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Development of a protective mental work demands questionnaire

Felix S. Hussenoeder,[1] Ines Conrad,[1] Steffi G. Riedel-Heller,[1] and Francisca S. Rodriguez[1,2]

[1]*Institute of Social Medicine, Occupational Health and Public Health, University of Leipzig, Leipzig, Germany*
[2]*Center for Cognitive Science, University of Kaiserslautern, Kaiserslautern, Germany*

ABSTRACT

Objectives: Research shows that mental demands at work affect later-life cognitive functioning and dementia risk, but systematic assessment of protective mental work demands (PMWDs) is still missing. The goal of this research was to develop a questionnaire to assess PMWDs.

Design: The instrument was developed in accordance with internationally recognized scientific standards comprising conceptualization, pretesting, and validation via confirmatory factor analysis (CFA), principal component analysis (PCA), and multiple regression analyses.

Participants: We included 346 participants, 72.3% female, with an average age of 56.3 years.

Measurement: Item pool, sociodemographic questions, and cognitive tests: Trail-Making Test A/B, Word List Recall, Verbal Fluency Test, Benton Visual Retention Test, Reading Minds in the Eyes Test.

Results: CFAs of eight existing PMWD-concepts revealed weaker fit indices than PCA of the item pool that resulted in five concepts. We computed multivariate regression analyses with all 13 PMWD-concepts as predictors of cognitive functioning. After removing PMWD-concepts that predicted less than two cognitive test scores and excluding others due to overlapping items, the final questionnaire contained four PMWD-concepts: Mental Workload (three items, Cronbach's $\alpha = .58$), Verbal Demands (four, Cronbach's $\alpha = .74$), Information Load (six, Cronbach's $\alpha = .83$), and Extended Job Control (six, Cronbach's $\alpha = .83$).

Conclusions: The PMWD-Questionnaire intends to assess protective mental demands at the workplace. Information processing demands and job control make up the primary components emphasizing their relevance regarding cognitive health in old age. Long-term follow-up studies will need to validate construct validity with respect to dementia risk.

Key words: mental demands, workplace, job demands, cognitive functioning, test development, job control, information load, brain health

Background

About 50 million people around the globe are affected by dementia (WHO, 2017), and social systems worldwide were facing estimated, dementia-related costs of 818 billion USD in 2015 (Prince *et al.*, 2015). In addition, there is an adjusted overall prevalence of 16% (effect size, 95% CI 12–20%) for mild cognitive impairment (MCI), increasing with age (Hu *et al.*, 2017). While MCI is less severe than dementia, it already has significant negative impact on quality of life (Conrad *et al.*, 2015). In the face of demographic change, cases of dementia and MCI are likely to rise.

While there is no cure for dementia yet, there are modifiable, protective factors that can contribute to a later onset of symptoms and improved cognitive functioning, enabling those affected by the disease to live longer lives with better well-being and less need for care (Hussenoeder and Riedel-Heller, 2018). Research has shown that protective mental work demands (PMWDs) have the potential to protect cognitive functioning and delay dementia onset (Fisher *et al.*, 2014; Then *et al.*, 2017). For example, PMWDs are reflected in the complexity of work with regard to data (Dekhtyar *et al.*, 2016; Lane *et al.*, 2017; Smart *et al.*, 2014) or job control, i.e. the extent to which one can use personal judgment

Correspondence should be addressed to: Felix S. Hussenoeder, Institute of Social Medicine, Occupational Health and Public Health, University of Leipzig, Ph.-Rosenthal-Str. 55, 04103 Leipzig, Germany. Phone: +49 (0)341/9715404; Fax +49 (0)3419724569. Email: Felix.Hussenoeder@medizin.uni-leipzig.de. Received 13 Aug 2019; revision requested 01 Mar 2020; revised version received 17 Mar 2020; accepted 15 Apr 2020. First published online 21 May 2020

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and assert control over working time and pace (Andel *et al.*, 2011; Sabbath *et al.*, 2016). Many researchers assume that exposition to PMWDs during midlife contributes to a cognitive reserve (Stern, 2009) that later acts as a buffer against age-related decline (e.g. Andel *et al.*, 2016; Potter, Helms and Plassman, 2008; Rodriguez *et al.*, 2017).

At the moment, research on PMWDs is at an early stage, scattered, there is uncertainty about what are the important concepts, and standardized assessment is missing (Hussenoeder *et al.*, 2019). To better understand, analyze, and research PMWDs and their association with cognitive functioning and to develop meaningful workplace interventions, it is important to adequately conceptualize, operationalize, and measure them. Hence, it was the goal of this research to develop a questionnaire to assess PMWDs that protect against cognitive decline and dementia.

Methods

The process of developing the instrument was realized following the recognized scientific standards in the "Handbook of Recommended Practices for Questionnaire Development and Testing in the European Statistical System" (EuStat; Brancato *et al.*, 2006) and the "Patient-Reported Outcome Measurement Information System (PROMIS): Instrument Development and Psychometric Evaluation Scientific Standards" (PROMIS, 2013).

Questionnaire development phases comprised the conceptualization with a definition of an item pool, a pretesting by expert focus groups and potential end users, and the validation and finalization of the instrument. Details are described in the following sections.

Defining the item pool for the questionnaire

In a first step, we conducted a systematic review of the literature on PMWDs and their effects on dementia and cognitive functioning as the theoretical foundation of our work. A detailed description of the search process and the results is published elsewhere (Hussenoeder *et al.*, 2019).

Our review and subsequent expert input identified eight dimensions: (1) Complexity with People, (2) Complexity with Data, (3) Job Control, (4) Novelty, (5) Mental Workload, (6) Executive, (7) Verbal Demands, and (8) Information Processing. The review also revealed a set of studies that conceptualized PMWDs as a rather eclectic set of Mental Demands at Work (Rodriguez *et al.*, 2017), Occupational Cognitive Requirements (Pool *et al.*, 2016), and Mental Stimulation (Marquie *et al.*, 2010). We included these items under the label of "Intellectual Demands."

In a second step, we conducted expert groups at our institute. Eight gerontologists/dementia researchers and four experts on the work environment came to a structured, open-ended-question group interview. The interview consisted of a brainstorming session and a systematic discussion of the PMWDs identified in the review, related items, and the usability of the existing concepts. Questions addressed relevance, potential problems, applicability, perspectives, underlying definitions, and context dependence. The most important conclusion from the expert interviews is that the conceptual model should include all factors that represent the interactivity and the dependence of the person, the work demands in general, and the level of PMWDs.

In a third step, we determined the item pool with the questions of the concepts identified in the literature review and with the experts ($n = 97$, a list of all items can be found in Appendix A). We carefully selected item format, response categories, wording, measurement units, and psychometric characteristics. We conducted a pretest with experts and potential end users. The pretest with the experts ($n = 12$) focused on reading level, clarity, wording with regard to person, grammar, language, applicability, stigmatization, and response categories. Pretests with potential end users ($n = 11$) were focused on literacy level, comprehension, and order of items. Based on the pretests, we rephrased items, adapted gender-neutral response formats, added a "not applicable" response category, added examples, split complex items in two parts, and reordered the items. These items comprised the preliminary questionnaire and could be answered on a scale from one to seven.

Cognitive tests

To validate the new questionnaire with respect to cognition, we assessed cognitive functioning. Following the recommendations of cognitive domains from the DSM-5, the following tests were used: Trail-Making Test – A (TMTA, complex attention), Trail-Making Test – B (TMTB, executive function), Word List Recall (WLR, learning and memory), and Verbal Fluency Test – Animals (VFT, language) from the neuropsychological test battery of the Consortium to Establish a Registry for Alzheimer's disease (CERADplus) (Aebi *et al.*, 2002; Chandler *et al.*, 2005); the Benton Visual Retention Test (BVRT, perceptual-motor) (Benton, 1974; Steck, 2002); the Reading Minds in the Eyes Test (RMET, social cognition) (German version: Bölte 2005 following Baron-Cohen *et al.*, 2001).

Sample

We applied the questionnaire to potential end users. Participants were recruited via convenience sampling

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from facilities and small companies in the neighborhood, at the Mitteldeutsche Institut für Arbeitsmedizin, at an orthopedic practice, through our website, local newspapers, email, flyers, and word of mouth between April and November 2018. Participant requirements were (1) age above 50 years; (2) currently holding a job; (3) not having received mental health treatment during the last 2 years. People who were interested in participating were briefed and received 20 Euros as compensation for approximately 40 minutes of testing. The final sample for validity analysis comprised 346 individuals (72% female).

Ethics

Our research was conducted in adherence to the Declaration of Helsinki and was approved by the ethics committee of the University. Participants provided written informed consent.

Statistical analysis

Statistical analyses were conducted using SPSS 25, AMOS 24.0 (CFA), and Stata 15 (item response theory [IRT]) to ensure the validity of the questionnaire. To guarantee content and construct validity, we ran confirmatory factor analyses (CFAs) of each of the concepts identified in the literature review and from expert input. To guarantee internal validity, we ran principal component analyses (PCAs) to identify the instrument's factor structure. To guarantee criterion validity, we ran multiple regression analyses for cognitive performance. Reliability was estimated via standard errors and Cronbach's α. Item-response theory was used to test the final questionnaire. Norms for the final questionnaire were calculated with regard to gender and education.

Confirmatory Factor Analyses

To analyze how items loaded on our eight theory-based scales, we conducted a CFA using maximum likelihood estimation. We utilized a three-step process for each of the concepts. In step one, we analyzed the items belonging to the original concept. In step two, we removed the items with factor loadings below .4 and/or commonalities below .3 to achieve a better and more parsimonious model. In step three, if necessary, we added items that were suggested by our experts to improve the concepts' fit. Criteria for good model fit were root mean square error of approximation (RMSEA) <.08 ($p \leq .05$) (Byrne, 2012), comparative fit index (CFI) ≥ .95, and Tucker–Lewis index (TLI) ≥ .95 (Hu and Bentler, 1999). An additional CFA was computed with the final questionnaire.

Principal Component Analysis

We conducted an initial PCA using varimax rotation and Kaiser normalization. The screeplot indicated five factors. We then ran iterating analyses sorting out items that either had factor loadings below .4 or that loaded on more than one factor. The PCA generated new scales, for which we ran CFAs to exclude items with factor loadings below .4 and/or commonalities below .3. If model fit indices could be significantly improved, we removed further items.

Multiple Regression Analysis

We conducted separate multiple linear regressions with PMWD-constructs as predictors, cognitive functioning as outcome, and age, gender, and education as control variables.

IRT

We conducted an IRT analysis using graded response models (GRM) in Stata 15, a useful model for ordinal data that allows discrimination for each item. As the responses to our items have different meaning, this model seemed appropriate. The log likelihood of 10625 was lower than that for other ordinal IRT models.

Results

Our study sample consisted of 346 persons, 72.3% female, with an average age of 56.3 years. Detailed information on the study population can be found in Table 1.

Confirmatory factor analysis

We analyzed eight PMWD-concepts using CFA.

Complexity With People

The original concept contained six variables (RMSEA: .119, $p < .001$, CFI = .779, TLI = .484). After removing two items (RMSEA: .168, $p = .001$, CFI = .877, TLI = .385), we added one item and removed another to improve model fit (RMSEA: .032, $p = .518$, CFI: .996, TLI: .979).

Complexity With Data

The original concept contained eight items (RMSEA: .154, $p < .001$, CFI = .827, TLI = .689). After removing three items (RMSEA: .189, $p < .001$, CFI = .909, TLI = .727), we further removed the item with the lowest factor loading to improve model fit (RMSEA: .042, $p = .447$, CFI: .998, TLI: .988).

Job Control

The original concept contained six variables (RMSEA: .169, $p < .001$, CFI = .862, TLI = .679). Removing one item improved model fit (RMSEA: .230, $p < .001$, CFI = .852, TLI = .557).

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Table 1. General characteristics of the study population

	TOTAL GROUP *(N = 346)*
Age	56.3 (4.9)
Female	250 (72.3 %)
Marital status	
Single	56 (16.4 %)
Married	187 (54.7 %)
Divorced/living separated	80 (23.4 %)
Widowed	19 (5.6 %)
Education	
Low *(secondary school)*	162 (47.4 %)
High *(Abitur, UAS entrance qualification)*	180 (52.6 %)
Occupational training	
Low (apprenticeship, vocational school)	186 (54.5 %)
Medium (Bachelor, Diploma UAS)	59 (17.3 %)
High (Master, Magister, Diploma University, Dissertation)	96 (28.2 %)
Verbal Fluency (Number of animals)	27.4 (6.7)
Word list – immediate recall (Number of words)	6.6 (1.3)
Word list – delayed recall (Number of words)	5.2 (1.8)
TMTA (seconds)	31.7 (11.6)
TMTB (seconds)	67.8 (24.2)
Benton (correct drawings)	6.0 (1.9)
Benton (errors)	6.0 (3.2)
RMET(number of correct answers)	6.6 (1.6)

Note: Continuous variables are given as mean (standard deviation); categorical variables are displayed as numbers (percentages). UAS = University of Applied Sciences; TMTA = Trail Making Test, Version A; TMTB = Trail Making Test, Version B; RMET = Reading Mind in the Eyes Test.

Novelty

The original concept contained five items (RMSEA: .049, $p = .444$, CFI = .962, TLI = .887). After removing two items (RMSEA: .192, $p < .001$, CFI = 1.000, TLI = not available), we added one item suggested by experts as it matched theoretically and improved model fit (RMSEA: .035, $p = .498$, CFI: .995, TLI: .975).

Mental Work Load

The original concept contained three items. Since it could not be further reduced, this remained the final model (RMSEA: .241, $p < .001$, CFI: 1.000, TLI: not available).

Executive

The original concept contained five items (RMSEA: .233, $p < .001$, CFI = .846, TLI = .539). After reducing two items (RMSEA: .453, $p < .001$, CFI = 1.000, TLI = not available), two items were added since they matched theoretically with the concept and improved model fit (RMSEA: .153, $p < .001$, CFI: .965, TLI: .896).

Verbal Demands

The original concept contained seven items (RMSEA: .159, $p < .001$, CFI = .780, TLI = .559). After removing three items, the model fit improved (RMSEA: .174, $p = .001$, CFI: .923, TLI: .617).

Information Processing

The original concept contained 10 items (RMSEA: .164, $p < .001$, CFI = .724, TLI = .567). After removing items with commonalities below .3 (RMSEA: .302, $p < .001$, CFI = .875, TLI = .375), we added two items and removed one further item to achieve better fit (RMSEA: .081, $p = .098$, CFI: .982, TLI: .947).

Results from the CFAs are displayed in detail in Table 2.

Principal component analyses

Results from the PCA were obtained in a step-wise manner. After five iterations and the exclusion of 20 items due to insufficient factor loadings and/or commonalities, we reached the final item pool with all factor loadings above .4 and no double loadings. Table 3 shows the rotated component matrix from the final PCA.

The PCA resulted in five components:

Information Load

Factor 1 contained 11 items with loadings from .485 to .705, with items from the original concepts Complexity with Data ($n = 4$), Intellectual Demands ($n = 4$), Verbal Demands ($n = 2$), and Mental Workload ($n = 1$). After running CFAs, Information Load contains six items (RMSEA: .127, $p < .001$, CFI: .934, TLI: .846).

Extended Job Control

Factor 2 contained eight items mainly from the concept Job Control ($n = 5$), but also Intellectual Demands ($n = 2$) and Novelty ($n = 1$). Factor loadings range from .470 to .784. After CFAs, Extended Job Control comprises six items (RMSEA: .196, $p < .001$, CFI: .843, TLI: .633).

Personnel

Factor 3 consisted of five items with factor loadings from .540 to .881 and contains items from Executive ($n = 2$), Intellectual Demands ($n = 2$), and Complexity with People ($n = 1$). Finally, Personnel covers four items (RMSEA: .210, $p < .001$, CFI: .972, TLI: .859).

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Table 2. Results from the confirmatory factor analysis and reliability analysis of existing concepts of protective mental work demands

	MEAN (SD)	FACTOR LOADINGS	COMMONALITIES	CORRECTED ITEM-TOTAL CORRELATION	CRONBACH'S α if item deleted
Complexity with People ($n = 313$)					
Convince others	3.15 (2.45)	.597	.356	.456	.605
Entertain customers or clients	3.73 (2.77)	.638	.407	.484	.587
Act service-oriented (level)	4.71 (2.39)	.582	.339	.456	.605
Represent employer (level)	4.56 (2.42)	.520	.271	.424	.626
Complexity with People Scale	4.04 (1.78)		Cronbach's α = .67/SE Mean = .10		
Complexity with Data ($n = 323$)					
Acquire information (level)	5.82 (1.47)	.678	.460	.622	.772
Document information (level)	5.02 (2.05)	.797	.635	.680	.727
Process information (level)	5.17 (2.00)	.897	.805	.757	.689
Analyze information (level)	3.49 (2.43)	.556	.309	.507	.833
Complexity with Data Scale	4.87 (1.60)		Cronbach's α = .81/ SE Mean = .09		
Job Control ($n = 307$)					
Flexible working times	4.62 (2.59)	.546	.298	.464	.821
Planning vacations	3.26 (2.80)	.709	.502	.657	.764
Planning breaks	3.36 (2.78)	.700	.491	.657	.764
Affect time management	3.96 (2.30)	.850	.722	.754	.739
Affect working speed	4.20 (2.11)	.639	.409	.530	.801
Job Control Scale	3.88 (1.92)		Cronbach's α = .82/ SE Mean = .11		
Novelty ($N = 312$)					
Independence	4.49 (2.03)	.470	.221	.378	.600
Act flexible	5.91 (1.53)	.389	.152	.283	.650
Innovative	4.50 (2.15)	.787	.620	.557	.454
Learn	5.41 (1.83)	.605	.367	.471	.532
Novelty Scale	5.08 (1.31)		Cronbach's α = .64/ SE Mean = .07		
Mental Workload[1] ($n = 314$)					
Mentally demanding job	5.78 (1.56)	.734	.538	.460	.395
Time pressure	4.65 (2.10)	.364	.132	.310	.672
Complexity	5.41 (1.45)	.708	.502	.458	.417
Mental Workload Scale	5.28 (1.28)		Cronbach's α = .58/ SE Mean = .07		
Executive ($n = 330$)					
Negotiate (level)	3.75 (2.51)	.482	.232	.479	.921
Instruct staff (level)	2.60 (2.58)	.928	.861	.830	.843
Coordinate activities others (level)	2.73 (2.45)	.872	.760	.825	.846
Responsibility staff (level)	2.49 (2.64)	.909	.825	.835	.842
Monitor processes (level)	2.48 (2.41)	.739	.546	.718	.870
Executive Scale	2.81 (2.10)		Cronbach's α = .89/ SE Mean = .12		
Verbal Demands[2] ($n = 318$)					
Interpret information (level)	2.99 (2.51)	.629	.396	.521	.697
Analyze information (level)	3.49 (2.42)	.792	.627	.626	.627
Apply expertise/ up-to-date (level)	5.57 (1.76)	.576	.332	.504	.706
Write texts (level)	5.06 (2.04)	.623	.388	.520	.692
Verbal Demands Scale	4.49 (1.53)		Cronbach's α = .74/ SE Mean = .09		
Information Processing ($n = 320$)					
Document information (level)	5.02 (2.05)	.807	.652	.692	.785
Process information (level)	5.17 (2.00)	.872	.760	.758	.766
Analyze information (level)	3.48 (2.43)	.577	.332	.547	.836
Acquire information (level)	5.82 (1.48)	.690	.476	.636	.810
Write texts (level)	5.03 (2.08)	.630	.397	.613	.808
Information Processing Scale	4.90 (1.58)		Cronbach's α = .83/ SE Mean = .09		

Note: SE = standard error.

[1] The Mental Workload scale is part of the final questionnaire.

[2] The Verbal Demands scale was adapted for the final version of the questionnaire. The scale in this table represents the final version.

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Table 3. Rotated component matrix of the principal component analysis *(original factors before item reduction)*

ITEM	ORIGINAL CONCEPT	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
Information Load						
Process information (level)	Cdata/ IP	.705				
Acquire information (level)	Cdata/ Verbal	.703				
Document information (level)	Cdata/IP	.677				
Memorize multiple things (level)	IDs	.599				
Understand texts (level)	IDs	.596				
Advice others (level)	Verbal	.586				
Phone	Verbal	.584				
Frequent interruptions	IDs	.581				
Time pressure	Mental Workload	.530				
Analyze for others (level)	Cdata/ IP	.520				
Solve problems (level)	IDs/ IP	.485				
Extended Job Control						
Influence time management	Job Control		.784			
Flexible working hours	Job Control		.711			
Vacation planning	Job Control		.702			
Planning breaks	Job Control		.690			
Influence working speed	Job Control		.619			
Independence	Novelty		.612			
Manage budgets (level)	IDs		.576			
Analyze company (level)	IDs		.470			
Personnel						
Advise staff (level)	Executive			.881		
Personnel	IDs			.853		
Coordinate others (level)	Executive			.814		
Supervise processes (level)	IDs			.708		
Train others	Cpeople			.540		
Exploring						
Learn	IDs				.764	
Improve	IDs				.716	
Diverse	IDs				.627	
Innovative	Novelty				.561	
Define tasks (level)	IDs				.558	
Develop goals and strategies (level)	Executive				.552	
Take decisions (level)	IDs/ IP				.520	
Critical Thinking						
Three-dimensional thinking (level)	IDs					.644
Assess quality (level)	IDs					.623
Identify something (level)	IDs					.620
Apply technical expertise (level)	IDs					.607
Compare data with standards	IDs					.590
Do quality control	IDs					.589
Fix, build in, install (level)	IDs					.563
Apply mathematical skills (level)	IDs					.507
Interpret information (level)	Cdata/ IP/ Verbal					.421

Note: Cdata = Complexity with Data; Cpeople = Complexity with people; IP = Information Processing; IDs = Intellectual Demands.

Exploring

Factor 4 contained seven items from the concepts Intellectual Demands ($n = 5$), Novelty ($n = 1$), and Executive ($n = 1$) with factor loadings ranging from .520 to .764. The final Explore scale contained five items (RMSEA: .191, $p < .001$, CFI: .906, TLI: .719).

Critical Thinking

Factor 5 comprised nine items with factor loadings from .421 to .644 that come from the concepts Intellectual Demands ($n = 7$) and Complexity with Data ($n = 2$). Due to the fact that all factor loadings were sufficient and every reduction of items caused significant decreases in fit indices, no items were

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Table 4. Results from the confirmatory factor analysis and reliability analysis of empirically derived protective mental work demands

	MEAN (SD)	FACTOR LOADINGS	COMMONALITIES	CORRECTED ITEM-TOTAL CORRELATION	CRONBACH'S α if item deleted
Information Load* **(*n* = 325)**					
Process information (level)	5.20 (1.99)	.823	.677	.710	.781
Acquire information (level)	5.82 (1.47)	.758	.575	.702	.792
Document information (level)	5.02 (2.05)	.790	.623	.683	.787
Memorize multiple things (level)	5.83 (1.32)	.570	.325	.543	.819
Understand texts (level)	5.67 (1.72)	.608	.370	.566	.812
Analyze for others (level)	3.24 (2.43)	.551	.304	.528	.833
Information Load Scale	5.13 (1.37)		Cronbach's α = .83/ SE Mean = .08		
Extended Job Control* **(*n* = 304)**					
Influence time management	3.96 (2.31)	.895	.801	.779	.769
Flexible working hours	4.62 (2.59)	.582	.339	.510	.823
Vacation planning	3.29 (2.80)	.655	.429	.641	.796
Planning breaks	3.38 (2.78)	.636	.404	.628	.799
Influence working speed	4.19 (2.12)	.656	.430	.560	.812
Independence	4.45 (2.04)	.592	.350	.535	.817
Extended Job Control Scale	3.98 (1.81)		Cronbach's α = .83/ SE Mean = .10		
Personnel (*n* = 331)					
Advise staff (level)	2.59 (2.58)	.935	.874	.866	.880
Personnel	2.49 (2.64)	.906	.820	.843	.888
Coordinate others (level)	2.72 (2.45)	.869	.756	.845	.888
Supervise processes (level)	2.48 (2.41)	.734	.538	.720	.928
Personnel Scale	2.57 (2.26)		Cronbach's α = .92/ SE Mean = .12		
Exploring (*n* = 317)					
Learn	5.39 (1.85)	.910	.828	.736	.746
Improve	4.88 (2.01)	.844	.713	.680	.760
Diverse	5.85 (1.54)	.653	.427	.560	.799
Innovative	4.51 (2.15)	.550	.303	.603	.785
Develop goals/strategies (level)	4.44 (2.21)	.458	.209	.510	.816
Exploring Scale	5.01 (1.50)		Cronbach's α = .82/ SE Mean = .08		
Critical Thinking (*n* = 304)					
Three-dimensional thinking (level)	2.21 (2.36)	.625	.391	.555	.773
Assess quality (level)	4.12 (2.49)	.718	.515	.628	.762
Identify something (level)	1.87 (2.24)	.562	.315	.488	.782
Apply technical expertise (level)	2.49 (2.58)	.559	.313	.493	.781
Compare data with standards	2.05 (2.28)	.514	.264	.449	.787
Do quality control	2.91 (2.70)	.684	.467	.594	.766
Fix, build in, install (level)	1.35 (1.95)	.465	.216	.415	.791
Apply mathematical (level)	3.38 (2.21)	.491	.241	.408	.791
Interpret information (level)	2.98 (2.50)	.461	.213	.394	.794
Critical Thinking Scale	2.60 (1.48)		Cronbach's α = .80/ SE Mean = .08		

Note: SE = standard error.

*The Information Load scale and the Extended Job Control scale are part of the final questionnaire.

removed from Critical Thinking despite several commonalities being below .3 (RMSEA: .116, $p < .001$, CFI: .828, TLI: .714).

Results from CFAs of final scales can be found in Table 4.

Multiple regression analysis

We conducted multiple regression analyses with all 13 PMWD-concepts from CFAs and PCA as predictors, cognitive functioning as outcome, and age, gender, and education as control variables. Results are shown in Table 5. Higher scores on the PMWD factor Verbal Demands were associated with better performance in four cognitive domains (Verbal Fluency, Word List immediate recall, TMTA, and Benton/Benton errors). Higher scores on the PMWD factor Information Processing were associated with better performance in three cognitive domains (Verbal Fluency, Word List immediate recall, and TMTA).

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Table 5. Regression coefficients of the linear regression analyses of protective mental work demands on cognitive test scores (adjusted for age, gender, and education)

	VERBAL FLUENCY	WORD LIST (*IMMEDIATE RECALL*)	WORD LIST – (*DELAYED RECALL*)	TMTA[1]	TMTB[1]	BENTON	BENTON ERRORS	READING MINDS
Complexity with People	.053	– .066	– .103	– .034	– .019	– .021	.075	– .006
Complexity with Data	.102	.090	.036	**– .114***	– .098	.031	– .048	.052
Job Control	**.113***	.065	.105	.024	– .013	**.148***	**– .133***	.025
Novelty	.090	.107	**.115***	– .017	– .025	.044	– .082	– .021
Mental Workload	.084	**.124***	**.112***	– .025	– .054	– .022	.004	– .095
Executive	.038	.026	– .010	.019	.019	– .056	.043	– .017
Verbal Demands[2]	**.123***	**.132***	**.117***	– .108	– .086	**.137***	**– .157****	.030
Information Processing	**.113***	**.113***	.062	**– .119***	– .095	.032	– .043	.035
Information Load	**.117***	**.121***	.056	– .098	– .092	– .007	– .023	.010
Extended Job Control	**.121***	.081	.109	.016	– .022	**.163****	**– .147***	.029
Personnel	.036	.030	.016	.022	.021	– .062	.037	– .001
Explore	.096	**.108***	.105	– .033	– .013	.059	– .085	– .024
Critical Thinking	.044	.063	– .004	– .003	.002	.101	– .097	– .058

Note: $^{*}p \leq .05$; $+^{**}p \leq .01$; $^{***}p \leq .001$.

[1] Higher scores indicate worse cognitive performance.

[2] The Verbal Demands scale was adapted for the final version of the questionnaire. The scale in this table represents the final version.

Higher scores on the PMWD factors Job Control and Extended Job Control were connected to two domains (Verbal Fluency, Benton/Benton errors), as were those on Mental Workload (Word List immediate recall, Word List delayed) and Information Load (Verbal Fluency, Word List immediate). Complexity with Data (TMTA), Novelty (Word List delayed), and Explore (Word List immediate recall) were associated with only one cognitive domain, and Complexity with People, Executive, Personnel, and Critical Thinking did not have any significant associations.

Final questionnaire

The six PMWD-concepts that were significantly associated with at least two cognitive domains (Job Control, Mental Workload, Verbal Demands, Information Processing, Information Load, and Extended Job Control) contained a total of $n = 19$ unique items, of which seven are part of two and one is part of three concepts.

All four items of Job Control were part of Extended Job Control and therefore the same construct. Since four out of five items in Information Processing were also part of either Information Load or Verbal Demands, we decided to remove this factor, which resulted in one now "left over" item. "Write texts (level)" was added to Verbal Demands since it matched theoretically as well as empirically. In addition, the item "acquire information (level)" had been part of two scales. Based on our analysis factor loadings, we removed it from Verbal Demands and kept it in Information Load. To validate these decisions, we ran a CFA of the final questionnaire, and the model fit confirms our choice (RMSEA: .097, $p < .001$, CFI: .824, TLI: .771).

The final questionnaire (Mean: 88.69, SD: 21.47, Median: 91.00, Range: 23–131) now contains 19 unique items and four concepts: Mental Workload, Verbal Demands, Information Load, and Extended Job Control. The final questionnaire can be found in Appendix B (the CFA in Appendix C).

Analysis of item response theory suggested a good variance with discrimination with eight items showing b < 1, seven items with a b between 1 and 2, and four items with a b > 2 (see Appendix D). The item with strongest discrimination, and therefore the best indicator for the latent factor that the instrument measures, is "processing information." Difficulties displayed a high range from – 7.01 to 4.3. There was a great variance in the internal ranges of the answer categories to each item, with "independence" having the largest range (11.3) and representing the full scale of the final questionnaire.

For calculating norms, we created four groups based on gender and education. Group means and cutoffs, i.e. mean minus one standard deviation, were (1) female + low education: M = 79.07, CO = 57.64; (2) female + high education: M = 94.10, CO = 77.02; (3) male + low education: M = 83.55, CO = 57.17; (4) male + high education: M = 97.78, CO = 77.94.

Discussion

The goal of this research was to develop a questionnaire to systematically assess PMWDs that protect against cognitive decline and dementia. Starting

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with a great variety of existing concepts, our final questionnaire now contains four concepts of PMWDs: Mental Workload, Verbal Demands, Information Load, and Extended Job Control. Detailed analyses of our initial item pool led to the exclusion of the concepts Complexity with People, Complexity with Data, Novelty, Executive, Personnel, Explore, and Critical Thinking since they exhibited insufficient associations with cognitive functioning and the exclusion of Job Control and Information Processing due to item overlap with other concepts.

Theoretical considerations

The concepts that form the final questionnaire center on information load, including verbal information processing, and job control. One approach to understanding the beneficial effects of complex information processing on cognitive outcomes can be found in the concept of cognitive reserve, i.e. the "ability to optimize or maximize performance through differential recruitment of brain networks, which perhaps reflect the use of alternate cognitive strategies" (Stern, 2002). High demands on information processing at work may stimulate the growth and maintenance of this cognitive reserve that could be understood as an active coping strategy to deal with age-related cognitive constraints as well as pathological changes. Indeed, the cognitive reserve brain network that researchers have identified seems to include areas on cognitive control for upregulating task-relevant processes and downregulating distraction (Stern *et al.*, 2018). Complex information processing at work may train exactly these networks. Further, verbal memory is considered to be a marker for cognitive reserve in elderly people (Zahodne *et al.*, 2015). Thus, it is likely that work demands that train verbal memory thereby contribute to a cognitive reserve. Further studies are necessary to validate these assumptions.

Mental workload

Mental Workload could be seen as a very general, comprehensive measure of work-related cognitive stimulation due to a complex work environment which matches with the rather broad and general conceptualization in the literature (Bosma *et al.*, 2003a; Bosma*et al.*, 2003b). Our data show that it is associated with learning and memorizing new information.

Verbal demands

Verbal Demands describe the cognitive stimulation of work tasks that contribute to the accumulation of knowledge, facts, and verbal skills that are acquired through life (Then *et al.*, 2013). This idea is well reflected in the items of our Verbal Demands scale, which refer to the analysis and interpretation of information, the writing of texts, and the application of expert knowledge, all of which require the previous accumulation of knowledge.

The broad and pervasive nature of the Verbal Demands scale is also reflected in the fact that it is associated with four different cognitive domains: language, learning, memory, and perceptual-motor skills. Verbal Demands could be understood as a factor representing crystallized experience as it is reflected in intelligence and can be connected to reduced dementia risk (McGurn*et al.*, 2008; Russ *et al.*, 2017). More research is needed to determine how different experiences and accumulated knowledge throughout the lifespan, and their cognitive and neural correlates, translate into cognitive reserve.

Information load

Information Load emerged as the first factor in the PCA, and the final scale contains all four items from Complexity with Data and two items from Intellectual Demands, "keeping in mind multiple things" and "reading and understanding texts." We can, therefore, argue that Information Load represents a modern, empirically tested, self-reported German adaption of Complexity with Data, a concept that is widely used in the literature (Correa Ribeiro *et al.*, 2013; Dekhtyar *et al.*, 2015; Lane *et al.*, 2017), and it was connected to lower risks for dementia and/or cognitive decline in 8 out of 13 studies in our systematic review (Hussenoeder *et al.*, 2019).

The strong correlation of Information Load with Verbal Demands ($r = .72$, $p \leq .001$) reflects the conceptual as well as empirical closeness between both concepts, i.e. between the complexity of an environment and the cognitive stimulation from acquiring knowledge and skills as a way of adapting to and flourishing in that environment.

Extended job control

According to the literature, job control reflects the extent to which one can use personal judgment or decision authority to assert control in the workplace (Andel *et al.*, 2015), specifically with regard to work time and tasks (Sabbath *et al.*, 2016). The literature shows that low job control is associated with decreased cognitive performance (Andel *et al.*, 2011), episodic memory (Andel *et al.*, 2015), executive functioning, psychomotor speed, phonemic and semantic fluency in later life (Sabbath *et al.*, 2016), and with increased dementia risk (Seidler *et al.*, 2004).

Our factor Extended Job Control mainly reflects control over time with five items addressing time management, flexible hours, planning vacations, planning breaks, and working speed. In addition,

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it includes one general item asking for independence covering tasks as well as time.

Our scale is significantly associated with verbal fluency, matching with the fact that higher job control most likely implies a heightened need to organize, coordinate, and therefore communicate with others leading to higher levels of cognitive reserve in the verbal area. In addition, there is an association between Extended Job Control and perceptual motor skills and visual memory that could represent an ability to adapt to new and different tasks, i.e. a form of cognitive flexibility or creativity that is connected to high levels of job control. In addition, there is a well-established link between stress and cognitive performance (Sandi, 2013), and the beneficial effects of Extended Job Control could to some extend be the consequence of stress reduction due to control over one's own working pace. Clearly, more research is needed to better understand the connection between this important PMWD and visual memory.

In addition, Extended Job Control could also be protective in another way, i.e. by being protective against depression, a risk factor for dementia (Hussenoeder and Riedel-Heller, 2018). Literature shows that low job control, especially in combination with high job demands, is connected to depressive symptoms and other mental disorders (Åhlin *et al.*, 2019; Harvey *et al.*, 2017), while high job control is associated with good mental health (Fan, Mustard and Smith, 2019). Moreover, depression is currently discussed both as a risk factor for and a prodromal symptom of dementia (Cherbuin *et al.*, 2015; Deckers *et al.*, 2015; Heser *et al.*, 2013).

Limitations

While this work benefits from comprehensive theoretical foundations as well as detailed cognitive testing, there are several limitations. There is an overrepresentation of white collar employees as compared to blue collar workers, of women, and of individuals with higher education limiting the generalizability of our results. On a methodological level, test–retest reliability needs to be established as well as predictive validity in a longitudinal follow-up. Minimally important differences and differential item functioning analysis need to be done retrospectively with a clinical group, as the problem is that people with dementia due to nature of memory problems cannot answer the questionnaires themselves. In addition, our self-assessment of complexity may be less appropriate to predict cognitive functioning then expert-assessed complexity rating measures. Traditionally, almost all operationalizations in the literature are based on the Dictionary of Occupational Titles (DOT) (ICPSR, 2017), a U.S. job classification system. The DOT allows researchers to connect job titles with expert-rated complexity scores unbiased by individual perceptions.

Conclusion

With dementia being a highly prevalent, terminal disease in old age, efforts must be focused on preventative factors. Having an intellectually challenging lifestyle is such a preventative factor and intellectual demands at work seem to contribute to that (Then *et al.*, 2014). However, until today, there was no standardized way to assess intellectual demands at work that have the potential to protect against dementia. We developed and evaluated a first questionnaire to assess PMWDs that are protective for cognitive functioning as a foundation for further research and application. Our work led to a questionnaire in "Stage 2: Developmental – Calibration Phase" according to the "Instrument Development and Validation Scientific Standards" (PROMIS, 2013). Further steps are necessary to validate it longitudinally. In the long run, our questionnaire can help practitioners to assess individual workplaces, develop and evaluate interventions, and to create mentally healthier workplaces. On the policy level, our work may contribute to guidelines for working environments that help protect brain health and that will shape the future of work at a time of demographic change.

Conflict of interest

None.

Description of authors' roles

FSH managed data collection, wrote the paper, and conducted analyses. FSR designed the study, supervised data collection and analysis, and assisted with writing the paper. SGRH and IC assisted with writing the paper and contributed to project management, organization of data assessment, and participant recruitment.

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Supplementary Material

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