International Archives of Occupational and Environmental Health (2019) 92:13–35
https://doi.org/10.1007/s00420-018-1352-1

REVIEW

Definition, symptoms and risk of techno-stress: a systematic review

Giuseppe La Torre[1] · **Alessia Esposito**[1] · **Iliana Sciarra**[1] · **Marta Chiappetta**[1]

Received: 29 January 2018 / Accepted: 2 September 2018 / Published online: 8 September 2018

Abstract

Purpose Techno-stress (TS) is an emergent phenomenon closely related to the pervasive use of information and communication technologies in modern society. Despite numerous studies existing in the literature, only few comprehensive reviews have been performed, which has led to fragmented information about TS. This systematic review aimed to clarify the definition, the symptoms, and the risk factors of TS, focusing on the differences between work-related and non-work-related sources of TS.

Methods A comprehensive literature review of three electronic databases was performed according to the PRISMA statement. 'Technostress' was used as the only keyword.

Results In the qualitative synthesis, 105 studies were included: 84 cross-sectional studies, 8 experimental studies and 13 reviews (11 narrative and 2 systematic reviews). 70 studies (67%) addressed work-related TS, 26 (25%) addressed non-work-related TS, while 8 (8%) did not differentiate between work and non-work fields. The presence and level of TS among individuals was described in 38 studies (29%), whilst the techno-stressors, and the consequences of TS, were described in 53 studies (51%). The antecedents of TS were reported in 47 studies (45%), its moderators in 40 studies (38%), whilst its symptoms in only 11 studies (10%).

Conclusions TS affects both professional and private life. It can determine a reduction in job and life satisfaction and in productivity, and is often associated to the occurrence of psychological and behavioral disorders. Efforts should be made to recognize situations with a high risk of causing TS, to prevent its progressive development in a prospective way using mainly cohort studies.

Keywords Techno-stress · Information and communication technology · PRISMA statement · Systematic review · Techno-stressors

Introduction

Information and communication technologies (ICTs) increasingly permeate professional and personal life. Thanks to them, we are capable of gaining access to information very easily and rapidly, and we are able to keep in touch with colleagues, friends and family simultaneously. Overall, such technologies improve our performance. Despite the positive impact of ICT, many negative aspects have been described deriving from the use of technology. First of all, ICTs have been known to induce anxiety and tension in users, a condition called *techno-anxiety* (Marcoulides 1989). In fact, depending on an individual's disposition toward ICTs, his or her interaction with computers can be characterized by nervousness and apprehension. This can create psychological effects such as insecurity about ICTs, and can decrease confidence and overall comfort regarding their use. Such conditions can lead to feelings of helplessness and of being hassled, and can result in an aversion to, or phobia about, the use of computers, a condition called *techno-phobia* (Abdul-Gader and Kozar 1995; Hudiburg and Necessary 1996). Moreover, the extensive and compulsive use of internet and smartphones can cause a condition of dependency called *techno-addiction* (Young 2017). Secondly, the use of ICTs has been described by some authors to create stress in users. In general stress is an adaptive reaction of the organism in response to factors, called stressors, which alter its homeostasis. It must be distinguished a short-term response to a stressor, that is generally beneficial, and represent the mechanism of resilience of healthy humans, from

✉ Giuseppe La Torre
giuseppe.latorre@uniroma1.it

[1] Dipartimento di Sanità Pubblica e Malattie Infettive, Sapienza Università di Roma, P.le A. Moro, 5, 00185 Rome, Italy

the long-term chronic stress that can be associated with pathological effects for humans (Romero et al. 2015). In this specific case the stress factor seems to be represented by the use of technology, in particular of the ICTs, and the long-term unhealthy reaction that can occur in some individuals is called *techno-stress* (*TS*). It was firstly defined by Brod in his book "Technostress: The Human Cost of the Computer Revolution" as the "inability to adapt or cope with new computer technologies in a healthy manner" (Brod 1984). According to Brod, TS "can manifest itself in two distinct but related ways: in the struggle to accept computer technology, and in the more specialized form of over-identification with computer technology". Later Lyon affirms also that people who identify themselves too much with computer technology lose the capacity to feel and interact with others (Lyon 1985). In 1997, Weil and Rosen modified the definition of TS considering it as "any negative impact on attitudes, thoughts, behaviors, or body physiology that is caused either directly or indirectly by technology" (Weil and Rosen 1997). Champion described TS as "The Price of Using Technology", addressed TS as a serious illness, which includes several symptoms such as: panic, anxiety, resistance, technophobia, mental fatigue, physical ailments, intolerance and perfectionism (Champion 1988). Other physical symptoms associated with TS have been described elsewhere, and include muscle cramps, headaches, joint aches, and lack of sleep/insomnia (Çoklar and Sahin 2011).

From its first description in the 1980s to today, many studies have been conducted to determine the nature of TS, its causes and consequences, possible ways to prevent its occurrence. However, they have often focused on different types of workers, or on the use of technology in private life. The first workers studied were librarians, who were among the first to get involved in the high-tech revolution, and which then led to the birth of electronic libraries. They reacted to the introduction of new technologies, showing behaviors such as resistance, and often exhibited an inability or unwillingness to be trained or to learn the new ICT systems. The final result of this phenomenon was absenteeism and tardiness (Bichteler 1987). A literature review showed that the most important causes of TS among librarians were the pace of change, the lack of training, the increased workload, the lack of standardization, the changing role of librarians and the scarce reliability of technology (frequent crashes and slow connections) (Ennis 2005).

More generally speaking, two relevant stressors have been identified as deriving from the use of ICTs in professional fields: the information overload and the constant availability. The first stressor is related to the large amount of information coming from multiple sources (e-mails, instant messages, etc.) that can lead to excessive stimulation and fatigue of end users. The second stressor refers to the fact that workers are always reachable or connected, from wireless internet access almost everywhere, to the use of tablets and/or smartphones. This availability can increase employees' work hours because ICTs create the expectation for faster response to work-related communications (Garbarino and Costa 2014).

The consequences of TS seem to impact both on business and relational sphere, causing absenteeism, decrease of professional effectiveness, conflict and isolation. Chiappetta and colleagues affirm that TS should be included in the document regarding work-related risk assessment, in that workplaces where a frequent daily use of digital technologies exists. The recognition of this condition of stress is essential in order to put in place adequate prevention measures, such as increased training of employees, to counteract the harmful effects of techno-stress, as well as aiding the implementation of specific strategies for managing symptoms (Chiappetta 2017; Di Frenna and Tecnostress 2015; Perciavalle and Prunesti 2016).

Despite numerous studies conducted aiming to better understand the multifaceted aspects of TS, only few proper reviews have been performed, and this has led to a fragmented knowledge about this phenomenon.

Aim of this study

The aim of this systematic review is to summarize and clarify the knowledge about the definition, the symptoms and the risk factors of TS, with particular focus on the differences between work-related and not work-related sources of TS, independently from the methodological quality of the papers.

Materials and methods

Identification of relevant studies

This systematic review was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al. 2010). Three electronic databases were searched: Medline (PubMed), Scopus and Web of Science (WOS). 'Technostress' has been used as keyword in order to be as sensible as possible, including all the articles that broadly addressed this phenomenon. Eligible studies were selected through a multi-step approach (title reading, abstract and full-text assessment) undertaken by three researchers working together.

Study selection and eligibility criteria

All articles that contained the keyword 'technostress' retrieved from the three databases were analyzed. A first

selection was performed by filtering duplicate articles by JabRef 3.8.1. Consequently, the articles which were identified were then screened by title and abstract, and finally by full-text. Articles were included in the review if they described any aspect of TS derived from the use of ICTs, including definition, prevalence, symptoms, risk factors, consequences and prevention. Treatment of TS was not evaluated nor was TS deriving from the use of Information Systems, for example electric vehicles. Studies were taken into consideration if they addressed either or both work-related TS and non-work-related TS, originating from the private use of ICTs. Studies addressing stress in general, or other types of work-related stress, were excluded. Commentaries, research protocols and articles which were not in English were also excluded. The references of the included studies were also screened in order to retrieve other relevant studies on this topic. Disagreement between reviewers was solved by consensus. A flowchart of the paper selection process is represented in Fig. 1.

Data extraction

Data were extracted by the same three researchers working together. The following characteristics were retrieved: first author, year of publication, study design, and main outcomes. Methodological quality assessment was performed using different scales compatible to the type of study design: (a) the Newcastle–Ottawa scale adapted by *Herzog* for cross-sectional studies, and considering the response rate as good if it was higher than 67% (cut off chosen by the researchers); (b) the Jadad scale for randomized clinical trials (Jadad et al. 1996); (c) the TREND checklist for non-randomized experimental studies (De Jarlais et al. 2004) ; (d) the INSA scale (International Narrative Systematic Assessment tool) for narrative reviews (La Torre et al. 2015); (e) the AMSTAR scale (assessment of multiple systematic reviews) for systematic reviews (Shea et al. 2007). Quality values of the papers have been taken into account for formulating the results.

Results

The Pubmed database produced only a few articles, while searches on Scopus and Web of Science databases led to more records being identified, 201 and 131 records, respectively (see Fig. 1). From an overall total of 345 records, 102 were excluded because they were duplicates, and the remaining 243 were screened by title and abstract reading. This first step of the analysis led to the exclusion of 95 records because they did not entirely fulfill the inclusion criteria previously described, or because they were written in a language other than English. Finally, other articles were excluded because it was not possible to retrieve their full text. This left 148 studies which were examined by full-text reading, in order to find the most relevant articles.

This second step of the analysis led to the exclusion of yet another 43 records, most of them because they were either commentaries and/or research protocols, and because they addressed the problem of TS but not from an ICT-related source. Two articles emerged from the screening of the bibliography of the selected studies, and were included because of their relevance to the TS topic. A total of 107 studies were thus included for our qualitative synthesis: 85 were cross-sectional studies, 8 were experimental studies and 14 were reviews (11 narrative and 3 systematic reviews). Table 1 lists the articles included in the review and their main features. Overall, of the 107 studies included, 73 of them (68%) addressed work-related TS, 27 (25%) addressed the not work-related TS, and 7(7%) did not differentiate whether they referred to work or private TS. The articles included were classified in different tables according to the type of study design: cross-sectional studies are listed in Table 2, experimental studies are listed in Table 3, and finally reviews are listed in Table 4. In each table, the studies are differentiated according to the type of TS investigated, it being either work-related, non-work-related, or both work and non-work-related TS together. The main topics addressed are also listed. Among the cross-sectional studies, 61 addressed work-related TS (72%), 23 addressed non-work-related TS (27%) and one addressed TS though with no distinction between the work and non-work-related sphere (1%). The presence and level of TS is described in all studies (100%); techno-stressors were described in 46 studies (54%), techno-stress consequences in 42 studies (49%), the antecedents of TS in 39 studies (46%), the moderators of TS in 34 studies (40%), while only three studies (4%) reported the symptoms of TS. Table 3 shows the eight experimental studies included, of which two addressed work-related TS, two addressed non-work-related TS and four addressed TS without differentiating between work and non-work related. Most of these studies were concerned with either the symptoms and/or the patho-physiology of TS (4 studies, 50%), whilst others were more interested in the consequences of TS (4 studies, 50%), or which type the stressors were (3 studies, 38%), or in the antecedents of TS (two studies, 25%), or in the moderators of TS [as addressed by one study (13%)]. The presence and level of TS was noted in all the studies (100%). Table 4 shows the breakdown of the 14 reviews, divided into 10 work-related, 3 both work and not work-related, and 1 non-work-related TS studies. All the studies described the presence of TS, though the consequences of TS was tackled in nine studies (64%), its antecedents in seven studies (50%), stressors in seven studies (50%), moderators in six studies (43%) and symptoms in four studies (29%).

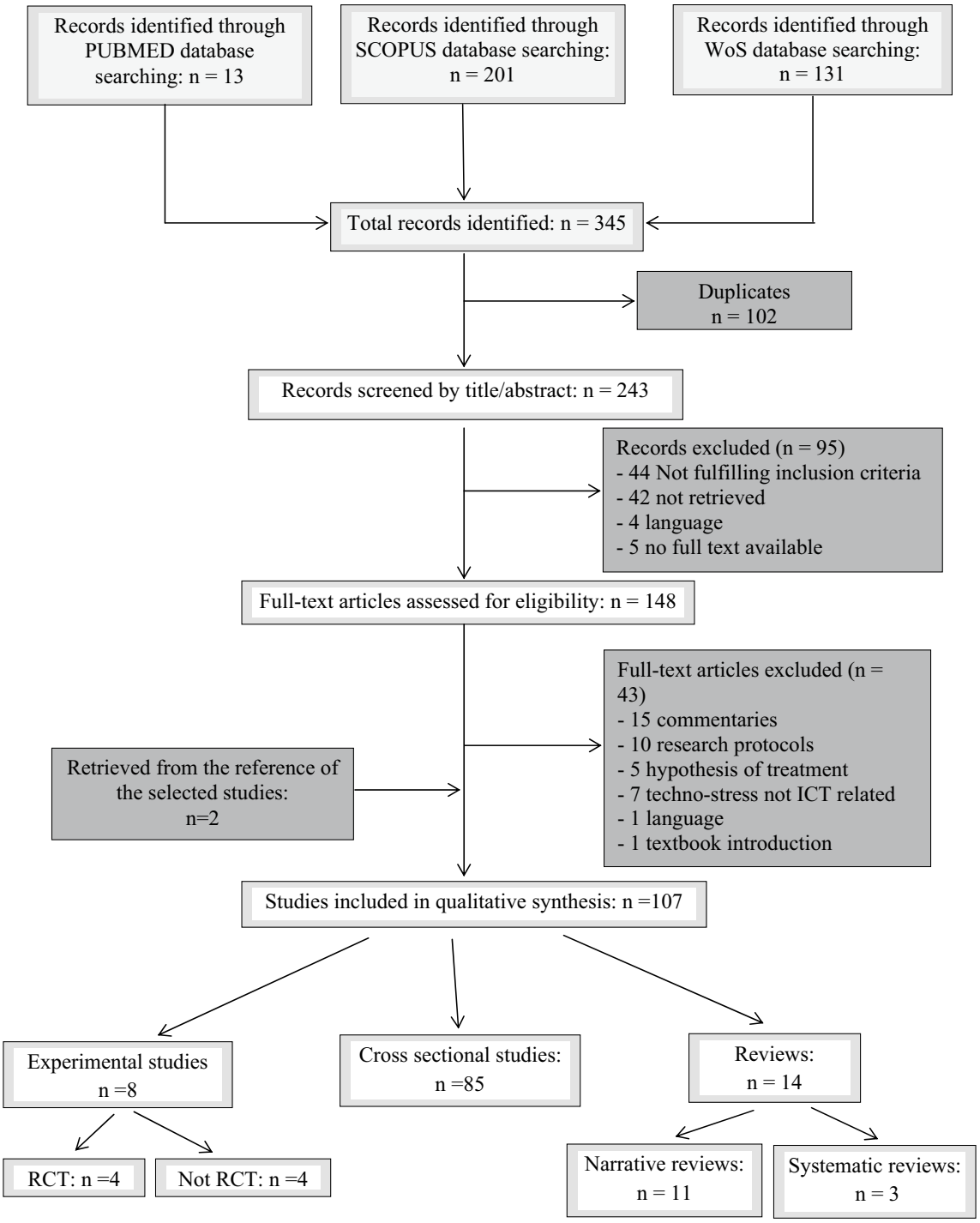

Fig. 1 PRISMA flow chart of the results of the systematic review

Methodological assessment of the quality of the studies included

Cross-sectional studies were evaluated using the Newcastle–Ottawa scale modified by Herzog et al. (2013), that consists of 7 items evaluating the quality of selection of the groups, the comparability between groups and the outcomes. Regarding response rate it was considered good if it was ≥ 67%, a cut-off chosen by the researchers. The scale has a minimum quality rating of zero stars and a maximum quality rating of ten stars. The mean star value obtained was 5.4, with a standard deviation of 1.3; the

Table 1 List of all studies that included and addressed the topic of TS

First author and year of publication	Title	Population size	Main outcomes	Quality assessment
Work-related techno-stress				
Imran M, 2017	To use or not to use: modeling end user grumbling as user resistance in pre-implementation stage of enterprise resource planning system	221	Techno-stress positively influences work exhaustion and end user grumblings, when an ERP system is implemented	6/10 stars
Stich JF, 2017	Workplace stress from actual and desired computer-mediated communication use: a multi-method study	504	Actual and desired computer-mediated communication use cause techno-stress	5/10 stars
Suh A, 2017	Understanding teleworkers' techno-stress and its influence on job satisfaction	258	Intensity of teleworking influences techno-stress occurrence	7/10 stars
Fischer T, 2017	Techno-stress research: a nurturing ground for measurement pluralism?	103	The large majority of the studies included used a mono-method approach based mainly on self-reported measures	5/11 stars
Tak S, 2016	A study of the connected smart worker's techno-stress	345	Techno-stress influences work–life conflict and job satisfaction	3/10 stars
Park HJ, 2016	The influence of information security techno-stress on the job satisfaction of employees	147	A greater information security decreases techno-stress levels	4/10 stars
Brooks S, 2016	Social media-induced techno-stress: its impact on the job performance of IT professionals and the moderating role of job characteristics	415	Social media-induced techno-stress is negatively related to job performance	4/10 stars
Califf CB, 2016	Rethinking techno-stress: a transactional approach through affordances	32	Stress is contextually dependent, and is influenced by the relationship between the individual and the environment	5/10 stars
Gaudioso F, 2017	The mediating roles of strain facets and coping strategies in translating techno-stressors into adverse job outcomes	241	Techno-invasion is positively associated with work–family conflict and work-exhaustion	5/10 stars
Jonusauskas S, 2016	Exploring techno-stress: results of a large sample factor analysis	1013	The authors identify different factors associated with techno-stress	6/10 stars
Lee SB, 2016	Techno-stress from mobile communication and its impact on quality of life and productivity	307	Techno-stress has consequences on life satisfaction and productivity	5/10 stars
Leung L, 2017	Mapping ICT use at home and telecommuting practices: a perspective from work/family border theory	509	Techno-stress induce work–life conflict	6/10 stars
Tacy JW, 2016	Understanding the effects of technology acceptance in nursing faculty: a hierarchical regression	1017	Technology use, job satisfaction and intention to stay in the profession are influenced by techno-stress level	6/10 stars
Choi SB, 2016	Effects of social and technology-overload on psychological well-being in young south korean adults: the mediatory role of social network service addiction	419	Techno-overload influences SNS addiction and psychological well-being	6/10 stars
Waizenegger L, 2016	The social media trap—how knowledge workers learn to deal with constant social connectivity	41	Constant connectivity induces techno-stress	4/10 stars
Tacy JW, 2016	Techno-stress: a concept analysis	–	Techno-stress is an emerging psychosomatic illness caused by working with computer technology, which can manifests in different fields including nursing education	4/7 stars

Table 1 (continued)

First author and year of publication	Title	Population size	Main outcomes	Quality assessment
Haddara M, 2016	Investigating the effectiveness of traditional support structures and self-organizing entities within the ERP shakedown phase	22 studies	Investigating the effectiveness of traditional support structures and self-organizing entities within the ERP shakedown phase	4/11
Califf CB, 2015	The bright and dark side of techno-stress: an empirical study of healthcare workers	402	Involvement, literacy and technical support decrease techno-stress level	7/10 stars
Jena RK, 2015	Techno-stress in ICT-enabled collaborative learning environment: an empirical study among Indian academicians	216	Techno-stress reduces job satisfaction, organizational commitment and technology-related performance, and increases negative affectivity	6/10 stars
Khuntia J, 2015	Juggling digitization and techno-stress: the case of alert fatigues in the patient care system implementation	98	Techno-stress among nurses reduces healthcare quality and patients' satisfaction	4/10 stars
Srivastava SC, 2015	Techno-stress creators and job outcomes: theorizing the moderating influence of personality traits	152	Techno-stress creators, job burnout and job engagement	7/10 stars
Tarafdar M, 2015	Techno-stress: negative effect on performance and possible mitigations	237	Techno-stress influences innovation and performance among salespersons	5/10 stars
Harris KJ, 2015	Relationship between technology-overload and work family conflict	219	Relationship between technology-overload and work family conflict	5/10 stars
Joo YJ, 2016	The effects of secondary teachers' techno-stress on the intention to use technology in South Korea	312	Scholl and peers support diminish techno-stress level among high school teachers	6/10 stars
Wulansari NA, 2015	Reduction effect of techno-stress with role of perceived organizational	108	Organizations' support is a moderator variables that influence techno-stress only on work overload	3/10 stars
Tarafdar M, 2015	The dark side of information technology	14	IT features such as usefulness, reliability, portability, user-friendliness and fast processing, may decrease employee productivity, innovation and well-being	4/7 stars
Kim HJ, 2015	An examination of work exhaustion in the mobile enterprise environment	210	Work-overload, personal privacy, technical complexity and occupational threats are positively related to work exhaustion	6/10 stars
Ninaus K, 2015	Benefits and stressors perceived effects of ICT use on employee health and work stress: an exploratory study from Austria and Hong Kong	25	Frequent interruptions and extension of working hours determine techno-stress	4/10 stars
Raisiene AG, 2015	Effect of networked workplace on employees' work–life balance. difference between population of managers and staff	1013	Professional role influences techno-stress level	6/10 stars
Tarafdar M, 2015	Special issue on "Dark side of information technology use": an introduction and a framework for research	–	One of the dark sides of technology is represented by techno-stress	3/7 stars
Tams S, 2015	Challenges in techno-stress research: guiding future work	–	In techno-stress research there are yet many key challenges to be addressed	4/7 stars
Saganuwan MU, 2015	Conceptual framework: AIS techno-stress and its effect on professionals' job outcomes	–	Techno-stress creators impact on job satisfaction and task performance	5/7 stars

Table 1 (continued)

First author and year of publication	Title	Population size	Main outcomes	Quality assessment
Tams S, 2014	NeuroIS—alternative or complement to existing methods? Illustrating the holistic effects of neuroscience and self-reported data in the context of techno-stress research	64	The importance of physiological measures to understand the effects of such IS phenomena as techno-stress	2/5 stars
Sellberg C, 2014	Techno-stress in the office: a distributed cognition perspective on human–technology interaction	12	Techno-stress is induced by: technology lacks in usability, problems with overview and synchronization of information, lack of knowledge about technology use, fragmentation of work tasks, higher work pace and longer workdays	4/10 stars
Weinert C, 2014	Does teleworking negatively influence it professionals? An empirical analysis of it personnel's telework-enabled stress	57	Exhaustion due to teleworking is influenced by workload	5/10 stars
Ahmad UNU, 2014	Moderating effect of techno-stress inhibitors on the relationship between techno-stress creators and organizational commitment	282	A certain amount of techno-stress increases organizational commitment	6/10 stars
Fieseler C, 2014	The leadership dimension of coping with techno-stress	491	Techno-stress is positively related to work exhaustion and work satisfaction	5/10 stars
Fuglseth AM, 2014	The effects of techno-stress within the context of employee use of ICT	400	Techno-stress influences ICT-related satisfaction and intention to extend ICT use	7/10 stars
Brown R, 2014	E-mail in the workplace: the role of stress appraisals and normative response pressure in the relationship between e-mail stressors and employee strain	218	E-mail stressors are associated with emotional exhaustion	6/10 stars
Ortbach K, 2013	How IT consumerization affects the stress level at work: a public sector case study	17	Increased reachability, IT complexity, workflow changes and system redundancies create techno-stress	1/10 stars
Hung WH, 2015	Does the proactive personality mitigate the adverse effect of techno-stress on productivity in the mobile environment?	836	Communication overload reduces productivity, but this effect is mitigated by the presence of proactive personality (the ability to confront situations)	5/10 stars
Khan A, 2013	An empirical analysis of correlation between techno-stress and job satisfaction: a case of KPK, Pakistan	148	Techno-stress influences job satisfaction	7/10 stars
Salanova M, 2013	The dark side of technologies: techno-stress among users of information and communication technologies	1072	Job demands induce techno-stress	4/10 stars
Schellhammer S, 2013	Towards contextualizing stressors in techno-stress research	144	The perception of strain and stressors is influenced by the context in which the tasks are embedded	11/21 items
Yan Z, 2013	A conceptual model of technology features and techno-stress in telemedicine communication	–	The study identifies the antecedents of techno-stressors regarding the use of telemedicine technologies	5/7 stars
Maier C, 2012	Conceptualization, operationalization, and empirical evidence for an individual's dispositional resistance to IT-induced changes	174	Techno-stress is influenced by individual's dispositional resistance to IT-induced changes	5/10 stars
Yun H, 2012	A new open door: the smartphone's impact on work-to-life conflict, stress, and resistance	12	Workload increases work-to-life conflict, job stress and user resistance	6/10 stars

Table 1 (continued)

First author and year of publication	Title	Population size	Main outcomes	Quality assessment
Ahmad UNU, 2012	The dimensions of techno-stress among academic librarians	162	Malaysian academic librarians are affected mainly by techno-uncertainty, techno-overload and techno-complexity	6/10 stars
Ahmad UNU, 2012	The relationship between techno-stress creators and organizational commitment among academic librarians	282	Techno-stress influences organizational commitment	6/10 stars
Bucher E, 2013	The stress potential of social media in the workplace	500	Being literate and successful in society and work inhibits techno-stress onset	7/10 stars
Hirose H, 2012	The relation between education effect and individual characteristics of WBT teaching materials	93	Individual features influence techno-stress among teachers	4/10 stars
Kwanya T, 2012	Techno-stress and techno-lust: coping mechanisms among academic librarians in Eastern and Southern Africa	24	Education, training, effective time management and scheduling of tasks, resource mobilization, maintenance of good health, improvement of personal image, can reduce techno-stress level	4/10 stars
Mark JG, 2011	"A pace not dictated by electrons": an empirical study of work without email	13	Workers experienced significantly less stress levels in the no-mail condition	14/20 items
Shu Q, 2011	The impact of computer self-efficacy and technology dependence on computer-related techno-stress: a social cognitive theory perspective	289	Computer self-efficacy and computer-related technology dependence influence techno-stress levels	8/10 stars
Hung WH, 2011	Managing the risk of overusing mobile phones in the working environment: a study of ubiquitous techno-stress	622	Techno-stress influences job productivity	6/10 stars
Koo C, 2011	What factors do really influence the level of techno-stress in organizations? (an empirical study)	98	Innovation culture and self-efficacy reduce techno-stress; task complexity enhances techno-stress	6/10 stars
Tarafdar M, 2011	Impact of techno-stress on end-user satisfaction and performance	283	Techno-stress reduce job satisfaction and performance. Organizational mechanism that support innovation and users involvement reduce techno-stress	7/10 stars
Ragu-Nathan TS, 2008	The consequences of techno-stress for end users in organizations: conceptual development and empirical validation	608	Techno-overload, techno-invasion, techno-complexity, techno-insecurity and techno-uncertainty are techno-stress creators, while literacy facilitation, technical support provision and involvement facilitation are techno-stress inhibitors. Techno-stress decreases job satisfaction and commitment	9/10 stars
Burke MS, 2009	The incidence of technological stress among baccalaureate nurse educators using technology during course preparation and delivery	180	Baccalaureate nurse educators experience techno-stress	4/10 stars
Wang K, 2008	Techno-stress under different organizational environments: an empirical investigation	1029	Organizational internal environment of an enterprise impact on level of techno-stress	8/10 stars
Al-Fudail M, 2008	Investigating teacher stress when using technology	9	Lack of fit between demands and abilities causes techno-stress among teachers	6/10 stars

Table 1 (continued)

First author and year of publication	Title	Population size	Main outcomes	Quality assessment
Ayyagari R, 2007	What and why of techno-stress: technology antecedents and implications	661	Role ambiguity, work-overload and work–home conflict are the main techno-stressors that contribute to strain developing	7/10 stars
Tarafdar M, 2007	The impact of techno-stress on role stress and productivity	264	Techno-stress influences role stress and productivity	6/10 stars
Al-Qallaf CL, 2006	Librarians and technology in academic and research libraries in Kuwait: perceptions and effects	147	Techno-stress enhances job performance	6/10 stars
Wang K, 2006	The moderating impact of perceived organizational support on the relationship between techno-stress and role stress	450	Techno-stress is related to role stress	6/10 stars
Sami KL, 2006	A literature survey on the effect of information technology on library users	–	Libraries users complain of techno-stress and techno-phobia	3/7 stars
Tu Q, 2005	Computer-related techno-stress in China	437	Overall techno-stress level did not affect significantly the productivity of Chinese employees	3/10 stars
Wang W, 2005	Empirical study of coping strategies for computer-related techno-stress of chinese employees	951	Enterprise-provided training in learning new technology, and technological support reduce levels of techno-stress	6/10 stars
Kasuga N, 2004	Study on relationship between techno-stress and antisocial behavior on computers	815	Techno-stress as risk factor contributing to antisocial behavior	6/10 stars
Poole CE, 2001	Technological change in the workplace: a statewide survey of community college library and learning resources personnel	302	Florida community college library employees do not manifest techno-stress	4/10 stars
Arnetz BB, 1997	Technological stress: psychophysiological symptoms in modern offices	–	Techno-stress is characterized by psychophysiological activation (higher circulating levels of stress-sensitive hormones) and cognitive symptoms	2/7 stars
Rose PM, 1998	A focus group approach to assessing techno-stress at the reference desk	16	Technology and environmental factors determine techno-stress among librarians	4/10 stars
Bichteler J, 1986	Human aspects of high tech in special libraries	32	Level of techno-stress among libraries is lower than in other workers	5/10 stars
Techno-stress non-work-related				
Yao J, 2017	The balancing mechanism of social networking overuse and rational usage	224	Social interaction overload, invasion of work and invasion of privacy had significant positive impacts on techno-stress	5/10 stars
Reinecke L, 2017	Digital stress over the life span: the effects of communication load and internet multitasking on perceived stress and psychological health impairments in a German probability sample	1557	Communication load and internet multitasking are related to techno-stress which determines burnout, anxiety and depression	5/10 stars
Nimrod G, 2017	Techno-stress: measuring a new threat to well-being in later life	537	Overload, invasion, complexity, privacy and inclusion are techno-stressors among older adults. Techno-stress decreases life satisfaction	7/10 stars
Zhang S, 2016	Do you get tired of socializing? An empirical explanation of discontinuous usage behavior in social network	525	Feature overload, information overload and social overload are techno-stressors	5/10 stars

Table 1 (continued)

First author and year of publication	Title	Population size	Main outcomes	Quality assessment
Zheng X, 2016	Excessive use of mobile social networking sites: negative consequences on individuals	490	Excessive use of mobile SNS induce technology–work conflict and technology–family conflict	6/10 stars
Brooks S, 2016	Technology addictions and techno-stress: an examination of Hong Kong and the US	300	Both internet addiction and social media addiction influence social media related techno-stress	5/10 stars
Hsiao KL, 2016	Compulsive mobile application usage and techno-stress: the role of personality traits	546	Compulsive usage of social media and techno-stress are influenced by personality traits	5/10 stars
Hsiao KL, 2017	Exploring the effect of compulsive social app usage on techno-stress and academic performance: perspectives from personality traits	136	Impact of techno-stress on academic performance	5/10 stars
Krishnan S, 2017	Personality and espoused cultural differences in techno-stress creators	322	Personality traits influence techno-stress occurrence	5/10 stars
Luqman A, 2017	Empirical investigation of Facebook discontinues usage intentions based on SOR paradigm	360	Techno-stress induces discontinuous use of SNS	6/10 stars
Hsiao KL, 2016	Exploring the antecedents of techno-stress and compulsive mobile application usage: personality perspectives	389	Personality traits influence techno-stress occurrence	5/10 stars
Lee J, 2016	Does stress from cell phone use increase negative emotions at work?	222	Information overload from cell phone use increase negative emotion	5/10 stars
Maier C, 2015	Giving too much social support: social overload on social networking sites	571	Social overload induce techno-stress in SNS users	7/10 stars
Jena RK, 2015	Compulsive use of smartphone and techno-stress: a study among Indian students	310	Compulsive use of smartphone induces techno-stress	6/10 stars
Lee AR, 2016	Information and communication technology-overload and social networking service fatigue: a stress perspective	201	Overload determines techno-stress	5/10 stars
Lee YK, 2016	Helpful–stressful cycle? Psychological links between type of mobile phone user and stress	350	Psychological factors are associated with techno-stress among smartphone users	7/10 stars
Maier C, 2015	The effects of techno-stress and switching stress on discontinued use of social networking services: a study of Facebook use	82	Discontinuous usage intention of SNS causes techno-stress	15/19 items
Ravindran T, 2014	Antecedents and effects of social network fatigue	201	Social network fatigue is determined by factors related to users, social networks, and technical platforms that hosts the networks	5/10 stars
Lee YK, 2014	The dark side of smartphone usage: psychological traits, compulsive behavior and techno-stress	325	Some psychological traits are related to compulsive smartphone use	7/10 stars
Riedl R, 2013	On the biology of techno-stress: literature review and research agenda	–	In information system research is essential to include neurobiology discipline	4/11 stars
Lee SJ, 2012	The influence of techno-stress and antismart on continuous use of smartphones	268	Antismart induces techno-stress, while innovativeness reduces it. Techno-stress influences the data communication preferences	5/10 stars
Ayyagary R, 2011	Techno-stress: technological antecedents and implications	661	Work-overload and role ambiguity create techno-stress	4/10 stars

Table 1 (continued)

First author and year of publication	Title	Population size	Main outcomes	Quality assessment
Coklar AN, 2011	Techno-stress levels of social network users based on ICTs in Turkey	287	Techno-stress levels of social network users	5/10 stars
Sahin YL, 2009	Social networking users' views on technology and the determination of techno-stress levels	765	Techno-stress of Facebook users is induced by environmental factors	6/10 stars
Yu JC, 2009	Assessing and managing mobile techno-stress	–	Techno-stress is a potentially negative outcome of interaction between human and mobile technology devices	5/7 stars
Ballance CT, 1991	Psychology of computers use. XXIV computer-related stress among technical college students	186	Technical college students experience more computer-related stress	4/10 stars
Hudiburg RA, 1989	Psychology of computer use .7. measuring techno-stress—computer-related stress	141	The Hassles Scale is useful for measuring techno-stress level	4/10 stars
Techno-stress both work and non-work-related				
Reinke K, 2016	ICT-based communication events as triggers of stress: a mixed methods study	59	ICT-related techno-stress is induced by the valence of communications, the lack of autonomy, and the interruptiveness	2/10 stars
Brooks S, 2015	Does personal social media usage affect efficiency and well-being?	209	Social media usage reduces task performance and happiness and increases techno-stress levels	12/19 items
Galluch PS, 2015	Interrupting the workplace: examining stressors in an information technology context	180	ITCs create episodic stress but also facilitate our ability to manage it	2/5 stars
Fischer T, 2015	The status quo of neurophysiology in organizational techno-stress research: a review of studies published from 1978 to 2015	–	Neuropsychological tools are essential to analyze techno-stress phenomenon	5/7 stars
D'Arcy J, 2014	Reflecting on the "dark side" of information technology use	–	Techno-stress in one of the dark sides of information technology use, besides information overload, multitasking, technology addiction, and misuse	5/7 stars
Riedl R, 2013	Computer breakdown as a stress factor during task completion under time pressure: identifying gender differences based on skin conductance	77	Skin conductance increase after a stress stimulus	2/5 stars
Riedl R, 2012	Techno-stress from a neurobiological perspective: system breakdown increases the stress hormone cortisol in computer users	20	Salivary cortisol levels increase after a system breakdown	2/5 stars

Table 2 List of cross-sectional studies that included and addressed the topic of TS

Article	Presence of techno-stress	Stressors	Symptoms or patho-physiology	Antecedents	Moderators (inhibitors)	Consequences
Work-related techno-stress						
Inram M, 2017	X	X				X
Suh A, 2017	X	X		X	X	X
Stich JF, 2017	X	X				
Park HJ, 2016	X			X		X
Tak S, 2016	X					X
Tacy JW, 2016	X					X
Leung L, 2017	X					X
Choi SB, 2016	X	X				X
Waizenegger L, 2016	X					X
Lee SB, 2016	X	X		X		X
Gaudioso F, 2017	X	X				X
Califf CB, 2016	X					X
Brooks S, 2016	X			X	X	
Jonusauskas S, 2016	X	X				
Wulansari NA, 2015	X				X	X
Tarafdar M, 2015	X				X	X
Srivastava SC, 2015	X				X	X
Califf CB, 2015	X	X		X	X	
Kunthia J, 2015	X	X		X		
Joo YJ, 2016	X				X	
Kim HJ, 2015	X	X		X	X	
Ninaus K, 2015	X				X	X
Raisiene AG, 2015	X				X	X
Harris KJ, 2015	X	X				
Jena RK, 2015	X				X	X
Sellberg C, 2014	X	X				
Weinert C, 2014	X			X	X	
Ahmad UNU, 2014	X	X			X	
Fieseler C, 2014	X	X			X	
Brown R, 2014	X	X			X	X
Fuglseth AM, 2014	X	X			X	X
Ortbach K, 2013	X	X				
Khan A, 2013	X	X				X
Salanova M, 2013	X	X		X		
Hung WH, 2015	X				X	X
Ahamad UNU, 2012	X	X				
Maier C, 2012	X			X		
Yun H, 2012	X			X	X	X
Ahmad UNU, 2012	X	X	X			
Bucher E, 2013	X	X			X	
Kwanya T, 2012	X				X	
Hirose H, 2012	X			X		
Shu Q, 2011	X			X		
Tarafdar M, 2011	X	X			X	X
Hung WH, 2011	X	X				X
Koo C, 2011	X				X	X
Wang K, 2008	X	X		X		
Ragu-Nathan TS, 2008	X	X		X	X	X

Table 2 (continued)

Article	Presence of techno-stress	Stressors	Symptoms or patho-physiology	Antecedents	Moderators (inhibitors)	Consequences
Burke MS, 2009	X	X			X	
Tarafdar M, 2007	X	X				X
Al-Fudail M, 2008	X	X	X	X		
Ayyagari R, 2007	X	X		X	X	X
Al-Qallaf CL, 2006	X	X				X
Wang K, 2006	X			X	X	X
Tu Q, 2005	X	X				X
Wang K, 2005	X	X			X	
Kasuga N, 2004	X			X		
Poole CE, 2001	X					
Rose, 1998	X			X	X	X
Ballance CT, 1991	X			X		
Bichteler J, 1986	X					X
Non-work-related techno-stress						
Yao J, 2017	X	X				X
Nimrod G, 2017	X	X				X
Reinecke L, 2017	X	X				X
Zhang S, 2016	X	X		X	X	
Zheng X, 2016	X			X	X	X
Brooks, 2016	X			X	X	
Hsiao KL, 2016	X			X		
Hsiao KL, 2017	X			X		X
Krishnan S, 2017	X	X		X		
Luqman A, 2017	X	X		X		
Hsiao KL, 2016	X			X	X	
Lee J, 2016	X	X			X	X
Maier C, 2015	X	X		X		X
Jena RK, 2015	X			X		
Lee AR, 2016	X	X		X		
Lee YK, 2016	X	X		X		
Ravindran T, 2014	X			X		X
Lee YK, 2014	X			X	X	
Lee SJ, 2012	X			X		X
Ayyagary R, 2011	X	X		X		
Coklar AN, 2011	X		X	X		
Sahin YL, 2009	X	X		X		
Hudiburg RA, 1999	X					
WR and non-WR-related techno-stress						
Reinke K, 2016	X	X				

minimum value observed was of 1/10 stars, while the highest value was of 9/10 stars. 41 of the 85 cross-sectional studies (48%) had a quality rating above the mean value. Overall the response rate was generally low, because only few articles controlled for the main influencing factors, and all studies used a self-reported method for evaluating TS (questionnaires or interviews).

Experimental studies were evaluated using the Jadad scale for randomized controlled trials, that consists of five items and analyze the randomization, the double blindness and the drop out at follow-up. The scale has a minimum quality rating of zero and a maximum quality rating of 5 stars; a trial is considered having a good quality if the score value is at least of 3. None of the randomized controlled

Table 3 List of experimental studies that included and addressed the topic of TS

Article	Presence of TS	Stressors	Symptoms or pathophysiology	Antecedents	Moderators (inhibitors)	Consequences
Work-related						
Schellhammer S, 2013	X	X		X		
Mark GJ, 2011	X		X			X
Non-work-related						
Maier C, 2015	X				X	X
Stefan Tams, 2014	X		X			
WR and non-WR						
Brooks S, 2015	X	X				X
Galluch PS, 2015	X	X				X
Riedl R, 2013	X		X	X		
Riedl R, 2012	X		X			

Table 4 List of reviews that included and addressed the topic of TS

Article	Presence of TS	Stressors	Symptoms or pathophysiology	Antecedents	Moderators (inhibitors)	Consequences
Work-related						
Fischer T, 2017[a]	X	X		X	X	X
Tacy JW, 2016	X	X				
Haddara M, 2016[a]	X	X				
Tams S, 2015	X		X	X	X	X
Tarafdar M, 2015	X	X				X
Tarafdar M, 2015	X				X	X
Saganuwan MU, 2015	X	X		X	X	X
Ziu Yan, 2013	X	X		X	X	
Sami LK, 2006	X			X		X
Arnets BB, 1997	X		X	X		X
Non-work-related						
Riedl R, 2013[a]	X		X			X
WR and non-WR						
Fisher T, 2015	X		X			X
D'Arcy J, 2014	X	X		X	X	
Yu JC, 2009	X					

[a]Systematic reviews

trials adopted a double-blind approach, and none had withdrawal at follow-up, therefore all the studies achieved a quality score of 2/5. For non-randomized trials, it was not possible to perform a real quality assessment, because of the lack of an applicable quality scale, and therefore the TREND checklist was used in order to evaluate the completeness and the clarity of the data reported. This checklist is composed by 22 items, therefore the maximum score is 22, however in the evaluation of these studies some of them were not applicable, so the maximum score in some cases is lower than 22.

Reviews were assessed using the INSA scale for narrative reviews, and the AMSTAR scale for systematic reviews. The AMSTAR scale consists of 11 items, to which the possible answers are yes, no, cannot answer and not applicable. The minimum value score is zero and the maximum is 11. All the three systematic reviews had a quality rating < 5 items. The INSA scale consists of seven items and the score can have a minimum level of zero and a maximum level of 7. A narrative review with a score ≥ 5 is considered of good quality. The mean value obtained for the narrative reviews was 4, with a standard deviation of 1. The reasons for the low quality are mainly due to the fact that, in many reviews, the description of the characteristics of the included studies was unclear, and the author's statement on any eventual conflicts

of interest was not present. Moreover, in many reviews, the conclusions of the studies analyzed were not clear or well-defined. Concerning the three systematic reviews retrieved from the literature, the quality assessment was quite low, because of common limits. In particular, the status of publication had not been used as an inclusion criterion, and the scientific quality of the included studies, as well as publication bias, had not been assessed. Moreover, one review did not provide the characteristics of the included studies.

The global values of the quality assessment of the studies included here are listed in Table 1.

In formulating the results, when it was possible, only the papers with an average or higher value of quality have been considered. Anyway it has been decided to not exclude from the review the papers with poor quality because they could be useful to be aware of the efforts done until now in this field of research, and to drive further research towards a better and high-quality understanding of this condition.

Techno-stress definition

From the 1980s to current times, the definition of techno-stress has changed. The first definition, developed by Brod (1982), described the phenomenon of TS as "the inability to adapt or cope with new ICTs in a healthy manner" (Brod 1984). Later Weil and Rosen expanded the concept of TS as "any negative impact on attitudes, thoughts, behaviors, or body physiology that is caused either directly or indirectly by technology" (Weil and Rosen 1997). Finally, the latest definition accepted today in the literature is that techno-stress is "an IT user's experience of stress when using technologies" (Ragu-Nathan et al. 2008).

Symptoms and patho-physiology of techno-stress

TS is a state of psycho-physiological activation characterized by higher circulating levels of stress-sensitive hormones, as well as cognitive symptoms, such as poor concentration, irritability, and memory disturbances (Arnetz and Wiholm 1997). Individuals can react psychologically to TS, by feeling exhausted from using IT, or they can react showing *behavioral strain* (Ayyagary et al. 2011). As other type of stress also the TS seems to be characterized by the activation of hypothalamus–hypophysis–adrenal gland axis that causes an increase of cortisol level in the blood. In a laboratory experiment conducted by Riedl et al., the salivary cortisol levels of a treatment group increased significantly after a system breakdown (that represented the stressor) in a non-time-dependent human–computer interaction task with respect to a control group (Riedl et al. 2012). In a subsequent experiment performed by the same authors, the skin conductance of individuals was measured before and after a computer breakdown, and during the execution of a task in a time pressured (treatment group) or non-time-pressured (control group) environment. Skin conductance was measured because it reflects the activation of the sympathetic division of the autonomic nervous system. In the treatment group, there was a significant increase in skin conductance after the stress stimulus, particularly in males with respect to females. These findings support the hypothesis that a stressor activates the sympathetic nervous system, and that males may be more susceptible to achievement stress (Riedl 2013). These two experiments show the pathophysiological effect that TS can have in individuals both in a work environment than in a private environment. In another experimental study, email usage was interrupted in a sample of information workers for 5 days. In the 'no mail' condition, participants spent significantly longer times in a document or program window, and had a significantly lower mean frequency of window switches, with respect to baseline. Moreover, the authors measured the levels of stress in seven employees using the heart rate variability (considering that the lower the measure of HRV, the higher the amount of stress that an individual experiences), and found that participants experienced significantly less stress during the 'no mail' period with respect to the baseline condition where they had email access (Mark et al. 2011).

Tams et al. induced stress in individuals working on a computer based task through instant messages that appeared on the computer display. The messages came in two frequencies: low for the control group (every 90 s) and high for the experimental group (every 15 s). The stress level was measured physiologically via the analysis of the salivary stress enzyme, α-amylase, before and after the task. Salivary α-amylase (sAA) was chosen because it is a marker of the activation of the sympathetic nervous system which reflects changes in the levels of the stress hormone, adrenalin. Moreover, they also assessed stress psychologically through the use of questionnaires and they analyzed the relationship between psychological and physiological measures of stress. The results showed that there was no significant correlation between psychological and physiological measures of stress, leading them to conclude that both kinds of data are necessary and complementary to obtain a more complete or holistic understanding of the impact of TS (Tams et al. 2014).

Regarding non-work-related TS, an interesting experimental study was performed where participants were not allowed to use Facebook, but were free use other SNS. The authors measured the level of techno-exhaustion as described by Ayyagary et al. (2011), and found that the perception of exhaustion resulted in the development of discontinuous usage intentions, which was then subsequently translated into discontinuous usage. They concluded that exhaustion causes behavioral responses, which leads individuals to stop using a technology (Maier et al. 2015a, b).

Techno-stressors

Technology-related factors, such as stimuli, events and demands perceived by individuals, and which can cause TS are commonly called techno-stressors. There are five accepted techno-stressors in scientific literature and these were firstly described by Tarafdar et al. (2007), in a cross-sectional study. More precisely these factors are:

1. Techno-overload: this refers to an ICT's potential to drive an employee to work faster and longer;
2. Techno-invasion: this refers to an ICT's potential to invade an employee's personal life when performing job tasks, because employees can be reached at anytime and they may feel the need to be constantly connected;
3. Techno-complexity: this refers to the inherent quality of an ICT that makes employees feel inadequate with regard to their computer skills;
4. Techno-insecurity: refers to situations where users feel threatened about losing their jobs;
5. Techno-uncertainty: refers to the constant changes and upgrades of software and hardware that may impose stress on employees (Tarafdar et al. 2007; Ragu-Nathan et al. 2008).

These factors have been underlined and discussed by other authors too, and the questionnaire developed by Tarafdar et al., measuring these five domains, has been used in the majority of the cross-sectional studies. The importance of work-overload and role ambiguity has been stressed by Ayyagary, while Weinert found that work-overload in teleworkers is the main influencing factor for exhaustion (Ayyagari 2007; Weinert et al. 2014). Constant connectivity, which causes techno-invasion, is identified as one of the major causes of techno-stress among knowledge workers (Waizenegger et al. 2016). Other stressors have been identified: the lack of fit between demands and abilities among teachers (Al-Fudail and Mellar 2008); the frequent interruptions during work hours (Ninaus et al. 2015); e-mail related stressors such as high e-mail quantity and poor e-mail quality (Brown et al. 2014); the intensity of teleworking (Suh and Lee 2017), and finally the discrepancy between actual and desired use of computer (Stich et al. 2017).

Regarding non-work-related TS, determined by the use of Social Networking Sites (SNS), the factors that have been identified as stressors are quite different. Sahin and Çoklar (2009) highlighted the importance of environmental stressors among Facebook users: the high costs of technology, the unwanted e-mails, the insufficient speed of computers or internet access, the possibility of personal information being accessed online, and the risk of infection by computer viruses. Information overload, communication overload, as well as social interaction overload, are also important factors that create techno-stress among SNS users (Zhang et al. 2016; Yao and Cao 2017). In particular, the social overload is determined by the extensive usage of SNS, the high numbers of SNS friends, and the social relationship characteristics. In fact, individuals who excessively use SNS feel the need to give a lot of social support (Maier et al. 2015a, b). Moreover, internet multitasking and compulsive usage of smartphones are related to techno-stress (Reinecke et al. 2017; Jena 2015a). Reinke et al. (2016) assert that three factors associated with ICT-based communication determine the occurrence of stress: valence of communications (positive, negative or neutral), lack of autonomy, and interruptiveness.

Nimrod (2017) developed a new scale to assess techno-stress both in work and non-work-related fields in older adults (> 60 years) using ICT. The domains of the scale are defined as:

1. Overload: having to cope with more tasks and to perform them more rapidly;
2. Invasion: incursion into daily life because of blurred boundaries between public and personal contexts;
3. Complexity: complexity and constant change of ICT use, making conditions difficult to learn and use;
4. Privacy: personal information threatened because ICT use can be traced;
5. Inclusion: a sense of inferiority compared with younger users and consequent pressure to make an effort to be included in the contemporary technological environment (Nimrod 2017).

Techno-stress antecedents

Antecedents of TS are described as factors that can influence the effect of the stressors on individuals and may provoke more frequent techno-stress occurrence or even amplify the level of techno-stress. Regarding work-related TS, the antecedents can be represented by individual factors, such as age, gender and education, factors concerning the technology itself, and job-related factors. In a well-conducted cross-sectional study age has been found to have a significant positive relationship with TS levels, so the higher was the age the higher was the level of TS ($r = 0.122$, $p < 0.5$) Moreover employees with higher computer self-efficacy, which is the belief of one's capability to use a computer, had lower levels of TS ($r = -0.169$, $p < 0.05$), while employees with higher computer-related technology dependence shown higher levels of TS ($r = 0.264$, $p < 0.01$).In particular, this study shows that computer self-efficacy mitigate the effect of the techno-complexity and techno-insecurity, while have no effect on techno-uncertainty, overload and invasion (Shu et al. 2011). Regarding gender, Riedl (2013) demonstrated that males developed a higher level of stress, with respect

to females after a stress stimulus, supporting the hypothesis that males are more susceptible to achievement stress. In a large cross-sectional study Ragu-Nathan et al. showed that males experienced more TS than females too, but they found out an inverse relationship between TS levels and age, in contrast with the results by Shu. Moreover, they showed that TS level decreased as education and computer-confidence increased (Ragu-Nathan et al. 2008). Another individual features described to influence TS levels is the personal dispositional resistance to IT-induced changes (Maier et al. 2012). Features inherent to the technology itself can facilitate the occurrence of TS, in particular the intrusive characteristics of a technology which can often be the dominant predictor of stressors (Ayyagary et al. 2011).

Environmental and professional factors are also important in determining TS levels among workers. Among these factors, task complexity was found to significantly influence TS level in a cross-sectional study (Koo and Wati 2011), while perceptions of overload and strain have been found to be higher in team members that are more embedded in ICT-mediated communication networks during an experimental study (Schellhammer and Haines 2013). A large cross-sectional research shows that managers feel significantly less irritation when they are required to work after working hours, meaning that the professional role of a workers influence his level of stress (Raisiene and Jonusauskas 2015; Jonušauskas and Raisiene 2016). Organizational and internal workplace environment seem to influences TS levels too. In particular, a large and well-conducted cross-sectional study shows that two factors are positively associated with TS levels: the centralization of power ($r = 0.286$, $p < 0.01$), and the tendency towards innovation($r = 0.153$, $p < 0.01$) (Wang et al. 2008).

Concerning non-job-related TS, the most important factors that predispose one to the excessive use of SNS (and therefore to higher potential TS levels) are certain psychological factors, and some personality traits. Neuroticism, extraversion, agreeableness, openness to experience, social interaction anxiety, need for contact, materialism and external locus of control are all significantly related to the compulsive usage of mobile-social applications (Hsiao et al. 2017; Krishnan 2017; Lee et al. 2014). The level of TS has been found to be lower in users aged 26 and above, and in users with higher familial monthly income (Sahin and Çoklar 2009). Gender and number of friends seem to have little influence on overall TS or compulsive usage (Hsiao et al. 2017).

Moderators of techno-stress

The moderators of TS, also called inhibitors, are factors that can reduce TS levels and its consequences. The most important moderators of work-related TS have been well described by Ragu-Nathan et al. in a well-conducted cross-sectional study in 2008, and can be distinguished in three main categories:

1. Technical support provision: describes activities related to end-user support that reduce the effects of TS by solving users' ICT-related problems;
2. Literacy facilitation: describes mechanisms that encourage and foster the sharing of ICT-related knowledge within the organization;
3. Involvement facilitation: refers to keeping users informed about the rationale for introducing new ICTs, by letting them know about the effects of such introduction, and by encouraging them to use and experiment with new ICTs (Ragu-Nathan et al. 2008).

In addition to these three inhibitors, *innovation support* has also been identified as a moderator of TS. The relationship between good training, learning of new technology, and employee workload has been found to be significantly positive (Wang and Shu 2006). Tarafdar et al. described that the mechanisms that facilitate user involvement and which encourage users to learn and explore new ideas, and experiment within the context of ICT use, can reduce the impact of techno-stressors and increase satisfaction with the ICT usage. This consequently promotes an increase in productivity and innovation in ICT-related tasks (Tarafdar et al. 2011). Califf et al. (2015) also demonstrated that involvement, literacy and technical support are positively related to techno-eustress, and they are negatively related to techno-distress. Moreover, organizational support has been found to be negatively related to work exhaustion (Kim et al. 2015). A large and good-quality cross-sectional study showed that some personality traits such as openness to experience, neuroticism, agreeableness and extraversion play an important role as moderators towards the effects of TS creators. In fact these specific personality traits are described to resulting in positive job outcomes (Srivastava et al. 2015). Other moderators of work-related TS have been described in the literature such as: the innovation culture (Koo and Wati 2011); being literate in social media, which enables one to cope with overload, invasion and uncertainty (Bucher et al. 2013); a proactive personality of employees, which could reduce the effect of communication overload (Hung et al. 2015); technology self-efficacy of employees (Tarafdar et al. 2015a, b); and technical and social support from peers (Joo 2016).

Regarding non-job-related TS, only two factors have been described that have been suggested to reduce TS level: innovativeness, which is the tendency for the active utilization of innovative technologies (Lee 2012) and perceived usefulness of cell-phone devices (Lee 2016).

Consequences of techno-stress

TS has been described to determine a wide variety of consequences both in professional and in private fields. Regarding professional life, the most important and researched work-related outcomes are productivity, job performance, job satisfaction and organizational commitment.

Job satisfaction is defined as a positive emotional state resulting from the appraisal of one's job. It is an important outcome because of its impact on employee functioning, productivity, and ultimately on organizational costs. Organizational commitment can be defined as the extent to which an employee identifies with, and is involved in, the organization. Ragu-Nathan et al. showed that TS creators decrease job satisfaction, leading to decreased organizational commitment (Ragu-Nathan et al. 2008), while another study showed that a certain amount of TS increases organizational commitment (Ahmad et al. 2014). Besides these two outcomes, TS can reduce technology-related, and the overall, performance of employees too, which is defined as the capability of an individual to complete work-related tasks (Jena 2015a; Tarafdar et al. 2007, 2011). However, a cross-sectional study conducted among librarians in Kuwait showed that TS enhanced job performance (Al-Qallaf 2006). TS seems also to worsen the negative affectivity of individuals, which is a tendency to experience a range of negative feelings such as worry, anxiety and a negative self-view (Jena 2015a). A study of university librarians in Pakistan confirmed that stress caused by technological innovations has a significant negative effect on job satisfaction, with technology-overload in particular being a predictor of job dissatisfaction (Khan et al. 2013). Suh and Lee demonstrated that work overload, invasion of privacy and role ambiguity are three of the most important factors that cause TS and, in turn, reduce job satisfaction (Suh and Lee 2017). On the contrary, another study showed a significant positive correlation between techno-overload, and techno-uncertainty, with organizational commitment, concluding that a certain amount of stress is necessary for the well-being of the employees and the organizations (Ahmad and Amin 2012). Tacy and Northam showed that technology use among nurse educators was predicted by lower levels of TS and higher levels of perceived usefulness, perceived ease of use, attitude toward using ICTs, and behavioral intention to use technology. In addition, job satisfaction was predicted by lower levels of TS, while intention to stay in the profession was primarily predicted by higher levels of perceived usefulness, perceived ease of use, and job satisfaction (Tacy 2016). ICT information overload generates frustration and stress in users, and leads to a decline in their performance, as well to job dissatisfaction (Saganuwan 2015). On the contrary, a study conducted among Kuwait librarians showed that those who were optimistic about technology use in the workplace, and those who believed that technology improved their job performance, were more satisfied with their jobs (Al-Qallaf 2006).

Concerning the satisfaction with ICT use, a study demonstrated that employee's perceptions of the existence of TS creators in their organizational environment are negatively associated with their level of satisfaction with ICT use, while employee perceptions of the existence of TS inhibitors in their organizational environments are positively associated with their level of satisfaction with ICT use. Employee satisfaction with the use of ICT, in connection with their job tasks, is positively associated with their intentions to extend their use of new ICT (Fuglseth and Sørebø 2014).

Another important work-related outcome is represented by the workers' work–life conflicts. In fact, work-overload and flexibility due to technology use, increases work–life conflict, job stress and user resistance (Yun et al. 2012). Furthermore, using ICTs to perform work tasks at home makes employees perceive their work/family borders as flexible and/or permeable. As expected, work-to-family conflict was significantly and positively associated with TS (Leung and Zhang 2017).

Work productivity seems also negatively affected by TS. Tarafdar et al. showed that productivity and TS are inversely related; in fact a survey conducted on employees who use mobile phones routinely in their work showed that TS creators had a negative effect on their productivity (Tarafdar et al. 2007; Hung et al. 2011). Furthermore, from a narrative review conducted by Tarafdar, it emerges that the same characteristics that make IT useful (reliability, portability, user-friendliness and fast processing) may also undermine employee productivity, innovation and well-being (Tarafdar et al. 2015a, b).

Other consequences of TS that have been described among employees are: antisocial behavior on computers, that can especially affect males with respect to females (Kasuga et al. 2004); emotional exhaustion due to the high quantity and poor quality of e-mails (Brown et al. 2014); and role stress caused by role conflict and role overload both enhanced by TS (Wang and Shu 2006).

Concerning the consequences of non-work-related TS, it has been demonstrated that the excessive use of mobile SNS has a strong effect on both the technology–family conflict and technology–work conflict (Zheng and Lee 2016), and leads users to discontinue or reduce the use these due to exhaustion and reduction of user satisfaction (Luqman et al. 2017; Maier et al. 2015a, b). In addiction, the information overload from cell phone usage has been described to increase negative emotions, such as anger and anxiety, in users, while the perceived usefulness of cell-phone devices mitigates this effect (Lee 2016). Other psychological consequences of TS are represented by burnout, depression, anxiety and perceived social pressure to be constantly available

or connected, to be under communication overload, and to prove capabilities at internet multitasking (Reinecke et al. 2017). Another study demonstrated that TS influences data communication preferences, leading to a preferred voice communication (Lee 2012). In older adults (age > 60) higher levels of TS have been found to be significantly associated with lower life satisfaction (Nimrod 2017).

Discussion

TS is a syndrome of increasing interest because of the extensive use of ICTs both in work environments and in private lives. On one hand ICT have facilitate different aspects of modern life and have simplified work tasks, on the other hand many clinical condition have been related to the use of them, such as TS. This condition seems to be considered a different disease from general stress, depression, anxiety, or technology addiction, because it is characterized by peculiar physical, psychological, cognitive and behavioral symptoms (Chiappetta 2017; Ragu-Nathan et al. 2008).

This systematic review has been performed in order to clarify the definition, the symptoms and the related risk factors of TS, in particular focusing on the differences between work-related and non-work-related TS independently from the methodological quality of the papers.

The results shows that the definition of TS has changed over time, and the latest accepted definition is the one provided by Ragu-Nathan et al., who indicated that TS is "an IT user's experience of stress when using technologies" (Ragu-Nathan et al. 2008). It consists of a state of psychophysiological activation characterized by higher circulating levels of stress-sensitive hormones. It is characterized by cognitive symptoms such as poor concentration, irritability, and memory disturbances (Arnetz and Wiholm 1997), but also by feelings of exhaustion and behavioral responses (Ayyagary et al. 2011).

Factors, events and circumstances that cause TS are commonly called techno-stressors, while the antecedents are factors that can influence and amplify the effect of the stressors on individuals. Moderators, on the other hand, can mitigate or inhibit the occurrence of TS. Depending on the environment in which TS develops in individuals, the disease can be considered as work-related or non-work-related.

Job or Work-related TS has been more extensively studied in literature, because of its impact on productivity and business. Tarafdal et al. described the main five categories of work-related techno-stressors, which are represented by techno-overload, techno-invasion, techno-complexity, techno-insecurity and techno-uncertainty. Other stressors have been identified, and can be summarized as: role-ambiguity and constant connectivity derived by the extensive use of ICTs (Weinert et al. 2014; Waizenegger et al. 2016); lack of fit between demands and abilities in teachers' jobs; frequent interruptions during work hours (Ninaus et al. 2015); e-mail related stressors such as high e-mail quantity and poor e-mail quality (Brown et al. 2014); intensity of teleworking (Suh and Lee 2017); and finally discrepancy between actual and desired use of computers (Stich et al. 2017). The antecedents of this kind of TS are represented mainly by individual factors such as age, gender, education, personal disposition towards and resistance to IT-induced changes, and computer self-efficacy (Maier et al. 2012). Nevertheless, factor inherent to the technology itself too, as for example intrusive technology characteristics (Ayyagary et al. 2011), environmental and professional factors, such as task complexity (Koo and Wati 2011), centralization of power and tendency towards innovation (Wang et al. 2008) can influence the effects of techno-stressors. Concerning the moderators/inhibitors, they can be distinguished into three main categories or components: technical support provision, literacy facilitation, and involvement (Ragu-Nathan et al. 2008). Other relevant types of inhibitors are represented by innovation support and culture, the presence of a proactive employee personality, the technological self-efficacy of employees (Tarafdar et al. 2015a, b), the technical and social support from peers (Joo 2016), the desire for innovativeness, and finally the perceived usefulness of cell-phone devices (Lee 2016).

Not-work-related TS stems from the excessive use of SNS. Different stressors have been identified in this field and they can be summarized as: environmental factors (costs of technology, unwanted e-mails, insufficient speed of computers or internet access, the possibility of personal information being accessed online, and risk of computer viruses) (Sahin and Çoklar 2009); information overload, communication overload, and social interaction overload (Zhang et al. 2016; Yao and Cao 2017); internet multitasking and compulsive usage of smartphones (Reinecke et al. 2017; Jena 2015b). The antecedents of this kind of TS are represented mainly by psychological factors and personality traits (Hsiao et al. 2016; Krishnan 2017; Lee et al. 2014). Finally, only two factors have been described to reduce TS levels: the tendency of individuals for the active utilization of innovative technologies (Lee 2012) and the perceived usefulness of cell-phone devices (Lee 2016).

TS can lead to a great variety of consequences. In the professional environment, it is described to lead to a reduction in job satisfaction, organizational commitment and job performance, while it may enhance the negative feelings, such as worry, anxiety, self-criticism, negative self-view, as well as increasing the risk of developing a work–family conflict (Ragu-Nathan et al. 2008; Jena 2015b ; Tarafdar et al. 2007, 2011). On the other side two studies showed a positive impact of TS, respectively, on organizational commitment and job performance (Ahmad et al. 2014; Al-Qallaf 2006).

TS increases the risk of developing antisocial behavior on computers, especially in males (Kasuga et al. 2004). In addition, emotional exhaustion, role conflict and role overload may also been noted (Wang and Shu 2006), and can produce a decrease in sense of innovation and well-being (Tarafdar et al. 2015a, b). Non-work-related TS has been described to produce technology-family and technology-work conflicts (Zheng and Lee 2016), and to enhance negative feelings (Lee 2016). Perceived stress is positively related to burnout, depression and anxiety (Reinecke et al. 2017). Finally, TS can influence the data communication preferences also, leading individuals to prefer oral communication (Lee 2012).

The importance of this systematic review is represented by the comprehensive summary of different aspects of TS, in particular the factors that cause it, that facilitate or inhibit its occurrence, and the consequences of TS disorders. Moreover, it addressed not only TS experienced by workers (which has represented, up to now, most of the antecedent research), but also TS that can affect anyone who uses ICTs excessively for private purposes.

Concerning the workplace TS can affect different types of workers that are embedded in ICT usage, with different symptoms and degree of severity. In fact besides teachers, librarians, salespersons, business people, managers, etc. which have been studied in the articles on this topic, many other categories of workers should be considered at risk of developing TS, and therefore should be studied. In particular all the new professional categories born in the latest decades for which the use ICT is pervasive should be considered, for example web content editors, programmers, advertising workers, call center operators, journalists and so on (Rose et al. 1998; Di Frenna and Tecnostress 2015; Perciavalle and Prunesti 2016). In all workplaces where digital technologies are frequently used, TS should be included in the document regarding work-related risk assessment in accordance with the Consolidated Italian Law 81/2008 of Health and Safety at work. Given the recent concerns about TS, the risk assessment in professional fields is essential to identify appropriate protection and prevention measures concerning the organization of work, procedures, information and training of workers. (Chiappetta 2017; Di Frenna and Tecnostress 2015; Perciavalle and Prunesti 2016).

Of course there is the need to continue the research in this field to better understand and clarify the epidemiology of the disease, its clinical presentation as well as its causes. It is also important to analyze the possible impact of the improvement in the attitude and ability of the workers in using technologies on the occurrence and severity of TS. Studies with a rigorous methodology should be performed, in particular longitudinal studies, in order to overcome the limits of the current literature that we have identified.

This review presents some limits. First of all grey literature and papers which were not in English have been excluded. In fact, it was not possible to retrieve papers written in Japanese or Portuguese, which could have added some knowledge about TS. Secondly, the choice of 'technostress' as the unique keyword could have limited the number of studied retrieved in the databases used, although already numerous. However, the choice for this review was to use a sensible, and not specific, search. Therefore it could be interesting to perform other systematic reviews using correlation of words such as 'stress AND technology' or 'stress AND information and communication technologies' in order to widen the results obtained on this topic. Moreover the studies included had just an average quality level, although we have considered this aspect when writing results. In fact the aim of our study was mainly to list up good research questions, independently from the methodological quality of the papers, in order to be as broad as possible.

Suggestions for future research are related to the methodology used to assess the presence and the level of TS in individuals. This evaluation should include self-reported measures, fundamental when studying stress, but also objective measures. In fact, although it has been demonstrated that a multi-method approach is a more efficient way to study TS, only a minority of studies have used this kind of approach, whilst the large majority of them have more often used a mono-method approach, based mainly on self-reported measures (questionnaires, interviews) (Fischer and Riedl 2017). The studies included in this review had an average quality value. In particular, the narrative reviews had the lowest quality values, while the half of the cross-sectional studies (that were the most frequent) had a quality value above 5. Furthermore, because of the extent and complexity of this topic, studies should focus on a single aspect of TS, rather than simultaneously approaching multiple stressors and consequences, in a prospective way, i.e., using cohort studies. Finally, it would be desirable to expand the analysis of non-work-related TS, which may not have an immediate impact on productivity, but can produce psychological and behavioral consequences in individuals, that can subsequently have an impact on society overtime.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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