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Computers and types of control in relation to work stress and learning

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Traditional machine-paced work shows adverse effects on worker health and learning. It is hardly known whether technological pacing shows the same effects in computer work. Hypotheses on work stress and learning were formulated regarding the effects of technological pacing, in the context of computer work performed during at least half of the working day, especially. Further, method–order (m–o) autonomy was conceived as another control and standardisation mechanism and taken into account as a potentially important modifier of the effects. As hypothesised, this study's secondary analyses of a European survey of 18,723 employees revealed that the level of adverse work stress for technological pacing among computer workers was almost equal to the level found for 'traditionally machine-paced' workers. Distinct interactions with m–o autonomy were also shown. For instance, lack hereof was especially problematic for work stress among technologically paced computer workers. Software's flexible nature and its relatively easy adaptability to chosen work organisation modes may explain this. Lastly, in technologically paced work, m–o autonomy appeared to reinforce learning. In sum, many hypotheses were supported especially on the main and interaction effects regarding work stress, but less so regarding learning. Recommendations for future research and practical implications are discussed.

Keywords: automation; ICT; exploratory learning; moderating effect

1. Introduction

Previous research and theorising suggests that technology characteristics may affect worker health and well-being (Blauner 1964; Karasek and Theorell 1990). For example, a mechanically controlled car assembly line is archetypical of such associated outcomes as 'alienation' of the worker and of health complaints. Main production and service processes are nowadays often controlled by computers, sometimes reintroducing the 'traditional production line'. Modern computer technology enhances the capacity to control the flow of tasks through the organisation. The downside is that in numerous information-intensive jobs, new technologies may allow increasing the work pace (Green 2004, 2006, 70, 174); the possibilities offered by workflow-software and enterprise resource planning systems are typical in this respect (Batenburg, Benders, and van der Blonk 2008). In such information-intensive processes, each worker is required to add and transform information in a manner almost entirely prescribed by the system which, in turn, takes the information to the next workstation. Computer work in a regime of technological pacing can be found in a broad array of jobs and tasks such as administration, processing insurance policies, placing orders and scheduling work and in many call centre jobs (Miozzo and Ramirez 2003; Green 2006, 70, 77; Deery, Iverson, and Walsh 2010, 182).

Pacing by computerisation as a new control strategy may constitute an important emerging risk, with employee outcomes similar to those caused by machine pacing. Early research suggested that pacing produced by computerisation affects work stress even stronger than factory pacing, since computers can operate at high speed on a continuous basis, and can provide close monitoring of worker performance (Smith et al. 1981; Smith and Amick 1989, 281; cf. Vanderburg 2004). However, comparative studies on computer-paced versus machine-paced work are scarce. Moreover, the studies that are available neglect the possible *combined* influence of technological pacing and other control and standardisation mechanisms in the work organisation on employee health and well-being. Nevertheless, such features of the work organisation may be of crucial importance in mitigating or reinforcing employee outcomes of jobs which are (or are not) characterised by technological pacing (cf. Orlikowski 2010). For instance, the extent to which technological pacing affects the worker likely depends on the choices by management: pacing

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combined with rigid bureaucratic control and standardisation of working methods and order of tasks may show very different results from pacing in environments that empower the worker (Zuboff 1988; cf. Adler and Borys 1996). In any case, computer pacing brings back dominant engineering principles, such as Taylor's scientific management or a business process re-engineering approach. Such approaches may reinforce adverse health and well-being effects.

This study aims to examine, by re-analysing a large-scale European data set, whether and how mental health (i.e. work stress) and learning-by-doing are affected by types of technological pacing. Special attention will be paid to the question whether computer-paced work shows similarities with traditional, machine-paced 'assembly-line work', or, conversely, with non-paced computer work, in relation to these employee outcomes. Also, the difference that autonomy makes in these relations regarding working method and order is an important research question to be addressed by this paper. That is, besides technological pacing, the level of method–order (m–o) autonomy is another control and standardisation mechanism in the work organisation (Meyer and Rowan 1977; Mintzberg 1979) and potentially an important modifier of effects by technological pacing on employee outcomes.

2. Concepts, background and hypotheses

2.1. *Concepts*

The central concepts in this article are computer work and pacing of the work rhythm by technology, besides m–o autonomy as another control dimension in the work organisation. On the one hand, the features of computer work and underlying choices in the work organisation remain a 'black box' in many studies on relations of computer work and employee outcomes (cf. Orlikowski 2010). As a consequence, upgrading, downgrading and polarisation trends have been reported in terms of quality of working life (cf. Andries, Smulders, and Dhondt 2002; Orlikowski and Scott 2008). Technological pacing, on the other hand, originates to a large extent from the division of labour principles as proposed by Adam Smith and developed further and practised by such scientific management protagonists as Taylor and Ford in the beginning of the previous century. For instance, Karasek and Theorell (1990, 267) state that optimising the use of machine-driven production technologies such as assembly lines has justified management's need to control all factors in its operating environment. This justification may also hold true for the deployment of new computer technologies. Besides, to date, different types of computer software also allow centralised coordination and control of the pace, order and method of operations that were previously integrated by worker autonomy (Karasek and Theorell 1990, 267). Therefore, both pacing by computer software and pacing by a machine represent a type of (low) employee job control, stemming from job design choices by management.

At present, computer-paced tasks, which can be found in administration, processing insurance policies, placing orders and scheduling work, can easily be coordinated and prescribed by integrated company-wide software systems. There may be strain-producing side effects, however, as illustrated by the first-generation (company-wide) workflow-software systems. Such systems could easily control the division of workload across functions, such as team leader, office clerk or a sales job. However, the division of workload across employees could not easily be achieved by these early systems. Another feature of these systems which produces strain for employees while also decreasing learning opportunities (as elaborated in the next section) is the extent to which rigid prescriptions in the order of activities (for example 'activity *n* follows activity *m*') and/or set deadlines dictate the planning of activities. However, new systems allow more flexibility in the flows since they permit workers to choose among multiple equivalent execution orders of activities. This provides the worker with more autonomy in dealing with the workload (cf. Van Kaathoven et al. 1999). However, in many inbound call centre jobs, for instance, software still determines the delivery of calls to the workers, with phone calls following one another without interval (Miozzo and Ramirez 2003; Green 2006, 70, 77; Deery, Iverson, and Walsh 2010, 182). Further, computer pacing of the employee's work rhythm may also come from programmable robots or advanced computer-aided manufacturing.

As set out in the introduction, this study will contrast technologically paced computer work with traditional machine-paced work, while both will also be contrasted with non-paced computer work and work in which no such technological devices are used. Technological pacing implies a limitation of the employee's control ('autonomy') on the work rhythm. Another control dimension concerns autonomy in deciding the work method or the order of tasks. This dimension is distinguished from technological pacing of the work rhythm since – as illustrated above – such discretion on the method and order may moderate pacing effects on work stress and learning.

2.2. *Types of job control and the demand–control model*

More generally, decision latitude or job control is a key aspect in Karasek's demand–control (DC) model (Karasek 1976, 1979; Karasek and Theorell 1990). The DC model is well known and influential in the field of work organisation, work stress and learning research. The model is based on theories developed in the areas of job (re)design, socio-technical thinking and organisational sociology (e.g. Blauner 1964; cf. Benders et al. 2006), psychological work stress (e.g. Selye [1936] 1976) and learning (e.g. German action regulation theory; Hacker 2003) (Karasek

Table 1. Research questions and hypotheses (H) under study.

Question 1	How do computer work and technological pacing interrelate with each other and with m–o autonomy and workload?
H1a, H1b	Technological pacing strongly associates with low levels of m–o autonomy (H1a) and associates strongly with high levels of workload (H1b)
Question 2	How are computer work and technological pacing related to work stress (2a) and learning (2b)?
H2	Technological pacing of the work rhythm associates with high work stress levels
H4	Technological pacing of the work rhythm associates with low levels of learning
Question 3	What are the implications for work stress and learning in technologically paced computer work, compared to work stress and learning associated with traditional machine-paced work and computer work that is not technologically paced – given differences in m–o autonomy and workload levels? (i.e. two-way interaction by computer work and technological pacing)
H3a, H3b	Computer work that is technologically paced likely yields relatively high work stress (H3a), as does traditional machine-paced work (H3b), compared to computer work that is not technologically paced
H5a, H5b	The lowest level of learning is found in traditional machine-paced work (H5a), an intermediate level in technologically paced computer work (H5b), and the highest level in computer work that is not technologically paced
Question 4	How does m–o autonomy moderate relations between, on the one hand, computer work, technological pacing, its combinations and, on the other hand, work stress (4a) and learning (4b)? (i.e. three-way interactions by technological pacing and computer work and m–o autonomy)
H6a, H6b	In traditional machine-paced work (H6a) and in technologically paced computer work (H6b), m–o autonomy mitigates work stress more strongly than in (computer) work that is not technologically paced
H7a, H7b	In traditional machine-paced work, high m–o autonomy relates more strongly to higher levels of learning (H7a) – and in technologically paced computer work, it does so to a lesser extent (H7b) – than it does in (computer) work that is not technologically paced

1976, 1979; Karasek and Theorell 1990). One of the predictions of the DC model states that high–low job control represents a risk factor that is detrimental to (mental) health outcomes such as work stress and coronary heart disease. The model also predicts that high job control fosters motivation and learning (Karasek and Theorell 1990).

In the DC model, decision latitude is an operationalisation of the much broader control concept (which, in some literature, for instance, also includes participation in decision-making on organisational restructuring). Decision latitude has often been defined as the combination of decision authority and skill discretion (the opportunity to use and develop skills on the job). In this paper, we apply a more narrow approach of the job control concept, being decision authority (autonomy). Of course, the presence of decision authority can provide employees with feedback on the results of their decisions, which also fosters learning new things.

Besides, we limit decision authority to the areas of working method and order and technologically set degrees of freedom regarding work pace. Therewith, the present study tries to assess the importance of specifying control dimensions (Mikkelsen, Øgaard, and Landsbergis 2005) in models on work organisation, such as the DC model, and of paying attention to technology-related variables.

Lastly, another concept to be taken into account concerns workload – which is a job demand (and also part of the DC model). This concept has been shown to be relevant for work stress and learning (cf. Karasek and Theorell 1990). However, in the present paper, since the focus is on technological pacing, in computer work, and its interrelation with m–o autonomy as another control dimension and a potential modifier, we will not discuss the workload concept in detail. We will just adjust the analyses for workload.

2.3. *Research questions and formulation of hypotheses*

The four research questions in this paper concern the relations among the concepts described, being those among (1) computer work, technological pacing and m–o autonomy and workload; (2) computer work, technological pacing and work stress and learning; (3) two-way interactions between computer work and technological pacing in the relations with work stress and learning; and (4) three-way interactions between m–o autonomy, computer work and technological pacing in the relations with work stress and learning. Table 1 provides an overview of the research questions and hypotheses to be elaborated next.

The first research question is: *How do computer work and technological pacing interrelate with each other and with m–o autonomy and workload? (Question 1).* As described in Section 2.1, technological pacing and other specific work organisation modes likely stem from the same management choices aimed at centralised control and coordination of operations (Karasek and Theorell 1990) – hence the hypotheses ('H'): *Technological pacing strongly associates with low levels of m–o autonomy (H1a), and strongly with high levels of workload (H1b).* With respect to computer work as such, no specific, theoretically grounded, hypotheses are formulated. Indeed, computers and associated work organisation and control practices are flexible by nature. Therefore, computer work can take many work organisation characteristics, dependent on managerial choices and alike. For instance, computer work deployed in a rigid bureaucracy with standardised, prescribed working methods may show very different results from computer work in organisational settings where management chose to leave more control to the employees.

Research question 2 reads: *How are computer work and technological pacing related to work stress (2a) and learning (2b)? (Questions 2a and 2b).* Based on Section 2.1, we expect that *technological pacing of the work rhythm associates with high work stress levels (H2).* With respect to learning, being the second – and motivation-related – outcome in Question 2, it follows from the DC model's predictions for the control concept that technological pacing may show an adverse effect on learning too. We hypothesise: *Technological pacing of the work rhythm associates with low levels of learning (H4)*.

Research question 3 looks at two-way interaction effects by computer work and technological pacing on work stress and learning: *What are the implications for work stress and learning in technologically paced computer work, compared to work stress and learning associated with traditional machine-paced work and computer work that is not technologically paced–given differences in m–o autonomy and workload levels?* (*Question 3*). As set out in the introduction, we hypothesise a two-way interaction between computer work and technological pacing such that *Computer work that is technologically paced, likely yields relatively high work stress (H3a), as does traditional machine-paced work (H3b), compared to computer work that is not technologically paced–also when controlling m–o autonomy and workload levels*.

Regarding learning, computer work that is not technologically paced, is likely to represent jobs that offer the best opportunities for development and learning. For example, the higher level of control on the work speed in such work allows altering the speed of the work or taking short breaks. This may offer opportunities for reflection on the work done and skills used, or may leave room for experimentation. Both are conditions for learning (cf. Karasek and Theorell 1990; Hacker 2003; Taris et al. 2003). What likely remains as a result of automation in manual work, are routine 'residual tasks' that are hard-to-automate (*cf.* Benders 1995): a situation that will often apply to 'traditional' machine-paced work. Conversely, in technologically paced computer work, it is likely that especially non-routine and more complex procedures are left to decide for by the worker (cf. Karasek and Theorell 1990, 172; Green 2006, 39). Learning effects will therefore be stronger in technologically paced computer work than in traditional machine-paced work, although equally characterised by technological pacing of the work rhythm. In sum, we hypothesise on the two-way interaction between computer work and technological pacing that: *The lowest level of learning is found in traditional machine-paced work (H5a), an intermediate level of learning is found in technologically paced computer work (H5b), and the highest level of learning is found in computer work that is not technologically paced–also when controlling m–o autonomy and workload levels.*

The last, fourth, research question addresses a further three-way interaction in the relations with the outcomes. Now, the importance of m–o autonomy is also assessed on top of interactions between computer work and technological pacing. The research question reads: *How does m–o autonomy moderate relations between, on the one hand, computer work, technological pacing and its combinations, and, on the other hand, work stress (4a) and learning (4b) – given differences in workload levels?* (*Questions 4a and 4b*). For instance, in technologically paced computer work, such as in call centres, the extent of m–o autonomy may vary. Here, m–o autonomy may involve opportunities of adjusting the conversation scripts (cf. Karasek and Theorell 1990, 269) or, in administrative workflow-software processes, may involve the selection of work routines or the adjustment of data-entry formats for non-routine cases (i.e. the work method itself). Similarly, there are opportunities to adapt the work order and method in traditional machine-paced work. Thus, the absence (or presence) of such control possibilities by m–o autonomy should reinforce (or mitigate) work stress, especially in technologically paced work settings. The three-way interaction hypothesis on technological pacing, computer work and m–o autonomy in relation to work stress is: *In traditional machine-paced work (H6a) and in technologically paced computer work (H6b), m–o autonomy mitigates work stress more strongly than in (computer) work that is not technologically paced.*

Lastly, with respect to learning, m–o autonomy may compensate adverse technological pacing effects in traditional machine-paced work, especially (and to a lesser extent, in technologically paced computer work). Here, learning can be enhanced most. Indeed, enrichment with more m–o autonomy involves more interesting tasks and the use of process knowledge (e.g. Karasek and Theorell 1990, 264, 269) – hence the three-way interaction hypothesis on m–o autonomy, computer work and technological pacing: *In traditional machine-paced work, high m–o autonomy relates more strongly to higher levels of learning (H7a)– and in technologically paced computer work, it does so to a lesser extent (H7b) – than it does in (computer) work that is not technologically paced.*

3. Method

3.1. Participants

In the present study, secondary analyses were carried out on data from the fourth European Working Conditions Survey (EWCS). This rich cross-sectional survey was conducted by the European Foundation for the Improvement of Living and Working Conditions (EUROFOUND) in the EU27 in 2005. Workers were interviewed face to face in their homes using a structured questionnaire on their employment situation and working conditions. In each country, the

EWCS sample followed a multi-stage, stratified and clustered design. The overall response rate was 48%. In each country about 1000 interviews were carried out, except for some small countries, in which about 600 interviews were undertaken. The sample of the EWCS is representative of the workers (employed and self-employed) during the fieldwork period in each of the countries covered (Parent-Thirion et al. 2007).

In this article, we focused on salaried employees only; freelancers and the self-employed were excluded from the sample. This selection criterion is based on the aim of studying computer work and technological pacing in relation to (formal) other control practices that employees face. Conversely, freelancers and self-employed themselves can choose to a large extent what their work organisation looks like. Next, after list-wise deletion of missing values on the study variables, 18,723 out of 21,415 employees were in the final sample, averaging 40 years of age (SD = 12), while 53% were female.

3.2. Instruments

The operational definitions of the variables were based on the available indicators in the EWCS 2005. Due to the EWCS's aim to give a broad overview of working conditions, the questionnaire generally included abbreviated, sometimes slightly modified versions of existing scales. However, the questions had high face validity.

Computer work was established by the item: 'Does your main paid job involve working with computers: PCs, network, mainframe?' Response alternatives were anchored on a seven-point time scale. For the aim of this study, these were dichotomised into: half of the time or more, versus around a quarter of the time or (almost) never. *Technological pacing* of work was measured by the EWCS question 'On the whole, is your pace of work dependent, or not, on automatic speed of a machine or movement of a product?' (response alternatives: 'no' and 'yes'). As a result, when technological pacing is present in an employee's job but no computer is used during about half of the working time, or more, this situation likely represents traditional assembly-line work. On the contrary, employees using a computer at least half of the time and whose work rhythm is technologically paced likely perform computer-paced work. Next, in the data, a group of employees can be distinguished who work with a computer half of their time or more but not in a regime of technological pacing. Lastly, there is a group which is rather heterogeneous: apart from non-users of technology, this category likely contains users of other types of technology not established by the EWCS. Due to this group's heterogeneity, this paper focuses on the first three groups when describing the results.

M–o autonomy was measured with two items that were adapted from the Job Content Questionnaire (JCQ) scales (Karasek, Pieper, and Schwartz 1985). The two items were: 'Are you able, or not, to choose or change...?' 'your order of tasks', 'your methods of work' (response categories: 'no' and 'yes'). The inter-item correlation r was .55. The mean of the two item scores constituted the score for the autonomy concept.

Workload was operationalised by EWCS items on *work intensity*. These two items were adapted (by EUROFOUND) from the JCQ self-report measure of psychological job demands (Karasek, Pieper, and Schwartz 1985). Although, as the developers argue, self-report of a 'demanding' job doubtless includes an element of subjective perception of stress, there is also a strong evidence of validity for an objective component (Karasek et al. 1981). The item wordings were designed to keep individual appraisal processes to a minimum (cf. Zapf 1993). The questions were formulated as 'Does your job involve ...?': 'Working at high speed', 'Working to tight deadlines' (1 ='never', 7 ='all of the time'); r was .52.

The outcome variable *work stress* was assessed by a scale compiled from possible indicators that represent work-related symptoms (cf. D'Amato and Zijlstra 2003; McAnaney and Wynne 2006), predicting adverse long-term mental health outcomes. In the EWCS questionnaire's routing, work relatedness of health effects was measured first by the indicator: 'Does your work affect your health, or not?' ('no' and 'yes'), and if the latter applied, 'How does it affect your health?'. Multiple answers were possible. The symptoms selected were 'stress'; 'overall fatigue'; 'sleeping problems'; 'anxiety' and 'irritability' (0 ='no' and 1 ='yes'). Cronbach's α of the scale was .83; the scale score was calculated as the sum of the five symptoms.

Finally, in line with the Karasek tradition, *learning* was conceptualised by a measure compiled from two questions/statements: 'Generally, does your main paid job involve learning new things?' (0 ='no' and 1 ='yes') and 'At work, I have opportunities to learn and grow' (1 ='almost never' to 5 ='almost always'). The JCQ (Karasek, Pieper, and Schwartz 1985) was the source of both items, which were slightly modified by EUROFOUND. Due to the differences in the number of answer categories per item, first we standardised the item scores (z-transformation) before these were averaged; r was .44. In this study, learning therefore refers to 'informal' learning or learning-by-doing (instead of formal training-related learning).

3.3. Data analyses

Multiple linear regression analyses were conducted for the work stress and learning variables, with the predictor variables entered in steps. In order to increase the robustness of the results, we adjusted the analyses for several socio-demographic background variables, which in earlier research have shown to be associated with both the predictor variables and work stress and learning.

Table 2. Univariate associations of computer work and technological pacing with socio-demographic, m–o autonomy, work intensity, work stress and learning variables (column percentages and means) ($N = 18,723$).

	Computer work ≥ half of the time					On the whole, technologically paced work				
	No	Yes	Total	df	$\chi^2/t/F$	No	Yes	Total	df	$\chi^2/t/F$
Sex				1	90.0***				1	314.4***
male	49	42	47			44	61	47		
female	51	58	53			56	39	53		
Age (in years)	41	40	40	15,092	4.6***	41	39	40	18,721	8.7***
Educational attainment				2	2043.1***				2	481.1***
no/primary/lower secondary	26	8	20			18	28	20		
upper/post-secondary/(pre-) vocational	57	48	53			52	60	53		
tertiary – first or advanced level	17	45	27			30	12	27		
Occupation				9	4781.1***				9	1971.1**
legislators, senior officials and managers	3	8	5			5	3	5		
professionals	11	21	15			17	5	15		
technicians and associated professionals	12	23	16			17	10	16		
clerks	6	29	15			16	10	15		
service workers and shop and market sales workers	16	8	13			14	7	13		
skilled agricultural and fishery workers	1	0.1	0.8			0.8	0.8	0.8		
craft and related trades workers	19	4	14			11	27	14		
plant and machine operators and assemblers	11	2	8			5	21	8		
elementary occupations	20	4	14			14	16	14		
armed forces	0.7	0.8	0.7			0.8	0.4	0.7		
M–o autonomy (0 = low to 1 = high)	0.58	0.76	0.64	16,283	−30.7***	0.68	0.47	0.64	4645	24.9***
Work intensity (1 = low to 7 = high)	3.0	3.2	3.0	14,682	−8.0***	2.9	3.7	3.0	4452	−25.0***
Work stress (0–5 symptoms)	1.0	0.81	0.90	14,154	6.2***	0.86	1.1	0.90	4618	−9.3***
Learning (*z*-scores: −1.70 = low to 0.99 = high)	−0.20	0.36	0.00	17,763	−49.8***	0.03	−0.15	0.00	18,721	11.2***

*$p < .05$.
**$p < .01$.
***$p < .001$.

Table 3. Means (M), standard deviations (SD) and correlations of the central study variables ($N = 18,723$).

	M	SD	1	2	3	4	5
1. Computer work[a]	0.36	0.48	1				
2 Technological pacing[b]	0.17	0.38	−0.10***	1			
3. M–o autonomy (0 = low to 1 = high)	0.64	0.42	0.21***	−0.19***	1		
4. Work intensity (1 = low to 7 = high)	3.0	1.7	0.06***	0.20***	−0.06***	1	
5. Work stress (0–5 symptoms)	0.90	1.4	−0.04***	0.07***	−0.03***	0.18***	1
6. Learning (range: −1.70 = low to 0.90 = high)	0.00	0.85	0.32***	−0.08***	0.29***	0.05***	−0.01*

[a] 0 = (almost) never up to one-fourth of the time and 1 = around half of the time or more.

[b] 0 = no and 1 = yes.

$^{*}p < .05$.

$^{**}p < .01$.

$^{***}p < .001$.

Regression model 0 (M0) contained the socio-demographic background variables sex, age, educational attainment (three levels), occupation (first digit code from the International Standard Classification of Occupations; categories also listed in Table 2) and country. In M1, the computer work and technological pacing dummies were added to the regression. Next, in M2 the analyses were adjusted for work organisation (main terms). Lastly, to test for moderation (interaction), interaction terms were created using the guidelines of Aiken and West (1991). The models M3 to M5 contained, respectively, the two-way interaction terms of computer work and technological pacing; the two-way interaction terms of these technology variables and the work organisation characteristics, and the three-way interaction terms of computer work and technological pacing and the work organisation characteristics. If significant, these interactions were graphically represented. Additionally, we chose values of the – continuous – predictor variables one standard deviation below and above the mean. Next, simple regression lines were generated by entering these values in the equation.

In order to further increase the robustness of the results, we also adjusted models 2–5 for another work content characteristic and its interactions, namely an indicator on job complexity (in addition to other adjustments such as for educational attainment and occupation; results not included in Table 4). This additional indicator on job complexity was measured rather straightforwardly by the EWCS question 'Does your job involve complex tasks? (0 =no; 1 =yes)'.

Since the large sample size favours the statistical significance of small effect sizes, we also include a relevance criterion: only significant associations with (−).05 as the lower threshold for the effect sizes will be discussed. Significant two- and three-way interaction effects, however, will be discussed also when they are below the threshold, for it is harder to bring these effects to the fore, in general, due to multiplication of error terms.

4. Results

4.1. Descriptive analyses

In terms of gender, age, educational attainment and occupation, Table 2 shows the profiles of employees carrying out computer work half of their time or more and also of employees performing technologically paced work. About 36% of the employees in the sample used a computer half of their working time or more. Computer work was most common among females, among employees with intermediate or tertiary educational qualifications and was relatively often carried out by clerks, technicians and associate/assistant professionals as well as by professionals. Technological pacing of work was faced by 18% of the employees in the sample. This type of work was performed relatively more often by men and these workers were younger than those in work without technological pacing. Workers with lower educational qualifications were overrepresented and the dominant job titles were craft and related trades workers, plant and machine operators and assemblers, and elementary occupations (e.g. transport labourers and freight handlers).

Besides, computer work and technological pacing were associated, albeit to some extent only. Overall, in the EU27, when applying cross-national weights on the sample, cross-tabulations of the two technology variables revealed that 5% of the employed working population performed computer work during half of their working time or more in a regime of technological pacing, while 13% performed 'traditional' technologically paced work (without or only marginal use of a computer). Computer work during at least half of the working time that was generally not technologically paced was performed by 33% of the employees. The remaining 48% worked with a computer for only a small part of the working time without technological pacing or in a work environment with no or unknown technology use – at least without technological pacing.

Table 4. Results of the multiple linear regression analyses of work stress and learning (standardised regression coefficients (β); $N = 18,723$).

	Work stress					Learning				
	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5
	β	β	β	β	β	β	β	β	β	β
Technology:										
CW: Computer work (0 = no/little; 1 ≥ half of the time)	−.02*	−.02*	−.05***	−.07***	−.07***	.15***	.10***	.10***	.08***	.08***
TP: Technological pacing (0 = no; 1 = yes)	.07***	.08***	.04***	.02	.02	.00	.00	.00	.02	.02
Other work organisation control dimensions:										
MOA: m–o autonomy (0 = low to 1 = high)		−.03***	−.03***	−.04***	−.04***		.12***	.12***	.12***	.12***
WI: Work intensity (1 = low to 7 = high)		.17***	.17***	.17***	.17***		−.00	−.00	−.00	.00
'Computer work technologically paced' (two-way interaction):										
CW*TP			.02*	.02*	−.02			.00	−.00	.01
Other two-way interactions:										
CW * MOA				−.03*	−.03*				−.04**	−.04**
CW * WI				.00	−.00				.00	.00
TP * MOA				−.02	−.03				.03*	.03*
TP * WI				−.00	−.00				−.00	.00
Three-way interactions:										
CW * TP * MOA					−.03*					.01
CW * TP * WI					.01					.00
R^2	.077***	.118***	.118***	.119***	.120***	.257***	.331***	.331***	.334***	.334***
R^2 change	.005***	.042***	.000	.001**	.000*	.015***	.074***	.000	.003***	.000
F	37.8[a]	56.8[b]	55.7[c]	49.5[d]	46.9[e]	157.6[a]	210.0[b]	205.3[c]	183.6[d]	173.4[e]

Note: Analyses adjusted for sex, age, educational attainment (3 categories), occupation (10) and country (27) (Model 0). Besides models 2–5 also adjusted for 'Complex tasks, in job' (0 = no; 1 = yes) and its two- and three-way interactions with technology (results not included in the table).

[a] This F-value has 41, 18,681 df.
[b] This F-value has 44, 18,678 df.
[c] This F-value has 45, 18,677 df.
[d] This F-value has 51, 18,671 df.
[e] This F-value has 54, 18,668 df.
*$p < .05$.
**$p < .01$.
***$p < .001$.

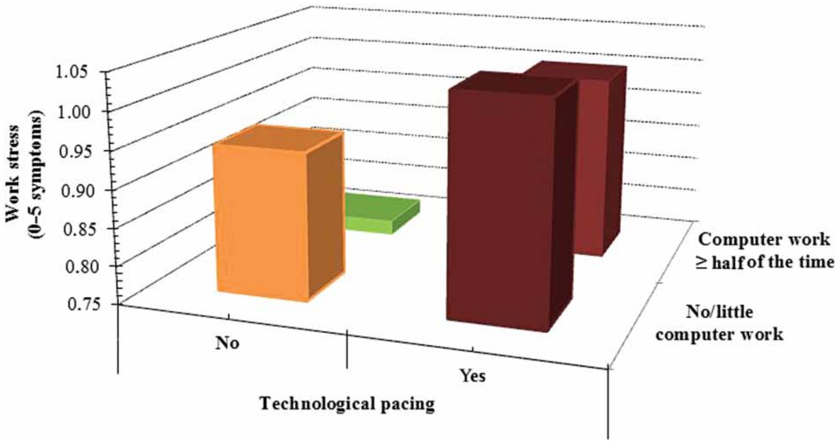

Figure 1. Two-way interaction effect of computer work and technological pacing on work stress (means multivariately adjusted based on linear regression).

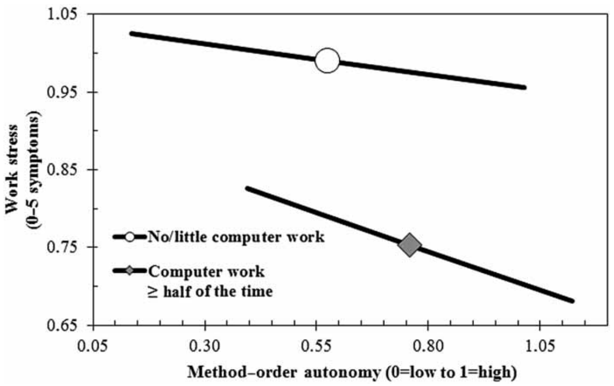

Figure 2. Two-way interaction effect of computer work and m–o autonomy on work stress (means multivariately adjusted based on linear regression).

4.2. *Computer work and technological pacing related to work organisation, work stress and learning*

Tables 2 and 3 also show the univariate associations between performing computer work during about at least half of the time and technological pacing and m–o autonomy and work intensity. Besides, the relations are shown with work stress and learning. These univariate associations provide answers to research question 1 and preliminary answers to research question 2.

Employees working with computers half of their time or more – labelled, here: 'computer workers' – are rated more favourably for m–o autonomy than employees not or only very partially using a computer (m–o autonomy mean score of .58 versus .76, Table 2) ($r = .21$; $p < .001$, Table 3). The first group also faced somewhat higher work intensity levels (3.2 on average versus 3.0) ($r = .06$; $p < .001$). There was hardly any association between computer work and work stress levels, while learning scores were relatively favourable for computer workers (*z*-scores .36 versus −.20) ($r = .32$; $p < .001$).

Employees in technologically paced work showed relatively low levels of m–o autonomy (.47 versus .68 for non-technologically paced work) ($r = -.19$; $p < .001$) and learning (−.15 versus .03) ($r = -.08$; $p < .001$), but high levels on work intensity (3.7 versus 2.9) ($r = .20$; $p < .001$), while work stress was also more common among employees in technologically paced work than among employees in work without technological pacing (1.1 versus .86) ($r = .07$; $p < .001$). With respect to research question 1, H1a and H1b were, therefore, supported: employees in a technological pacing regime ranked low on m–o autonomy, and high on work intensity.

4.3. *Work stress*

In addressing research question 2 and its accompanying hypothesis, the bivariate relations between computer work and technological pacing and work stress and learning were analysed using multiple regression. Table 4 presents the results of the regression models. Model 1 (M1) shows that, even when controlling for background characteristics, workers in a regime of technological pacing reported relatively high work stress ($\beta = .07$; $p < .001$). Similar to the univariate analyses, there was no relevant association between computer work and work stress.

Adding m–o autonomy to the work stress model, and adjusting for work intensity too (M2, Table 4), the associations of technological pacing with work stress remained intact (H2 supported). M3 included the interaction term of technological pacing and computer work (cf. research question 3). It turned out that especially computer work which is not technologically paced showed the most favourable levels of work stress. Conversely, technologically paced computer work showed adverse work stress levels which were (almost) equal to traditional machine-paced work ($\beta = .02$; $p < .05$; Table 4 and Figure 1). H3a and H3b on the two-way interactions between computer work and technological pacing were, therefore, supported.

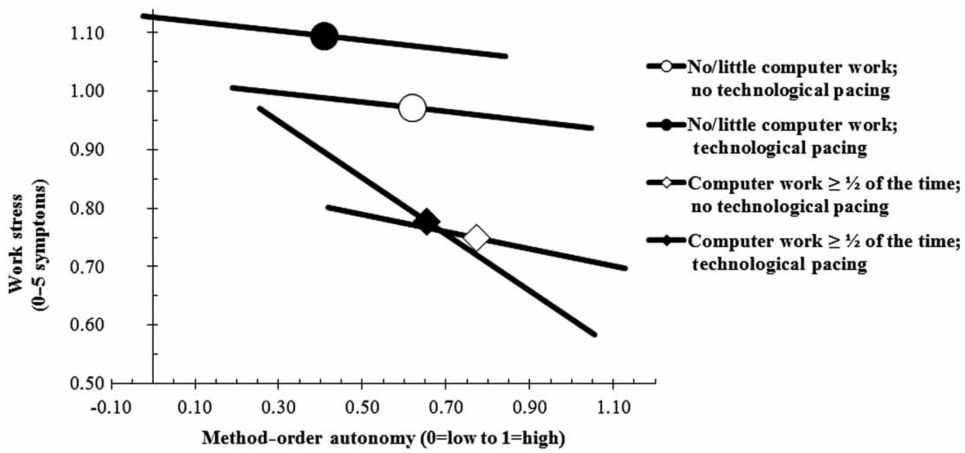

Figure 3. Three-way interaction effect of computer work and technological pacing and m–o autonomy on work stress (means multivariately adjusted based on linear regression).

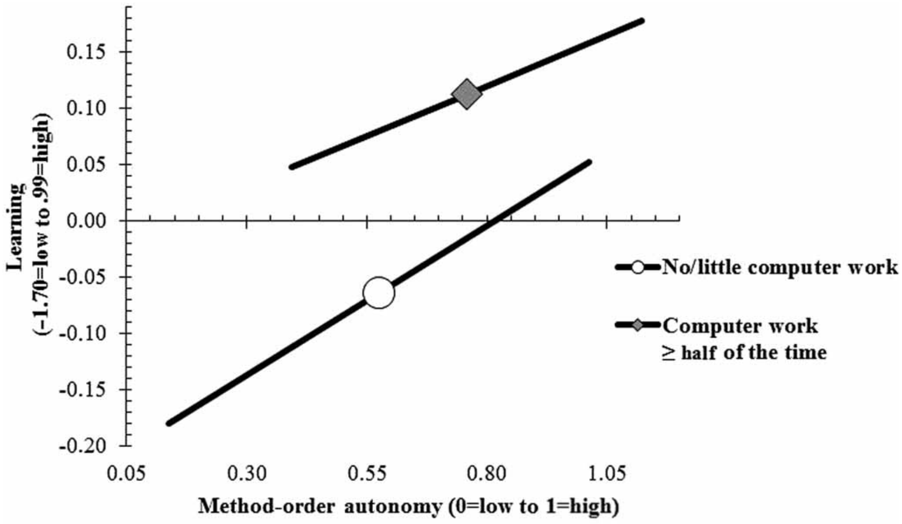

Figure 4. Two-way interaction effect of computer work and m–o autonomy on learning (means multivariately adjusted based on linear regression).

M4 included the two-way interaction terms of, on the one hand, computer work and technological pacing, and, on the other hand, the work organisation measures (cf. research question 4). The analysis showed that m–o autonomy moderated the association between computer work and work stress ($\beta = -.03$; $p < .05$; Table 4 and Figure 2): in computer work, especially, high levels of m–o autonomy were associated with relatively low-work stress and vice versa. No indications were found for work intensity as a moderator in the association between technological pacing and work stress, nor for moderations by m–o autonomy or work intensity in the technological pacing and work stress relation.

The three-way interaction term of technological pacing and computer work and m–o autonomy was added to the full model, M5. The interaction term was significant ($\beta = -.03$; $p < .05$; Table 4). As depicted in Figure 3, m–o autonomy moderated the association between computer work and technological pacing, and work stress. Among employees in technologically paced computer work, especially, high levels of m–o autonomy were associated with low levels of work stress and vice versa. These two- and three-way interaction results disagreed with H6a (hypothesising relatively strong mitigation by m–o autonomy in traditional machine-paced work), but supported H6b (hypothesising relatively strong mitigation by m–o autonomy in technologically paced computer work).

4.4. Learning

The difference in learning, as found in the univariate analysis, between employees in technologically paced work and employees in not technologically paced work disappeared in the multivariate analysis (M1; Table 4) (H4 rejected). However, computer work remained positively related ($\beta = .15$; $p < .001$), although weaker than in the

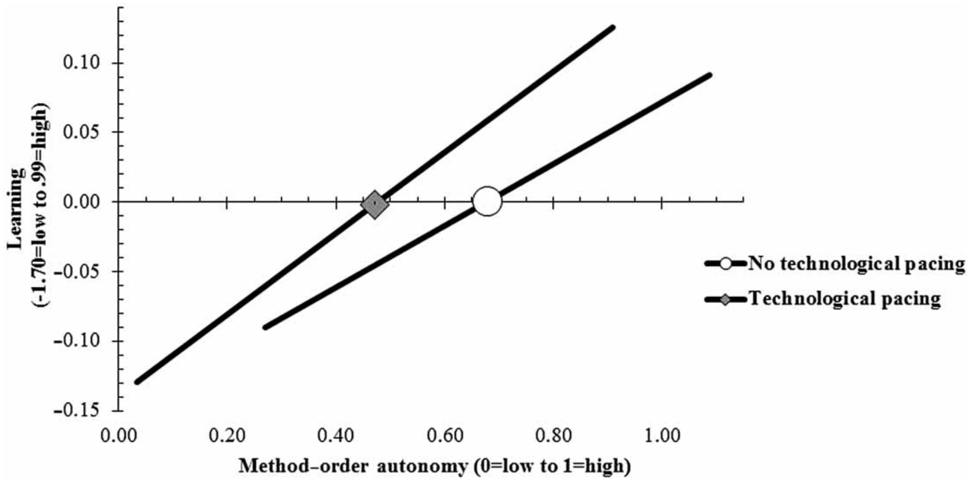

Figure 5. Two-way interaction effect of technological pacing and m–o autonomy on learning (means multivariately adjusted based on linear regression).

univariate analysis. Analysis of M2 (Table 4) revealed that computer work and learning remained positively related ($\beta = .10; p < .001$) after adjustment for m–o autonomy and work intensity.

Addressing research question 4b (M3), no indication was found for a two-way interaction effect by computer work and technological pacing on learning. This is a rejection of H5a and H5b which stated that the lowest level of learning could be expected in traditional machine-paced work (H5a), an intermediate level in technologically paced computer work (H5b) and the highest level in computer work that is not technologically paced. There were, however, significant moderations by m–o autonomy (interactions; M4) in both the relation of computer work and learning ($\beta = -.04$; $p < .01$), and the relation of technological pacing and learning ($\beta = .03; p < .05$) (whereas, as discussed, there was no significant main effect by technological pacing). In other words, in the group without computer work (or performing computer work to some extent, only), the m–o autonomy relation with learning was stronger than among those in computer work (Figure 4). Besides, as Figure 5 visualises, higher levels of m–o autonomy favour employees in technologically paced work more strongly.

Apart from these two-way interaction effects, no indication was found for a three-way interaction effect (M5) by computer work, technological pacing and m–o autonomy on learning. This implies a rejection of H7a and H7b, which stated that high m–o autonomy relates to learning more positively in traditional machine-paced work (H7a) – and to a lesser extent in technologically paced computer work (H7b) – than in (computer) work that is not technologically paced.

5. Discussion and conclusions

5.1. Conclusions

The main aim of this study was to assess whether technologically paced computer work (e.g. workflow-software and call centre applications), traditional machine-paced work (e.g. working on an assembly line), non-paced computer work and work without these two technology characteristics differed in terms of their potential for work stress and learning. Special attention was given to the difference that m–o autonomy makes in these relations, since it is – next to technological pacing – an important control and standardisation mechanism in the work organisation (Meyer and Rowan 1977; Mintzberg 1979). Furthermore, it could potentially modify the effects of technological pacing. Four research questions were formulated and seven hypotheses. Regarding the work stress outcome, the results supported several of the hypothesised main effects and two- and three-way interaction effects. This was less so the case for the hypotheses on the learning outcome.

Turning to our central research questions, first we assessed how computer work and technological pacing interrelated with m–o autonomy, and work intensity (Question 1). In this paper, work intensity was conceived as a potential explanatory factor in relations of technology and autonomy with work stress and learning (Questions 2–4). We found that especially technologically paced work rated high for work intensity. Besides, employees performing computer work at least half of their time reported high m–o autonomy, whereas m–o autonomy of workers in technologically paced settings was low. Second, the results revealed that technological pacing was related to work stress, whereas computer work related only very weakly (Question 2). Higher work stress in case of technological pacing was not explained by high work intensity. This implies that technological pacing as such may be related to work stress, while it may also be due to associated 'straining' practices of close monitoring of worker performance (e.g. McGovern et al. 2007, 169–171; Deery, Iverson, and Walsh 2010). Besides, no (unfavourable) relationship between technological pacing as such and learning was found when adjusting for occupational and job content facets. Computer work, however, was characterised by favourable learning.

As set out in the introduction, previous research and theorising suggests that traditional machine-paced work will have adverse effects on worker health and learning (Blauner 1964; Karasek and Theorell 1990). However, it is not known whether technological pacing shows the same effects in computer work. Therefore, Question 3 involved the implications for work stress and learning in technologically paced computer work, compared to those associated with traditional machine-paced work and computer work that is not technologically paced. As expected, computer work in a technological pacing regime showed adverse work stress levels, comparable to 'traditional' machine-paced work. This implies that pacing by computerisation as a new control strategy likely constitutes an important emerging risk for work stress. With regard to learning, our second outcome measure, no such indication for a new risk was found.

The current study also examined how m–o autonomy may moderate the relationships between computer work and technological pacing, on the one hand, and work stress and learning, on the other hand (Question 4). With regard to work stress, the present study revealed a distinct interaction pattern for technologically paced computer work combined with m–o autonomy. It was shown that lacking m–o autonomy was especially problematic for work stress in this type of technology setting. The fact that especially software is flexible might explain why this group differed from the other three groups. Thus, the outcomes are likely to vary more depending on the other features of the software and on the alignment with surrounding work organisation practices, such as m–o autonomy. Therefore, with respect to healthy workplaces, there is much to be gained. In the case of higher m–o autonomy in this type of computer work, the employee can arrange a more proportionate division or less coercive method and a sequence of task performance. This is likely to result in positive outcomes for the employee. This may, compared to software, apply less to 'old', machine-paced technology, due to higher modification costs of the technology and less diverse supply in the technology market.

Moreover, it appeared from the interaction results that in technology-paced settings in general, m–o autonomy may well reinforce learning. It can be assumed that, in such settings, high m–o autonomy indicates longer cycle times (lower extent of machine or computer pacing) (Mullarkey et al. 1997). It has been shown that the length of the cycle time impacts learning favourably (Pack and Buck 1992). Cycle time, therefore, is a potentially important design parameter in achieving healthy workplaces for this type of work.

All in all, as regards the central topic of interest of our study, our study showed adverse work stress for technological pacing among computer workers, almost equal to the level found for 'traditional, machine-paced' workers. Distinct interactions with m–o autonomy were shown – e.g. lack hereof was especially problematic for work stress among technologically paced computer workers.

5.2. Limitations and recommendations for future research

There are some limitations to the present study. As in many studies, cross-sectional data were used, due to the lack of longitudinal data on the subject. However, since several interesting relations were demonstrated, the recommendation for replication of the results by longitudinal data also applies to the present study. Such replication may allow for inferring causality. Furthermore, the technology characteristic 'pacing' was established by a single item. Although its face validity was high, a multi-item measure might have shown stronger associations, resulting from higher reliability. Also, such a measure could have revealed stronger associations for the multiplicative interaction terms. As a result of measurement error, a downward bias (underestimation) in the strength of the moderation results could well be present for the current data set.

As discussed, technological pacing may also be related to work stress due to associated 'straining' practices of close monitoring of worker performance. It would, therefore, be interesting to include measures on this concept in future waves of the EWCS. The same recommendation holds for new indicators on the length of the cycle time, which, as our results seem to indicate too, may impact learning.

The results from the present study underline the importance of specifying control dimensions (Mikkelsen, Øgaard, and Landsbergis 2005) in models on work organisation, such as the DC model, and of paying attention to technology-related (control) variables. In follow-up studies, information on the intensity of technological pacing and other technology characteristics could be valuable in explaining mechanisms related to work stress and learning. This can also help to further open the 'black box' regarding the type of machine and computer use. In surveys, the use of ICT is very often conceptualised as just the use of a computer or similar hardware.

5.3. Practical implications

Turning to the practical implications of this study, it is important to note that technology in general – and software especially – is flexible, by definition. Besides adapting the surrounding work environment to new options offered by technology, one should therefore keep paying attention to improving the fit between technological solutions, humans and m–o autonomy in work processes. That is, computer work offers many opportunities in terms of work stress and exploratory learning, but these opportunities may easily be foregone if computer work is not combined with a sufficient level of m–o control. In order to reach optimal ICT solutions within different organisational practices and for different people, organisational (or 'tailor-made') solutions are necessary. This might require a complex implementation process, calling for ICT knowledge of all involved, as well as appropriate financial means. Financial restrictions force many organisations to implement ICT blueprints instead of tailor-made solutions. In this respect, policy-makers could, for instance, support firms financially, likely resulting in competitive advantage.

Since there was support for moderation by other control dimensions in the work organisation (i.e. m–o autonomy) which may, for instance, take a rigid bureaucratic or empowering shape, the results are relevant for employers' HR policy. Our results provide organisational decision-makers with food for thought and insights into adjusting technology implementation in line with control strategies chosen.

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