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ORIGINAL ARTICLE

Are effort–reward imbalance and social isolation mediating the association between education and depressiveness? Baseline findings from the lidA[§]-study

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Abstract
Objectives To investigate multiple mediations of the association between education and depressive symptoms (BDI-V) by work-related stress (ERI) and social isolation, the regional variation of the first mediation and a potential moderating effect of regional unemployment rate.
Methods 6339 employees born in 1959 and 1965 were randomly recruited from 222 sample points in a German cohort study on work, age, health and work participation. A multilevel model of moderated lower-level mediation was used to investigate the confirmatory research question. Multiple mediations were tested corresponding to Baron and Kenny. These analyses were stratified for age and adjusted for sex, negative affectivity and overcommitment.
Results In the association between education and depressive symptoms, indirect effects of work-related stress and social isolation were significant in both age cohorts whereas a direct association was observable in the younger cohort, only. The significant regional variation in the association between work-related stress and depressive symptoms was not statistically explained by regional unemployment rate.
Conclusions Our findings point out that work-related stress and social isolation play an intermediary role between education and depressive symptoms in middle-aged employees.

Keywords Depressive symptoms · Education · Work-related stress · Social isolation · Unemployment · Moderated lower-level mediation

Introduction

As a consequence of the demographic change, the German labour force is ageing and shrinking. The decline will be presumably up to 9 % till 2040 (Boersch-Supan and Wilke 2009) and not compensated by immigration (Federal Statistical Office 2009). The proportion of older employees (>50 years) will be rising steadily from 11 % in 2009 to 20 % in 2040 playing a decisive role regarding future work participation. Thus, concepts for the maintenance of their work ability, health and motivation are required.

Besides changing demographics, diseases accumulation in specific social strata can diminish the work force. The percentage of mental disorders on all medical diagnosis leading to early retirement was rising from 33 to 38 % between 2006 and 2009 in Germany (Kroll et al. 2011). Depression is there the most frequent mental disorder and accounts for high absenteeism and economic loss (Rau et al. 2010). The relationship between socioeconomic status (SES) and depression is well known (Lorant et al. 2003). A social gradient in depression and depressive symptoms was found (Melchior et al. 2013; Busch et al. 2013).

[§] **l**eben **i**n **d**er **A**rbeit (English: living at work).

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Recent research into social inequality in health attempts to identify sociological and psychological pathways explaining associations between SES and health. Several studies investigated the association between working conditions and health (e.g. Borg and Kristensen 2000) as well as between SES and psychosocial working conditions (e.g. Kristensen et al. 2002). Due to the changing nature of work during the last decades psychosocial stress became a work-related exposure of increasing relevance (Siegrist et al. 2004). German employees claim meanwhile as often about psychosocial as about physical exposures (Kroll et al. 2011).

A well-known measure of work-related stress is the model of effort–reward imbalance (ERI, Siegrist et al. 2004). Earlier investigations found associations between ERI and physical and mental health indicators (Dragano et al. 2008; Rugulies et al. 2013; Van Vegchel et al. 2005). The relationship between SES and ERI is not totally clarified yet. Some studies found a stronger association between ERI and CHD in lower SES groups (Van Vegchel et al. 2005). Others found gender-specific differences in this association (e.g. Chandola et al. 2005). Furthermore, the influence of ERI and SES on different health outcomes might be additive rather than multiplicative. The association between ERI and depression or depressive symptoms was observed mainly for specific occupational groups like health professionals so far (e.g. Tsutsumi et al. 2012).

One central question in modern economies is which part of the association between SES and health is mediated by factors like work stress. Only moderate evidence exists to support the hypothesis that work-related factors are mediators between SES and health (Hoven and Siegrist 2013). Regarding the association between education and depressive symptoms, evidence is mixed and many studies focus on specific occupational groups. Therefore, our aim was to investigate whether a social gradient in depressiveness is mediated by work-related (ERI) and non-work-related (social isolation) factors in two age cohorts of a general working population. If mediation by ERI was observed, we were interested whether it might be different depending on area. If so, could this variation be explained by regional unemployment rate? We assumed that distress arising from poor reward particularly from poor job security in the ERI-model should be more pronounced under unfavourable conditions, i.e. high regional unemployment rates. The following a priori hypotheses were formulated accordingly:

H_1: the association between education and depressive symptoms is mediated by work-related stress (ERI) and by social isolation in two middle-aged cohorts of a general working population in Germany.

H_2: the mediation of the association between education and depressiveness shows regional variation explainable by regional unemployment rate.

Methods

Participants

The German lidA ('leben in der Arbeit')-study is a prospective cohort study (Hasselhorn et al. 2014). All employees born in 1959 or 1965 subject to social security contributions and working on December 31, 2009 in Germany were eligible for participation in the first wave of the study 2011. The study sample was drawn by a two-stage random sampling process from an administrative data set of the Federal Employment Agency. This data set includes all employees in Germany subject to social security (about 80 % of all employees). Civil servants and self-employed do not belong to the study population. First 222 sampling points were randomly drawn from 206 of all 12,227 German communities. 34,000 addresses randomly drawn proportionally to the size of the sampling points were oversampled to reach the precalculated sample size of 6,600 subjects. This number resulted from a power calculation considering multilevel design, multiple testing and anticipated loss to follow-up. The younger cohort was oversampled to compensate for future loss to follow-up. Our research hypothesis is one of three confirmatory models of the lidA-study (Fig. 1). The study was approved by the ethics commission of the University of Wuppertal.

Measures

Age

One central characteristic of the lidA-study is the comparison of the two age cohorts (1959, 1965), cross-sectionally now as well as longitudinally in the future. Besides age-adjusted analysis for the total sample, also age-stratified analyses were performed.

Education

SES was operationalized by a combined quasi-metric score of education and vocational training provided by survey data in agreement with the demographic standards as recommended by the German Society of Epidemiology (Jöckel et al. 1998): For each combination of education and training a certain value from 1 (=not any graduation) to 8 (=school leaving examination and graduation from college) was calculated.

Depressive symptoms

Depressive symptoms instead of depression were the outcome, since already few depressive symptoms might lead to absenteeism, loss of productivity and early retirement. Depressive symptoms were measured by an applied version

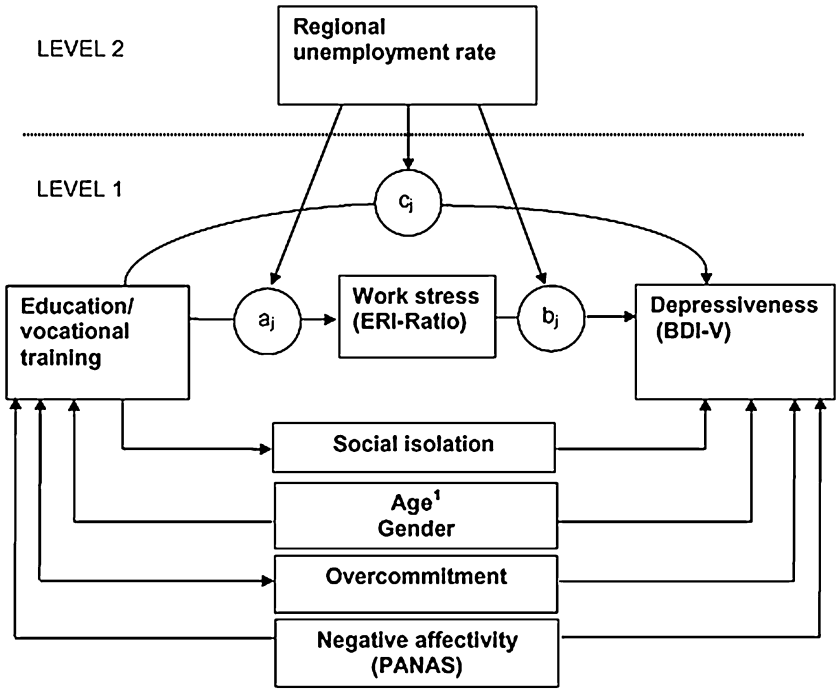

Fig. 1 Confirmatory model of moderated lower-level mediation applied to 6,339 employees from the first wave of the lidA ('leben in der Arbeit')-cohort study 2011 in Germany. Association between education and depressive symptoms mediated by work-related stress and social isolation, adjusted for covariates and moderated by regional unemployment rate; [1]to be stratified for. Abr.: *ERI* effort–reward imbalance, *PANAS* positive and negative affect schedule, *BDI-V* applied version of Beck's Depression Inventory, *aj* slope of education in the association between education and work stress, *bj* slope of work stress in the association between work stress and depressiveness, *cj* slope of education in the association between education and depressiveness, *Level 1* individual level, *Level 2* regional level

of the Beck's Depression Inventory (BDI-V). The original BDI, a clinical questionnaire for assessment of severity of depressive symptoms has been cut to 20 items for epidemiological investigations and successfully validated in the setting of a general population (Schmitt et al. 2006). The paper and pencil version of this questionnaire was used (better response rates than in personal interviews in the pretest, reduction of interviewer bias).

Work-related stress

Work-related stress was measured by the reliable and valid 17-item 4-point Likert-scaled version of the ERI questionnaire (Siegrist et al. 2004). ERI measures the level of subjective stress by an imbalance between efforts spent (e.g. work load, responsibility) and rewards (e.g. earnings, approval by supervisor) gained at work. The ERI-ratio we used is the sum of values of the effort and reward items including a weighting factor for different item numbers in both scales (Siegrist et al. 2004).

Overcommitment

The intrinsic component of the ERI-model overcommitment represents a certain coping strategy characterised by excessive efforts, high ambitions for control, intensive striving for approval and the inability to stop thinking about work (Siegrist et al. 2004). We used the 6-item 4-point Likert-scaled version a short form well tested for reliability and validity (Siegrist 2004). Overcommitment was treated as a confounder assuming that it was associated with social status and depressive symptoms (Dragano et al. 2008).

Negative affectivity

Negative affectivity (NA) was controlled by an international short version of the Positive and Negative Affect Schedule (PANAS) tested for good reliability and validity (Thompson 2007). The internal consistency of the NA scale was acceptable in our investigation ($\alpha = 0.61$). We adjusted for NA to diminish mood-driven judgement of the interviewee, i.e. subjects with negative emotions are more likely to report about work-related stress and depression.

Social isolation

Social isolation was measured with a composite sum score of five variables with a maximum value of 20 points treated like a continuous variable. The participants had to estimate,

how many persons they knew, (1) To whom they can talk about personal concerns and problems, (2) Who could support them in smaller duties and responsibilities, (3) Who would help them in the contact with public authorities, (4) Who would lend money to them and (5) Who would visit or invite them. The answers in four categories reached from "none" to "more than four persons". With regard to contents, the questions were geared to certain items of the "Mannheim Interview on Social Support" (MISS). MISS is a structured comprehensive interview designed to elicit information about the availability and distribution of various specific support resources in an individual's social network (Veiel 1990).

Regional unemployment rate

The regional unemployment rate was based on official data from the Federal Employment Agency from June 2012. It was tested for being a second-level moderator in our model (see below, statistical analysis).

Statistics

Statistical analysis

To test hypothesis 1, a multiple mediation analysis based on multiple linear regressions was conducted to estimate the direct, indirect and total effects of the association between SES and BDI-V mediated by ERI as well as by social isolation (Fig. 2; Table 2). Normal distribution of dependent and independent variables was proved by inspection of histograms and Normal Q–Q Plots.

Mediation was defined according to the criteria of Baron and Kenny (1986):

1. The independent variable (X) must have a significant effect on the mediator (Z).
2. X must have a significant effect on the dependent variable (Y) in a regression model without adjustment for Z.
3. Z must have a significant effect on Y.
4. The effect of X on Y decreases, when adjusted for Z.

This analysis was performed for the total sample and stratified by age. In a multiple linear regression model with depressive symptoms as the dependent variable, the total effect of education was calculated adjusted for overcommitment, gender and negative affectivity. Subsequently, we embedded ERI and social isolation into the model. The slope of SES was now considered as the direct effect. The indirect effects mediated by ERI and social isolation were simultaneously calculated with the MEDIATE macro (Preacher and Hayes 2008). With this macro, we tested additionally for interaction between the mediators and independent variable and calculated 95 % percentile bootstrap confidence intervals for the indirect effects. Bootstrap provides the most powerful and reasonable method of obtaining confidence limits for specific indirect effects under most conditions (Preacher and Hayes 2008). The percentage mediated by ERI or by social isolation were calculated as the proportion explained in the standard way, i.e. the proportion of the total effect of exposure on disease that is explained by the indirect effect using an additive model (Hafeman 2009).

Hypothesis 2 was tested in two steps. First, a multilevel model based on linear regressions was performed to test for regional variation of direct and indirect (as mediated by ERI) effects of education on depressiveness (Fig. 3). Second, lower-level moderated mediation (LLM) analysis (Bauer et al. 2006) was calculated to include the regional

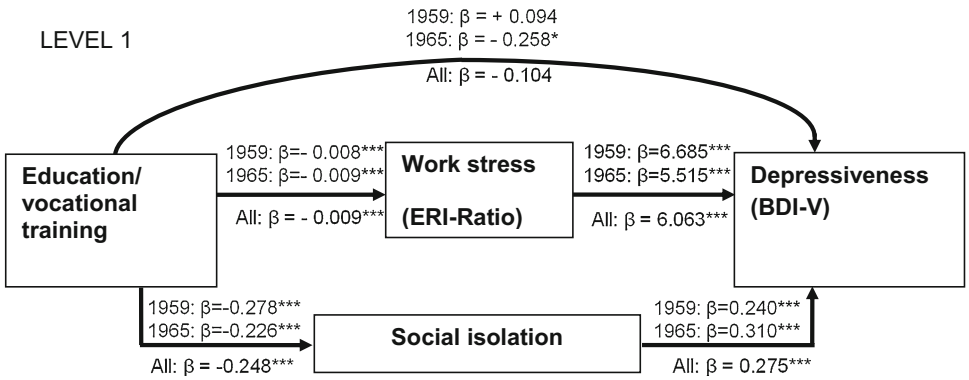

Fig. 2 Mediation[a,b] between education and depressiveness by work stress and social isolation—6,339 employees from the first wave of the lidA ('leben in der Arbeit')-cohort study 2011 in Germany [a]Model 1 with stratification by age cohort (1959, 1965) and model 2 without stratification by age cohort [b]Associations adjusted for age (model 2 only), gender, overcommitment and negative affectivity *p value < 0.05, **p value < 0.01, ***p value < 0.001 Abr.: *ERI* effort–reward imbalance, *BDI-V* short version of Beck's Depression Inventory, *1959* employees born in 1959, *1965* employees born in 1965, *all* all employees, *ß* slope, *Level 1* individual level

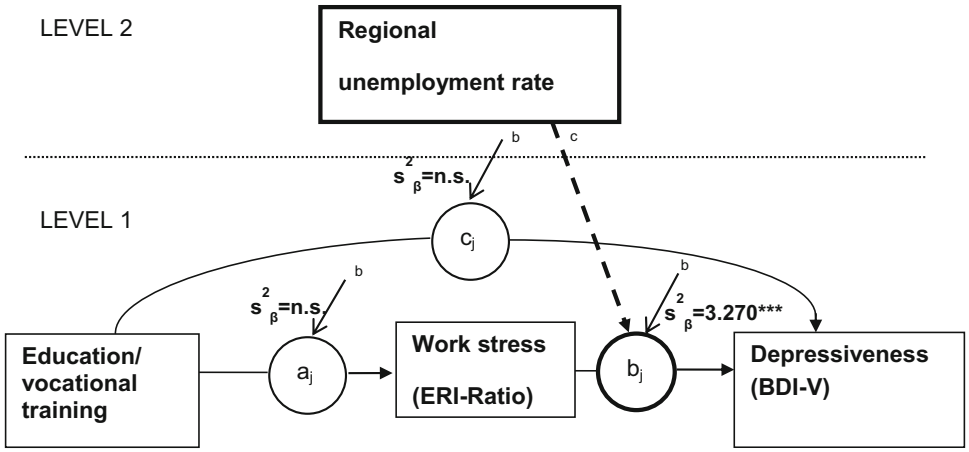

Fig. 3 Regional variation of the slopes in the association between education and depressiveness mediated by work stress and second-level moderation—6339 employees from the first wave of the lidA ('leben in der Arbeit')-cohort study 2011 in Germany. The multilevel analysis found a significant regional variation for the association between work stress and depressiveness, only. The question here is whether part of this variation could be explained by the 2nd level moderator regional unemployment (see also Tables 3 and 4 for the younger cohort) all associations adjusted for age, gender, overcommitment and negative affectivity slope variation between regions effect size of regional unemployment rate on bj see Tables 3, 4 ***p value < 0.001, *n.s.* not significant Abr.: β slope, *ERI* effort–reward imbalance, *BDI-V* short version of Beck's Depression Inventory, *Level 1* individual level, *Level 2* regional level

unemployment rate as level 2 moderator of the level 1 associations (Fig. 3; Tables 3, 4). LLM is a specific multilevel method where the mediator is located on the individual (lower or first) and the factor which moderates this mediation on the regional (upper or second) level (Fig. 1). We estimated the second-level moderating effect of regional unemployment rate on the lower-level association between education and depressive symptoms as mediated by ERI. This estimation was calculated if regional variation was observable in any part of the association between education and depressive symptoms mediated by ERI in step 1. A grand mean centering for all continuous variables has been calculated for all multilevel analyses (to keep in mind when comparing effect estimates of this part of the analysis with others).

All analyses were performed for both age cohorts separately to reveal age-specific differences. The models were controlled for gender, negative affectivity and overcommitment.

Missing data treatment

Missing data (MD) were replaced by multiple imputations (MI) with the fully conditional specification algorithm. This MI procedure enables the imputation of MD in parametric and non-parametric continuous as well as categorical items (Raghunathan et al. 2001). 20 imputed data sets were generated in agreement with the simulation results provided by Graham et al. (2007) as the fraction of MD was <30 % in our data set and the loss of power should be <1 %.

Statistical software

Statistical analyses and MD imputations were performed with SPSS 19.

Results

Participants

Of the 34,000 addresses initially drawn, 26,697 were needed to reach the precalculated sample size. Of 24,322 subjects having still the same address, 3,950 were not reachable or could not participate for other reasons (e.g. sickness). 13,735 (51.4 %) refused to participate. Of 6,637 realised interviews, 6,585 were valid. The response rate was 27.3 % according to the American Association for Public Opinion Research criteria (AAPOR 2009). After exclusion of non-working participants, 6339 employees were eligible for analysis. The existence of non-working participants is the result of a time-lag between the social security data (they are at least 1-year back in time) and the interview date. Those subjects became unemployed in the meantime.

Description

Gender distribution was well balanced in both cohorts (Table 1). Mean educational and depressive levels were slightly higher in the younger cohort. Social isolation and overcommitment were more pronounced in the older

cohort. Both age cohorts were comparable regarding ERI and negative affectivity.

Multiple mediation analysis

In all 6,339 employees, the significant association between education and depressiveness adjusted for age, gender, overcommitment and negative affectivity could be mainly explained by mediation with work-related stress and social isolation, whereas the direct effect was not significant (Fig. 2; Table 2). Nevertheless, all criteria for mediation according to Baron and Kenny (1986) were fulfilled for both mediating factors in this association.

In the age-stratified analysis, age-specific differences were observed in total, direct and indirect associations between education and depressive symptoms after adjustment for covariates (Fig. 2; Table 2). Firstly, the total association was significant for participants born in 1965, but not for those in 1959. Secondly, the indirect effect mediated by work-related stress and by social isolation was significant for both age cohorts. Finally, the direct association between education and depressive symptoms was significant for the younger cohort, only. The association between education and depressive symptoms was mediated by ERI and social isolation in the younger group, only. Therefore, multilevel analyses step 1 is displayed in detail for the total sample (Table 3) and the younger cohort (Table 4), only. There was no interaction between the mediators and the independent variable, neither in the total sample nor in age-stratified groups.

Table 1 Sample description of 6,339 employees born in 1959 and 1965 recruited in the first wave of the lida-study in Germany 2011

Variable	Birth year	
	1959	1965
Sex		
Female: N (%)	1,499 (53.8)	1,869 (52.6)
Male: N (%)	1,286 (46.2)	1,685 (47.4)
Education: mean (± SD)	4.66 (1.76)	4.82 (1.74)
Missing values	8	5
BDI-V: mean (± SD)	20.00 (13.58)	20.13 (13.73)
Missing values	432	495
ERI-Ratio: mean (± SD)	0.57 (0.28)	0.57 (0.28)
Missing values	583	709
Social isolation: mean (± SD)	11.25 (3.39)	11.08 (3.32)
Missing values	4	1
Overcommitment: mean (± SD)	13.44 (4.40)	13.32 (4.28)
Missing values	26	39
Neg. affectivity: mean (± SD)	9.91 (2.42)	9.99 (2.42)
Missing values	5	10

Data extracted from the responses to the first wave of the lidA-cohort study 2011 in Germany

Mean arithmetic mean, *SD* standard deviation, *BDI-V* Beck's Depression Inventory (applied version), *neg.* negative, *ERI* effort–reward imbalance

Multilevel analysis

In the total sample, the association between education and depressive symptoms as well as the association between education and work-related stress showed no significant regional variation (Fig. 3; Table 3). For the younger cohort, the association between education and depressive symptoms showed no significant regional variation. In the association between education and work-related stress, the regional variation was not high enough and the model did not converge. The random slope for work stress was statistically significant in the total as well as in the younger group (Fig. 3; Tables 3, 4). It was 0.013 in the total sample and 0.016 in the younger cohort. There was no effect modification by regional unemployment rate in the association between ERI and depressive symptoms in the total sample or in the younger group.

Table 2 Direct, indirect and total effect estimates in the association between education and depressive symptoms—all employees and those stratified for age from the first wave of the lidA-cohort study in Germany 2011

Effect	All subjects			Birth year					
				1959			1965		
	Estimate (CI)	*p*	(%)[a]	Estimate (CI)	*p*	(%)[a]	Estimate (CI)	*p*	(%)[a]
Direct	−0.10 (−0.29;0.08)	n.s.	45.5	0.09 (−0.23;0.41)	n.s.	–[b]	−0.26 (−0.48;−0.04)	*	68.4
Indirect (ERI)	−0.05 (−0.08;−0.03)	***	22.7	−0.05 (−0.10;−0.02)	***	–[b]	−0.05 (−0.08;−0.02)	***	13.2
Indirect (social isolation)	−0.07 (−0.10;−0.05)	***	31.8	−0.07 (−0.12;−0.04)	***	–[b]	−0.07 (−0.11;−0.04)	***	18.4
Total	−0.22 (−0.41;−0.04)	*	100	−0.03 (−0.34;0.28)	n.s.	–[b]	−0.38 (−0.59;−0.16)	*	100

CI 95 % confidence intervals, *ERI* effort–reward imbalance, *n.s.* not significant

* p value < 0.05, ** p value < 0.01, *** p value < 0.001

[a] Percent of total effect

[b] Percent not calculated as total effect not significant

Table 3 Multilevel models of the associations between education, work-related stress[a] and depressive symptoms[b]—all 6,339 employees from the first wave of the German lidA-cohort study 2011)

Dependent variable	Model 0a ERI	Model 0b Depressiveness	Model 1 ERI	Model 2 Depressiveness	Model 2 ext. Depressiveness	Model 3 Depressiveness
Fixed effects						
Level 1						
Gender	–	–	−0.061**	0.184***	0.185***	0.183***
Negative affectivity	–	–	0.081***	0.398***	0.399***	0.398***
Education	–	–	−0.054***	−0.029*	−0.027*	−0.028*
Overcommitment	–	–	0.494***	0.175***	0.175***	0.176***
ERI	–	–	–	0.131***	0.131***	0.124***
Year of birth	–	–	0.010*	0.002	0.002	0.002
Level 2						
Unemployment rate	–	–	–	–	−0.02	–
Random effects						
Intercept variance	0.011**	0.010*	0.005	0.006	0.006	0.006
ICC (%)	1.1	1.0	0.7	0.9	0.9	0.9
Random slope	–	–	0.01	0.013**	0.014**	0.0002

Model 0a and model 0b do not have any predictors. Model 1: education has a random slope, Model 2: ERI has a random slope, Model 2 ext. (ext. = extended): ERI slope not explained by regional unemployment rate, Model 3: education has a random slope

ERI effort–reward imbalance, *ICC* intraclass correlation coefficient, *BDI-V* applied version of Beck's Depression Inventory

* $p < 0$ 0.05, ** $p < 0.01$, *** $p < 0.001$, T = tendency to significance

[a] Measured by ERI

[b] Measured by BDI-V

Table 4 Multilevel models of the associations between education, work-related stress[a] and depressive symptoms[b] 3,554 employees born in 1965 from the first wave of the German lidA-cohort study 2011

Dependent variable	Model 0a ERI	Model 0b Depressiveness	Model 1 ERI	Model 2 Depressiveness	Model 2 ext. Depressiveness	Model 3 Depressiveness
Fixed effects						
Level 1						
Gender	–	–	−0.055[T]	0.183***	0.185***	0.182***
Negative affectivity	–	–	0.0672***	0.407***	0.407***	0.408***
Education	–	–	−0.058***	−0.048**	−0.048**	−0.046**
Overcommitment	–	–	0.515***	0.198***	0.199***	0.201***
ERI	–	–	–	0.118***	0.120***	0.110***
Level 2						
Unemployment rate	–	–	–	–	−0.004	–
Random effects						
Intercept variance	0.015*	0.010	0.008	0.009	0.009[T]	0.008[T]
ICC (%)	1.5	1.0	1.1	1.3	1.4	1.2
Random slope	–	–	[(1)]	0.016*	0.015*	0.002

Model 0a and model 0b do not have any predictors. Model 1: education has a random slope, Model 2: ERI has a random slope, Model 2 ext. (ext. = extended): ERI slope not explained by regional unemployment rate, Model 3: education has a random slope

ERI effort–reward imbalance; *ICC* intraclass correlation coefficient, *BDI-V* applied version of Beck's Depression Inventory

* = $p < 0$ 0.05, ** = $p < 0.01$, *** = $p < 0.001$, [T] = tendency to significance, [(1)] No sufficient variance

[a] Measured by ERI

[b] Measured by BDI-V

Discussion

According to our a priori study hypothesis 1, work stress and social isolation were mediators in the association between education and depressive symptoms for the total sample and the younger cohort. Regarding a priori hypothesis 2, multilevel analysis showed regional variation of the association between work stress and depressive symptoms, but no moderating effect of the level 2 variable 'regional unemployment rate' on this association. The association between ERI and depressive symptoms was more pronounced amongst the older than amongst the younger cohort whereas regarding social isolation, it was the other way around.

To the best of our knowledge, associations between education and depressive symptoms have not been analysed in such a complex manner so far taking into account potentially mediating work (ERI) and non-work factors (social isolation) and regional variations of the associations under study. However, our findings are in line with results from studies investigating parts of this complex network of associations. It is well known from a number of cross-sectional and longitudinal studies that depression or depressive symptoms are more frequent amongst individuals exposed to ERI (e.g. Dragano et al. 2008; Rugulies et al. 2013; Tsutsumi et al. 2012) or social isolation (e.g. Hagerty and Williams 1999). Furthermore, SES was found to be related to depression (Lorant et al. 2003; Melchior et al. 2013). Some evidence from the literature indicates that social inequality in health may vary by region (e.g. Dragano et al. 2007).

One might criticise that we used only one indicator of SES in our analysis, i.e. a combined measure of education and vocational training. However, educational attainment plays a key role within parameters defining the SES since it works as a door opener for the others (occupational position, income). Furthermore, compared to other SES indicators, education shows usually the strongest effects regarding social inequality in health (Geyer et al. 2006). Finally, education is an SES indicator which is quite stable over time (Peter et al. 2007).

We have chosen ERI a successfully tested concept of work stress used worldwide (Siegrist et al. 2004; van Vegchel et al. 2005) as indicator of the psychosocial work environment. Our analytical model might have been improved using additional information on work stress like that provided by the demand-control model (Peter et al. 2002). However, we decided prior to analysis to stay with ERI to keep the analysis at a manageable level of complexity thereby taking into account possible underestimation of the work-related effects.

Social isolation is an important indicator of the psychosocial environment associated with both, morbidity and mortality (Brummett et al. 2001). The relationship between social isolation and depression has been described (Hagerty and Williams 1999). Furthermore, an effect of SES and age on social networking has been found (Ajrouch et al. 2005). Social isolation has been observed to be a mediator between SES and depression in a study by Bruce and Hoff (1994). However, unlike us they measured SES by income and the outcome was depression.

We assumed regional unemployment rates to influence the association between ERI and depressive symptoms since an important part of the measurement of the ERI concept relates to job insecurity. However, we did not find any effect of this variable. Variations of unemployment by region have been shown to be associated with lifestyle risk factors for chronic diseases (e.g. overweight) in a German study (Dragano et al. 2007). This study used very small-scaled information on regional unemployment going down to the street level whereas in lidA only information on a broader regional level was available. Furthermore, it was conducted in a specific area in Germany with high unemployment rates, the Ruhr area, whereas lidA is a nationwide study. Our information on regional unemployment might be too crude and too far away from the individual to influence the individual's perception of job insecurity. Regional unemployment rates in Germany are updated quarterly and may vary substantially within a region. Although regional unemployment did not modify the relation between ERI and depressive symptoms, we observed a significant regional variation of this association.

The effects of education and psychosocial variables differed between age groups. The relationship between ERI and depressive symptoms was more pronounced amongst the older cohort (Fig. 2). With employee's increasing age, work overload may intensify due to a growing lack of resources to cope with job demands. Not much is known about coping behaviours and their variation throughout the life course. Yet, some evidence exists showing that coping behaviour is age related (Abraham and Hansson 1995). Furthermore, education was not significantly associated with depressive symptoms in the older cohort (direct effect of education). Whilst the association between education and ERI was also weak in the younger cohort, the cohort difference might be explained by the fact that the overall educational level was lower amongst the older ones and thereby variation of education was reduced. The door opener function of education could have become more important over time, i.e. amongst the older cohort, all levels of education were more open to jobs at quite different levels of qualification and related work stress as well as depressive symptoms. However, selection bias as the reason for the observed age-related differences cannot be excluded. Finally, the observed differences might be due to age or cohort effects. Yet, this cannot be investigated at the

present stage of the study. In the future, the Schaie design of the lidA-study will allow disentangling effects between and within the age cohorts using longitudinal data (Schaie 1994).

LidA is a population-based study representative for employees subject to social insurance of two birth years (1959 and 1965) in Eastern and Western Germany. Selectivity analysis revealed almost no selection bias (Hasselhorn et al. 2014). Another strength is the application of well-tested questionnaires (e.g. ERI, BDI-V) improving the internal validity of the study.

We used standard methods to calculate effect proportions explained by mediation: If interaction between the exposure and the mediation variable is absent, a standard measures for mediation based an additive models will equal the corresponding natural effects ("pure" and "total") based on counterfactual-based definitions (Hafeman 2009). Whereas it was our primary goal to prove the hypothesis of the mediating effects of work-related stress and social isolation qualitatively, only we can in agreement with Hafeman (2009) provide a quantification of the indirect effects, additionally (Table 2) because interactions between exposure and both mediating variables were excluded in our data by a test of homogeneity provided by the MEDIATE macro. The accuracy of this quantification of the indirect effects, however, may be limited by bias introduced by the multilevel modelling approach where a full separation of between- and within-group effects is not possible without introducing bias (Preacher et al. 2010). An alternative approach to improve the quantification of the indirect effects using moderated lower-level mediation models could be a multilevel structural equation approach (Preacher et al. 2010). It would allow for unbiased estimates of multiple indirect effects in a multilevel framework. However, this method has not been applied for our situation so far. For the calculation of 95 %-CI for the indirect effects, we chose the percentile bootstrap confidence interval method recommended by Preacher and Hayes (2008) where normal distribution of the indirect effect is not a prerequisite.

Beside potential bias introduced by unknown covariates inherent to all observational studies, one particular limitation is the—currently—cross-sectional design of this analysis ruling out causal conclusions from our results. Yet, with availability of follow-up data, this confirmatory analysis can be conducted longitudinally taking into account timely sequence of exposure and outcome and changes over time. This can be an important contribution to fill an existing gap in methodological sound prospective studies investigating the mediating effect of work stress measured by effort–reward imbalance to explain social gradients in health (Hoven and Siegrist 2013). Furthermore, due to the cross-sectional character of data analysis, the risk of reversed causality cannot be ruled out, i.e. that persons characterised by depressive symptoms report higher levels of work stress or of social isolation. Our observed mediations can be proved by longitudinal data, only.

The relatively low response rate is in agreement with the declining willingness to participate in surveys in Germany (Hasselhorn et al. 2014). However, a sensitivity analysis showed that the representativeness of our study sample to the target population of all employees subject to social security contributions born in 1959 or 1965 is very high regarding different sociodemographic variables (Hasselhorn et al. 2014). In addition, we performed multiple imputations to reduce bias of our estimates introduced by item non-response. Finally, generalizability of results is restricted to the two age groups of employees subject to social security contributions working in Germany.

Conclusions

Our findings provide first cross-sectional evidence that ERI and social isolation are mediators of the association between education and depressive symptoms. These associations showed age-related and regional variations. After age stratification, we observed mediation according to Baron and Kenny (1986) for the younger cohort, only. Future longitudinal analysis will allow disentangling effects of cohort, age and time. If our results were proved longitudinally, this could provide a scientific base for future preventive programmes, i.e. to improve employee's mental health by reducing work-related stress.

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