and numeracy over a three-year period (in 2011/2012 and 2015). As a result, long-term effects on the development, loss, and maintenance of cognitive skills over the life span cannot be investigated. However, no other large-scale longitudinal assessment study in Germany currently offers more information on adult literacy and numeracy skills. The NEPS adult cohort (NEPS-SC6) may be a promising candidate for future research in this area. However, to date (Wave 11, 2018/19), each of the two NEPS-SC6 subsamples (initial and

refreshment sample) have also been re-assessed only once in reading and mathematical competence (Fuß et al. 2016: 7; Wicht et al. 2021).

The present contribution provides researchers with an overview of the broad information available in the PIAAC-L data and offers some insights into the analytical potential of the PIAAC-L data, which has not yet been fully exploited. We hope researchers will be motivated to use this data source for their scientific work.

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Appendix

Table A1: Comparison of percentage distributions of education levels, age groups, and sex in each PIAAC-L wave with German Microcensus benchmark data

Year	PIAAC-L unweighted			PIAAC-L weighted					Microcensus weighted						
	<i>Highest level of education</i>														
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High			
W1 (2014)	25.2	36.4	38.5	32.5	33.2	34.4	32.5	33.2	34.4	32.5	33.2	34.3			
W2 (2015)	22.2	36.2	41.7	32.0	33.0	35.1	32.0	33.0	35.1	32.0	33.0	35.1			
W3 (2016)	21.8	36.2	42.0	31.3	32.8	35.9	31.3	32.8	35.9	31.3	32.8	35.9			
	<i>Age (in years)</i>														
	min-25	26-35	36-45	46-55	56-max	min-25	26-35	36-45	46-55	56-max	min-25	26-35	36-45	46-55	56-max
W1 (2014)	15.9	18.2	19.9	25.1	20.9	12.7	18.5	20.5	25.1	23.2	12.4	18.8	20.1	25.4	23.2
W2 (2015)	14.1	17.4	18.5	26.1	23.8	10.6	18.6	19.6	25.6	25.6	10.5	18.8	19.5	25.7	25.5
W3 (2016)	12.2	17.2	18.3	26.4	26.0	9.1	18.2	19.3	25.9	27.6	8.7	18.9	19.0	25.9	27.6
	<i>Sex</i>														
	Male		Female			Male		Female			Male		Female		
W1 (2014)	49.0		51.0			50.1		49.9			50.1		50.0		
W2 (2015)	48.7		51.3			50.0		50.0			50.0		50.0		
W3 (2016)	48.6		51.4			50.1		49.9			50.1		49.9		

Source: Adapted from Burkhardt et al. (2018: 19).

Table A2: Key information about data files in the PIAAC-L SUF (ZA5989)

Data file	Unit description	No. of cases	Content
Household_14	Households 2014	3,737	HH questionnaire 2014, incl. DVs
Persons_14	Participants 2014 (APs, HH members 18+)	6,231	PS questionnaire 2014, incl. DVs PVs for PIAAC literacy, numeracy, PS-TRE (assessed in PIAAC 2011/2012, re-scaled)
Weights_14	Anchor persons 2014	3,758	Weighting factors
Persons_15	Participants 2015 (APs, spouses/partners in HH)	4,631	PS questionnaire 2015, incl. DVs PVs for PIAAC literacy, numeracy (assessed in PIAAC 2011/2012, re-scaled) PVs for PIAAC literacy, numeracy (assessed in PIAAC-L 2015) WLEs for PIAAC literacy, numeracy (assessed in PIAAC-L 2015) WLEs for NEPS reading competence, mathematical competence (assessed in PIAAC-L 2015)
Weights_15	Anchor persons 2015	3,263	Weighting factors
Household_16	Households 2016	2,946	HH questionnaire 2016, incl. DVs
Persons_16	Participants 2016 (APs, HH members aged 18+)	4,881	PS questionnaire 2016, incl. DVs
Cognit_16	Participants 2016 (APs, HH members aged 18+)	4,818	SOEP short scales measuring cognitive ability
NumberSeries_16	Pre-selected anchor persons 2016	910	Number Series Study
Weights_16	Anchor persons 2016	2,967	Weighting factors
Calendar	Participants 2014 and/or 2016 (APs and HH members aged 18+)	31,361	PS questionnaire 2014, 2016: biographical calendar (spell data)
Registry	All persons ever registered in PIAAC-L	10,343	Basic information on persons and on participation in the waves

Note: APs = anchor persons. DVs = derived variables. incl. = including. HH = household. PS = person. PS-TRE = problem solving in technology-rich environments. PVs = plausible values. WLEs = weighted maximum likelihood estimates. 18+ = aged 18 years and older.

Table A3: Concepts of literacy and numeracy in PIAAC, PIAAC-L, and NEPS

PIAAC and PIAAC-L	NEPS
Literacy in PIAAC is conceived as “understanding, evaluating, using and engaging with written texts to participate in society, to achieve one’s goals, and to develop one’s knowledge and potential” (Jones et al., 2009, p. 8).	Reading competence in the NEPS focuses on text comprehension and text handling in everyday-type situations, i.e. the ability to read and comprehend different types of texts widely irrespective of prior knowledge (Gehrer et al., 2013).
In PIAAC, numeracy is defined as “... the ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life” (Gal et al., 2009, p. 21).	Mathematical competence is understood in the NEPS as the ability to flexibly apply mathematical knowledge in real world situations requiring mathematical problem solving (Ehmke et al., 2009).

Note. In PIAAC, literacy focused on printed and on digital reading material.

Source: Zabal et al. (2017: 16).