The Effects of Digitalization on Human Energy and Fatigue: A Review

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ABSTRACT

Information and communication technologies (ICTs) are generally assumed to save time and energy, yet user fatigue due to ICT use is assumed to be on the rise. The question about the effects of ICT use on human energy has sparked increased research interest in recent years, however, the course is complicated by the fact that the conceptualization of human energy is extremely diverse. The aim of this paper is therefore twofold. First, we provide a conceptual framework and classification of subjective energy concepts and reflect on the theoretical embedding of technology within the theories on subjective energy. Second, we review the leading empirical literature on the relationship between ICT use and eight different subjective energy concepts prominent in different disciplines. We also include the new phenomena of social networking sites (SNS) exhaustion and SNS fatigue. With this, we aim to consolidate the existing research, illuminate the gaps, and provide a conceptual baseline for future research on the relationship between ICT use and subjective energy of ICT users. We show that ICTs use has predominantly negative effect on users' energy, especially in organizational contexts, and show the main patterns and mechanisms through which technology drains as well as energizes users.

Keywords: Human energy, exhaustion, vigor, fatigue, vitality, depletion, ICTs, ICT use

1. INTRODUCTION

As we approach the third decade of the 21st century, our lives appear more and more like the wildest sci-fi dreams of the previous millennium: we own pocket-sized devices and wearables that are connected not only to our friends, family and colleagues, but also to our refrigerators, radiators and home cameras. At our fingertips or voice commands we have access to a library of infinite human knowledge and even at the remotest locations we can accomplish most of our tasks. The new information and communication technologies (ICTs) that help us achieve this were invented to make humanity more efficient and productive, save us time and energy, and improve our quality of life and well-being.

Yet at the same time, lack of time and energy is the number one complaint of modern society, and digital technology is often seen as a cause. The number of employees who suffer from fatigue and emotional exhaustion seems to be rising and often tips over 25% of the general working

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population, depending on country and assessment method (Aumayr-Pintar, Cerf, & Parent-Thirion, 2018; Bültmann, Kant, Kasl, Beurskens, & van den Brandt, 2002; Shanafelt et al., 2015; Shanafelt et al., 2019). The costs of burned-out employees is estimated to be up to 190 billion dollars per year in health-care spending in the US alone, and additional 5 billion US dollars in turnover and productivity loss among physicians only (Garton, 2017; Han et al., 2019; Waldman, Kelly, Aurora, & Smith, 2004).

Digitalization of the work place has been cited as a common reason for this decrease in employees' energy levels, and terms such as "techno-stress", "tech-invasion" and "digital fatigue" have entered the vocabulary (Ayyagari, Grover, & Purvis, 2011; Ragu-Nathan, Tarafdar, Ragu-Nathan, & Tu, 2008; Shin & Shin, 2016). Additional technology-related phenomena such as Internet addiction and addiction to Social Networking Sites (SNS) have also been associated to fatigue, which extends the problem beyond work environments to the general population, especially the younger generations (Bener et al., 2018; Lin, Tsai, Chen, & Koo, 2013). So the question arises, are ICTs saving or are they costing us energy?

Considering the trends, it is not surprising that research on this topic has started to proliferate in the last couple of years. As of 2019, 83% of the articles published on the topic in the leading Human Computer Interaction (HCI) and Information Systems (IS) journals date no earlier than 2014 and 69% as recently as 2016. However, if one attempts to review the results, it quickly becomes evident that human energy, especially the subjective experience thereof, is an extremely elusive and complicated construct. Different disciplines use different terms, different definitions and different theories to describe and explain subjective energy. For example, organizational scholars mostly refer to employees' feelings of "emotional exhaustion" and "vigor" (Bakker, Schaufeli, Leiter, & Taris, 2008; Cropanzano, Rupp, & Byrne, 2003). Personality and social psychologists on the other hand focus on "depletion" and "vitality" (Deci & Ryan, 2011; Muraven, Tice, & Baumeister, 1998). All these terms come with their own measurement instruments, sometimes multiple per term. Other terms such as mental or psychic energy, fatigue, tiredness, activity, (positive) arousal, inertia, etc., are frequently used to describe the subjective experience of having energy as well. Little consensus seems to exist on terminology and measurement, sometimes even within a single discipline like psychophysiology, cognitive and affective sciences, etc. When HCI and IS scholars now enter the field and borrow from all these disciplines, they risk using the terms arbitrarily and interchangeably.

The broadness of terms and conceptualizations makes it difficult (if not impossible) to systematically study the effects of IT use on human energy. Empirical studies are not comparable if they all use different definitions and measure different impacts in different ways. Thus, there is an urgent need for consolidation of the research, but even before that, for a systematic structure of all the different terms, their theories, and the way that they have been measured and used.

In this paper, we therefore provide a conceptual framework for the subjective energy constructs first, before we then attempt to structure the landscape of the existing research. Namely, in Section 2, we first investigate how individual energy-related terms are defined and how they are operationalized, i.e., measured. Here, we also delve into the prominent theories about the specific energy-concepts and reflect how technology can be fitted in these theories. In sum, Section 2 provides a detailed conceptual framework about subjective energy and technology and classifies the different energy-related terms. Only after this differentiated understanding of all relevant subjective energy constructs, and the method of our systematic literature review (Section 3), we

present the empirical findings of our literature review. Here we explore how each energy concept presented in Section 2 is influenced by IT use. In Section 5, we conclude by summarizing the general patterns across specific energy-related terns and by discerning the main gaps in research on the effects of digitalization on subjective energy.

The paper has several contributions to the field. First, we provide clarity and classification of the subjective energy constructs, which are otherwise scattered and sometimes ill-conceived. This section should help HCI and IS researchers interested in human energy to get an overview of the constructs and theories and choose the one (or several) construct(s) that are most suitable and relevant for their studies. Additionally, we help illuminate the state of the art on the relationship between digital technology and subjective energy. This is a first step to understanding what aspects of technology use are causing fatigue or are energizing the users. Together with the provided directions for future research, the paper provides a roadmap toward designing technology that truly nourishes human energy.

2. THE DIFFERENT FACES OF SUBJECTIVE ENERGY AND FATIGUE: CONCEPTUAL FRAMEWORK AND CLASSIFICATION OF THE TERMS

When scholars study subjective energy or subjective fatigue, the scope of the analyzed construct varies: Some study short-term, momentary experiences of energy or tiredness, while others look into longer lasting states thereof (*duration*). Some focus very narrowly on the experience of subjective energy and fatigue, while others combine it in broader concepts that entail attitudes or motivation (*range*). Again others emphasize the *cause* of energy loss or gain, for example *wor*k-stress as a cause of emotional exhaustion, while others postulate no specific cause for the experience of subjective energy. Last but not least, scholars embrace different *conceptualizations* of subjective energy: Some base their work on a bipolar (univariate) view, which sees subjective energy and subjective fatigue as two opposite ends on one energy dimension that ranges from tired to energetic. On the contrary, others embrace the more timely bivariate (unipolar) view, which postulates that subjective energy and subjective fatigue are separate feelings or mental states that are based on different energy dimensions and processes (Bakker & Demerouti, 2007; Shirom, 2011). This view thus recognizes that, somewhat contraintuitively, mixed feelings of energy and fatigue are possible. According to the bipolar view, if someone is feeling energetic and vigorous, they by definition cannot feel tired and fatigued at the same time. However, recent evidence, including neurological studies, have shown that subjective energy and subjective fatigue are based on two different brain networks, have different antecedents and behavioral consequences and can therefore be experienced at the same time (Mäkikangas et al., 2014).

In the following, we present all the relevant terms related to subjective energy, their underlying theories as well as their operationalization. Within the sections, we reflect on the place ICTs can have within these theories. Finally, we classify the concepts based on their duration, range, cause and conceptualization. We start, in Section 3.1., with emotional exhaustion and vigor, which come from the organizational sciences and are exclusively concerned with employees' energy. In Section 3.2., we present depletion and vitality, two prominent terms in personality and social psychology. In section 3.3., we discuss subjective energy and fatigue from the viewpoint of affect theories. The terms from these two sections apply to the general population. In Section 3.4., we conclude by introducing the new concepts of SNS exhaustion and SNS fatigue which is restricted to SNS users. An overview of the classification is presented in Table 1.

Table 1. Summary and classification of subjective energy constructs

Construct	Terms used for: Subjective energy	Terms used for: Subjective fatigue	Main definition	Main measures	Duration	Range/Scope	Specific cause	Field/Context
Emotional Exhaustion	Rarely, when reverse scored	Yes	Feeling exhausted and drained by work	Emotional exhaustion subscale of the MBI	Long lasting, chronic	Narrow to broad: work strain is also part of the experience	Work, work demands	Organizational science Occupational psychology _____ Applied to employees
Vigor	Yes	No	Feeling high levels of energy and mental resilience while working	*Vigor subscale of the UWES*	Long lasting	Broad: resilience and willingness to invest energy are also part of the experience	Work resources	
Depletion	No	Yes	Temporary reduction in the available energy for self-control	Dual-task paradigm. Performance measure on self-depleting tasks	Temporary, fluctuates daily	Broad: inability and unwillingness to invest energy are also part of the experience	Prior voluntary and self-controlling activities	Personality psychology Social psychology _____ Applied to the general population
Vitality	Yes	No	Experience of possessing energy and aliveness that comes from the self	Subjective Vitality Scale	Long lasting	Broad: optimism, feeling alive, awake and alert are also part of the experience	Satisfaction of basic psychological needs, especially the need for self-determination (autonomy)	
Vitality	Yes	Yes	Feeling energetic, vigorous, vital, full of pep	Vitality-fatigue subscale of SF-36	1 month	Narrow, only feeling of energy or fatigue	No specific cause	Psychophysiology Cognitive and Affective science _____ Applied to the general population
Vigor, energy	Yes	No		Vigor-energy subscale of POMS	1 week	Narrow, only feeling of energy	No specific cause	
General a activation, energy	Yes	No		General activation subscale of AD ACL	Momentary feeling	Narrow, only feeling of energy	No specific cause	

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Construct	Term used for:		Main definition	Main measures	Duration	Range/Scope	Specific cause	Field/Context
	Subjective energy	Subjective fatigue						
Fatigue	Yes	Yes	Feeling tired, worn out	Vitality-fatigue subscale of SF-36	1 month	Narrow, only feeling of energy and fatigue	No specific cause	Psychophysiology
	No	Yes	Feeling fatigued, exhausted	Fatigue subscale of POMS	1 week	Narrow, only feeling of fatigue, exhaustion	No specific cause	Cognitive and Affective science
Deactivation	No	Yes	Feeling tired, sleepy	Deactivation subscale of AD ACL	Momentary feeling	Narrow, only feeling of tiredness, sleepiness	No specific cause	Applied to the general population
SNS Exhaustion	No	Yes	Feeling exhausted and drained by SNS	SNS exhaustion (adopted from the MBI)	Long lasting	Narrow to broad: strain is also part of the experience	SNS use	Human Computer Interaction Science
SNS Fatigue	No	Yes	Feeling exhausted and drained by SNS. Feeling bored disinterested and indifferent	Adopted Mental Fatigue scales. Various self-constructed scales	Long lasting	Broad: indifference, boredom and disinterest are also part of the experience	SNS use	Information Systems Applied to SNS users

2.1. Work-related Emotional Exhaustion and Vigor

The most researched concepts related to subjective energy in the HCI and IS communities are work-related emotional exhaustion (*n=17)* and work-related vigor (*n=9*). The two concepts are primarily used in the fields of organizational sciences as well as education and are the focus of almost half (49%) of the studies we identified. There is a great agreement in these two disciplines about the definition of the two constructs, including their underlying theories. Consequently, the studies presented hereafter use the definitions, measures and theories relatively consistently.

Emotional exhaustion

Emotional exhaustion is defined as a feeling of chronic fatigue and being drained of emotional energy by one's work (Maslach & Jackson, 1981; Maslach, Schaufeli, & Leiter, 2001; Moore, 2000; Schaufeli, Leiter, Maslach, & Jackson, 1996). It is considered to be the most important and energetic aspect of work-related, chronic ill-being (Maslach, Schaufeli, & Leiter, 2001). Together with cynicism and inefficacy, it is a core symptom of job burnout. It is typically measured with a subscale from the Maslach Burnout Inventories (MBI), which contain items such as "I feel emotionally drained from my work" or "I feel fatigued when I get up in the morning and have to face another day on the job". Five different versions of the MBI tailor the measurements to different target populations, including workers in human services, medical personnel, educators, the general worker's population or students.

Emotional exhaustion is a key construct for the two most prominent work related stress theories: the Job Demands-Resource Model (J-DR) and the Person-Environment (P-E) fit model (Ayyagari et al., 2011; Bakker & Demerouti, 2007; Demerouti, Bakker, Nachreiner, & Schaufeli, 2001; Edwards, 1991; French, Rodgers, & Cobb, 1974; Maslach et al., 2001). Both theories consider emotional exhaustion to be a consequence of work stressors. According to the JD-R, prolonged work demands cause exhaustion when the work resources are low (Bakker & Demerouti, 2007). Work demands are those "aspects of a job that require sustained physical or mental effort and are therefore associated with physiological or psychological costs" (Demerouti et al., 2001, p.501). Workload and time pressure are common job demand examples. Job resources, on the other hand, are those aspects of a job that reduce the job demands, stimulate personal growth, or facilitate achieving work goals (Demerouti et al., 2001). Social support, autonomy and feedback have been established as prime examples of job resources.

Technology can be both a demand and a resource or it can indirectly increase or decrease the demands and the resources (Sardeshmukh, Sharma, & Golden, 2012). For example, too many e-mails can increase the information load or frequent updates can require permanent learning effort (Ayyagari et al., 2011). However, technology can also decrease the work demands or increase the resources, for example when it enables an employee to finish a task while at home or during commuting (Chen & Karahanna, 2018). Technology is therefore hypothesized as both: a cause of as well as a buffer against emotional exhaustion.

Unlike the J-DR, the P-E Fit Model does not weigh causes and buffers of emotional exhaustion, but rather emphasizes the *fit* between environmental demands (stressors) on one side and the needs or expectations of the person on the other (Ayyagari et al., 2011; Edwards, 1991; Maslach et al., 2001). The P-E Fit Model postulates that it is a misfit between a person's individual

needs and their environment that causes emotional exhaustion. In this respect, the same number of incoming e-mails can be perceived as e-mail overload that cause emotional exhaustion to some employees, but not to others (Reinke & Chamorro-Premuzic, 2014).

Emotional exhaustion is a long lasting, *chronic* feeling of low energy (*duration*). People are unable to recover and re-energize in their free time, thus permanently experiencing exhaustion. The construct is relatively narrow (*range*), but it does embrace related experiences like stress, because the MBI scales include the item "Working all day is a strain for me". Emotional exhaustion has a specific *cause* in the work of the employee. The demands, job characteristics, or the act of working itself are the direct causes of the feeling of exhaustion and hence the cause is part of the experience (e.g. "I feel emotionally drained *from my work*"). Originally, emotional exhaustion was *conceptualized* as low vigor, i.e., as the low end on one bipolar energy scale, however the authors now accept that vigor is a separate energy dimension (Maslach, Jackson, & Leiter, 1996; Maslach, Jackson, Leiter, Schaufeli, & Schwab, 1986; Maslach et al., 2001).

Vigor at Work and School

Vigor is defined as "high levels of energy and mental resilience while working, willingness to invest effort in work, and persistence in the face of difficulties" (Schaufeli, Salanova, González-Romá, & Bakker, 2002, p. 74). It is the ability not to be easily fatigued at work (Llorens, Schaufeli, Bakker, & Salanova, 2007). Similarly to emotional exhaustion, vigor is defined as a core and energetic dimension of work-related well-being (Bakker et al., 2008). Work-related vigor is a broad concept (*range*), which embraces a motivational side mirrored in the mental resilience of employees and their sustained willingness to invest effort. Together with dedication and absorption, it is one core aspect of the broader mental state of work engagement. The most used instrument to measure work-related vigor is the vigor subscale from the Utrecht Work Engagement Scale (UWES) (Schaufeli, Bakker, & Salanova, 2006). Example items are "At my work, I feel bursting with energy", "At my job, I am very resilient, mentally", and "When I get up in the morning, I feel like going to work". Unsurprisingly, the focus on work-related vigor" is part of the 'positive psychology movement' (Seligman & Csikszentmihalyi, 2014).

Vigor is a relatively long-lasting feeling of high energy levels (*duration*). Vigorous people feel energized during the workday and are re-energized by the thought of work in the morning. However, vigor is not specifically *caused* by work but it is rather the felt energy *at* work and *while* working. According to the JD-R model, it is the job resources that lead to work-related vigor especially when the demands are also high, resembling a state of "flow" which requires optimal challenge (M. Csikszentmihalyi, 1991; Mihaly Csikszentmihalyi, Abuhamdeh, & Nakamura, 2014). This motivational process that leads to high energy while working is *conceptualized* as a separate to the energy draining one that causes emotional exhaustion (Bakker et al., 2008; Mäkikangas et al., 2014; Shirom, 2011).

Any technology that can serve as a job resource can potentially energize and invigorate, for instance technology that supports autonomy and personal growth through learning or supportive technology that facilitates achieving work goals (Llorens et al., 2007; Sardeshmukh et al., 2012; van Zoonen & Rice, 2017).

2.2. Depletion and Vitality: Energy as a Fuel for Self-regulation and a Result of Self-determination

The next most prominent terms related to subjective energy are depletion (*n=6*) and vitality (*n=4*). Together they represent 19% of the considered studies. Both terms come from personality and social psychology and are theories about self-control or self-regulation. Depletion is rooted in the Strength Model of Self-Control (Baumeister, Vohs, & Tice, 2007). Vitality in contrasts stems from Self-determination Theory, which expands the Strength Model of Self-Control and shows why and when self-regulation is *not* depleting (Deci & Ryan, 2008; Ryan & Deci, 2000). Both theories are well established and so a rather consistent use of their definitions and methods is evident across the considered studies that focused on depletion and vitality.

Depletion

Depletion, also termed ego-depletion, is a temporary lack of capacity for volitional action and self-control caused by previous exertions of self-control (Baumeister et al., 2007; Muraven & Baumeister, 2000; Muraven et al., 1998). Depletion demonstrates itself in feelings of low energy and unwillingness to engage in further self-control. It is often accompanied with self-regulatory failures ranging from inability to regulate emotion, impulses, cravings and temptations to inability to control attention (Baumeister et al., 2007; Hagger, Wood, Stiff, & Chatzisarantis, 2010). Thus, depletion is broad in *range* in that it is not only a feeling of low energy, but also encompasses lack of motivation mirrored in the unwillingness to engage in many different tasks that require effort and self-control. Unlike emotional exhaustion or work-related vigor, it is not a lasting state but it is a relatively shorter reaction (*duration*).

Typically, depletion is measured with performance on tasks that are known to require self-control (Baumeister et al., 2007; Hagger et al., 2010). Typical examples are persistence on unsolvable anagrams, snack choice when presented with healthy vs. unhealthy options or performance on attention and cognitive-control tasks such as the Stroop task, which is a famous color-naming task that requires inhibition of the automatic response to read the text rather than name the color. Prior to the depleting task, participants are required to do an initial task that varies in its degree of required self-regulation. Drop in performance on the second task is then interpreted as evidence for energy depletion in the first one.

According to the Strength Model of Self-Control, people possess “psychic energy” in order to self-regulate. This resource is limited and can be drained by any deliberate control of cognition, emotion or behavior. Once depleted, people are no longer able or willing to exert self-control until rested or restored (for instance by sugar intake). Energy reservoirs are considered to be domain-independent (Baumeister et al., 2007), which means that prolonged self-regulation in any form will have hindering effects on any subsequent self-control tasks, even if these are unrelated. For example, prolonged cognitive effort will drain the energy for subsequent emotional impulse-control or decision making. Resisting unhealthy temptations will drain the energy for subsequent focused attention. The depleted energy can be restored quite easily however, by rest or engaging in activities that do not require self-regulation (Hagger et al., 2010). Self-control can also be trained so that frequent self-control in any domain will lead to slower depleting effects overall (Muraven & Baumeister, 2000). The *cause* for depletion is not as specific as job demands, however it is still specific enough to exclude tasks that do not require any effort.

Seen from this lens, any technology that requires self-restraint can deplete its users of their energy. For instance trying to abstain from mobile phone or social network use can be depleting (Du, van Koningsbruggen, & Kerkhof, 2018). On the contrary, if technology is created to decrease mental effort, reduce the need for self-regulation or even train self-control it can also nourish this valuable energy resource (Cranwell et al., 2014; Engin & Vetschera, 2017).

Vitality

The term “vitality” stems from Self-Determination Theory and is defined as a feeling of aliveness and vigor, a state of experiencing calm energy (Ryan & Deci, 2008). It is a eudemonic well-being related to self-realization and growth. This is in contrast to hedonic well-being, which is happiness that arises from immediate pleasures (Ryan & Deci, 2001; Ryan, Huta, & Deci, 2008). Vitality is felt as coming from within the self and is not related to any immediate external *cause*. It is often measured with Ryan and Frederick’s seven-item subjective vitality scale (SVS), with items like “I feel alive and vital”, " “I look forward to each new day” or "I don't feel very energetic” (Ryan & Frederick, 1997).

Self-Determination Theory (SDT) describes vitality as the optimal end of a favorable interaction between people and their environment. The theory postulates three basic human psychological needs: autonomy, efficacy and relatedness (Deci & Ryan, 2000, 2011; Ryan & Deci, 2000). When these needs are thwarted, the person cannot grow and achieve vitality. In contrast, when these needs are continuously satisfied, people are energized and experience vitality. Thus, autonomous (self-determined) activities, as well as activities that develop competences and belonging can all enhance vitality even if they imply invested effort. This is in direct contrast to the Strength Model of Self-Control, which postulates that self-regulating activities deplete people of energy. This is because autonomous activities and activities that promote competence and belongingness are intrinsically motivating and energizing. In sum, SDT is a theory that postulates the process of creating vitality as a function of (not always conscious) need satisfaction throughout life.

In our classification, vitality is a long lasting state of energy and “aliveness” (*duration*) that is felt at the present moment and that gives optimism to the future ("I look forward to each new day"). Thus, vitality’s *range* is broad in that it encompasses optimism, but also aliveness, awakeness and alertness. According to SDT, technologies that support the autonomy, competence and belongingness of their users can increase their vitality (James, Wallace, & Deane, 2019), those that thwart those needs deplete it (Akın, 2012; Jang, Bucy, & Cho, 2018; Satici & Uysal, 2015).

2.3. Subjective Energy and Fatigue as Positive and Negative Affect

At the core, the experience of energy or fatigue is an affective state, i.e. an affect. In psychology, an affective state is the subjective experience of a feeling. Affective states are commonly divided into emotions and moods. Emotions are usually shorter, more intense affective states with a known object, for example being angry with someone (the object of anger). Moods on the other hand are generalized affective states that are typically longer, fluctuating, and less intense. They are usually not related to specific objects, for example feeling blue (O'Connor, 2006; Shirom, 2011; Thayer, 1990). Subjective energy and fatigue are more often described as moods because feeling energetic or tired does not necessarily need a specific object and is experienced for longer time frames than typical emotions. From the concepts that we described so far, vigor can be

described as broader mental state that encompasses the energetic mood whereas emotional exhaustion is the chronic experience of the fatigue mood (O'Connor, 2006).

Theoretically, the nature and structure of affective states have been disputed since the birth of psychology. Especially contested are the number and the labeling of the core dimensions of affect, i.e., what constitutes the fundamental underlying characteristic of affective experience (Kuppens, Tuerlinckx, Russell, & Barrett, 2013). In the different theories of affect, the energy and fatigue have different prominence, from being a core underlying dimension to being just part of a broader positive or negative affect. They also appear under very different names, such as activation, arousal [2], vigor, fatigue, energy, tiredness, inertia, vitality, depletion, etc. In spite of these differences, the measures used to assess the feelings of energy and fatigue are remarkably similar.

If we combine all the studies that have used simple affect scales to measure subjective energy or fatigue they make a little more than one fifth (22%, *n=12*) of all the considered studies, with half of them considering both positive and negative affect. In the following, we present the most common measures of subjective energy and fatigue and the theories of affect that have included them. Subjective energy as positive affect

Subjective Fatigue as Positive Affect

Vigor, energy, activity, activation, arousal and vitality are amongst the many terms used to describe the experience of subjective energy as affective state. Subjective energy as affect can therefore be defined as the subjective feeling of being vigorous, energetic, active, and vital. Subjective energy as affect is thus very narrow in *range* with a focus only on the affective experience of energy and excluding other mental states or motivation, and without any focus on a specific *cause* of the experience. The most common way to measure it is with adjective scales that describe the exact feelings studied, such as to feel vigorous, energetic, active, wakeful, alert, lively, full of pep, etc. The three most widely used instruments across disciplines to measure subjective energy are the vitality-fatigue subscale of the MOS 36- Item Short-Form Health Survey (SF-36; Ware & Sherbourne, 1992); the vigor-energy subscale of the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971; Shacham, 1983) and the general activation subscale of the Activation Deactivation Adjective Checklist (AD ACL; Thayer, 1986). The vitality-fatigue scale of the SF-36 is a bipolar scale that measures subjective energy and subjective fatigue simultaneously (bipolar *conceptualization*), whereas the POMS and AD ACL are bivariate scales that have additional, separate fatigue scales (bivariate *conceptualization*). The adjectives among all scales overlap greatly; in fact, the POMS and the AD ACL are almost identical. The only notable differences between the scales are their time frames and their answering formats: Whereas the SF-36 inquires how one felt in the past month and the POMS in the past week, the AD ACL inquires how one feels right now. Depending on measure, the *duration* of the subjective energy can consequently range from momentary feeling (if assessed with the AD ACL) to a month-long feeling (if assessed with the SF-36).

There is no clear place for technology within the affect theories, since the theories themselves do not postulate the specific causes for affect (other than some physiological or neurological correlates). However, technologies can induce mood either by design (Herrero, Garcia-Palacios, Castilla, Molinari, & Botella, 2014; Serrano, Baños, & Botella, 2016) or as a

[2] Arousal and activation have mostly the same meaning within psychophysiology, but modern psychologists prefer the term activation. Neuropsychological literature, however, sometimes distinguishes between the two.

byproduct and thus the cited measurement instruments have been utilized for the study of the relationship between technology and subjective energy (Botella, Baños, Etchemendy, García-Palacios, & Alcañiz, 2016; Du et al., 2018; Huang, Wong, Yang, Chiu, & Teng, 2017; Kelley & Gruber, 2010; J. E. Lee, Xiang, & Gao, 2017).

Subjective Fatigue as Negative Affect

Subjective fatigue as affect can be defined as the subjective feeling of being fatigued, tired, worn-out, exhausted and weary. It is often seen as a symptom of ill-being. The variety of terms used to describe fatigue is much smaller than that for energy with a clear preference for the term "fatigue". Conceptually, subjective fatigue is the negative opposite of subjective energy, just as narrow in its conceptual *range*, measured with precise adjectives and rather short-termed in *duration* especially when compared to emotional exhaustion. Subjective fatigue is often studied separately from subjective energy and has its own subscales within the measurement instruments mentioned above. Most often it is measured with the vitality-fatigue scale of the SF-36 (e.g. items "tired", "worn-out") and the fatigue-inertia scale of the POMS (e.g. items "fatigued", "exhausted").

2.4. Social Media Exhaustion and Fatigue

The last energy related concepts that we introduce are "SNS exhaustion" and "SNS fatigue". They are new energy related phenomena introduced by HCI and IS researchers due to the establishment of SNS as main portals to the Internet in recent years. We consider SNS exhaustion and fatigue specifically because they represent 21% of the identified studies (*n=11*). Next to SNS exhaustion and fatigue, constructs such as cellphone messenger fatigue, privacy fatigue, general digital fatigue as well as user fatigue have also been introduced. However, these aspects of technology fatigue are still not very well established, which is why we do not discuss them here.

Social Media Exhaustion

SNS exhaustion is defined as an "aversive, potentially harmful, and unconscious psychological reaction" caused by SNS-use (Maier, Laumer, Eckhardt, & Weitzel, 2015) or excessive SNS use (Cao, Masood, Luqman, & Ali, 2018). It is mostly a user reaction caused by perceived social overload (Cao & Sun, 2018; Maier et al., 2015). SNS exhaustion demonstrates itself in feelings of tiredness from SNS use (Luqman, Cao, Ali, Masood, & Yu, 2017). It is often measured with a 4-item scale created by Maier and colleagues (Maier et al., 2015). The scale is an adaptation of the Maslach Burnout Inventory (MBI) where "work" and "my job" are replaced by "SNS activities" or "Facebook", but the item "I feel fatigued when I get up in the morning and have to face another day on the job" was omitted from the new scale. Example items of the SNS exhaustion scale are "I feel drained from activities that require me to use SNS" or "I feel tired from my SNS activities". The instruments sometimes specify the concrete social network (e.g. "I feel tired from my Facebook activities") or the device ("I feel tired from my mobile SNS activities").

SNS exhaustion is based on the work by Ayyagari et al. (2011) and is explained with the PE-fit model as well as job burnout theory. Ayyagari et al. (2011) investigated how new technologies and their features can cause "technostress" and were the first to explicitly specify ICTs as cause of emotional exhaustion with work. Even though they stayed within the borders of job burnout theory, this work inspired other HCI and IS researchers to investigate the role of ICTs

beyond work-related exhaustion. The basic premise is that some technology features, such as being always reachable and non-anonymous, create stress and lead to emotional exhaustion.

Based on its operationalization, we would argue that social media exhaustion is a longer lasting state (*duration*). However, the chronic aspect evident in work-related emotional exhaustion is not apparent in SNS exhaustion. Neither the definition nor the instruments (because of the omitted item) imply that one cannot recover from SNS exhaustion or that the permanence of these feelings of tiredness persist throughout the day and reoccur in the morning. The *range* of the term is narrower similarly to emotional exhaustion. Finally, SNS exhaustion has a very specific *cause* that is the prolonged or excessive use of SNS. Unlike job demands and work stressors that can vary greatly, social media exhaustion has only this one proposed stressor. Thus, SNS exhaustion seems more specific and less chronic than work-related exhaustion.

Social Media Fatigue

SNS fatigue has been defined as the subjective feeling of tiredness caused by SNS stress, overwhelming amounts of information, and too many SNS friends (Bright, Kleiser, & Grau, 2015; Lee, Son, & Kim, 2016). It is also seen as a tendency for SNS users to "back away" from social media (Bright et al., 2015). In this sense it is similar to SNS exhaustion. However, unlike SNS exhaustion, it is also characterized by feelings of boredom, indifference, and lower interest, as well as inability to relax and focus (Zhang, Zhao, Lu, & Yang, 2016). SNS fatigue has been measured with adopted subjective fatigue items such as ("After a session of using SNSs, I feel really…"fatigued", "tired", "worn out"). However, other self-constructed items include the most diverse statements and feelings like "After a session of using SNSs, I feel really bored", "I find it difficult to relax after continually using SNSs" or "After using SNSs, it takes effort to concentrate in my spare time". In this sense SNS fatigue is a very broad (*range*) negative emotional reaction to SNS use. It is also has a shorter duration than SNS exhaustion, mostly describing the immediate feeling post SNS use. Because of the specific focus on negative affect, there is no place for a univariate vs. bivariate distinction within the concepts of both SNS exhaustion and SNS fatigue. Being energized by SNS or having energy because of SNS use is not discussed as a potential process.

3. METHOD

For the purpose of our study we performed a systematic literature research on the relationship between digital technology and subjective energy in the top-ranked journals in the fields of Human-Computer Interaction (including Human Factors and Ergonomics) and Information Systems (including Information System Management and Management Information Systems), as well as the leading journals in Applied Psychology, Organizational Behavior and Consumer Research. In the first step of the analysis we identified the 30 leading journals in these fields (top 25 journals in the HCI and IS domain; top 5 in the external domains) using the Scimago Journal and Country Rank database which ranks the journals based on the SJR2 indicator (Guerrero-Bote & Moya-Anegón, 2012).

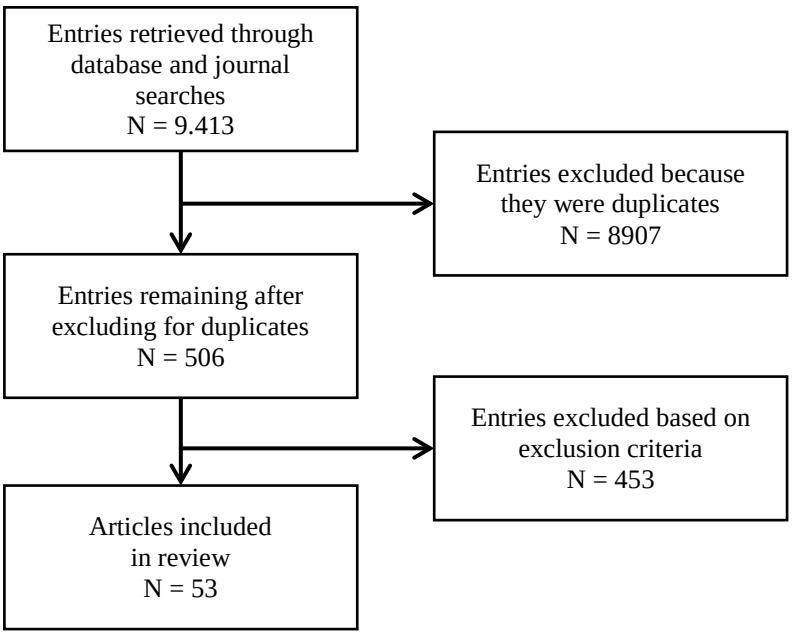
In the second step we searched these journals using the search terms "subjective energy", "mental energy", "psychological energy", "vitality", "vigor", "vigour", "positive arousal", "fatigue", "exhaustion" OR "depletion". For the journals outside the HCI and IS domains we additionally restricted the search (with the AND operator) to include "media", "phone", "laptop",

"computer", "social network", "digital", "ICT*", OR "information technology". We used the Web of science, Ebsco, ProQuest, and Science Direct databases to perform the search within the journals.

After excluding for duplicates, the search resulted in a total of 506 studies which were then scanned for relevance. The inclusion criteria required:

1. The study is an original empirical research
2. At least one measure of subjective energy is included in the study
3. At least an indirect relationship between the energy measure(s)and technology use is assumed and tested

Figure 1. Overview of the selection process for the review



Thus, the review excluded theoretical papers and papers that measured physiological proxies of subjective energy. The screening resulted in 53 studies that are discussed in this paper. The overview of the selection process is presented in Figure 1. All reviewed studies are presented and summarized in Taböe 2 of the Appendix.

4. RESULTS FROM THE LITERATURE REVIEW: THE EFFECTS OF TECHNOLOGY USE ON SUBJECTIVE ENERGY AND FATIGUE

In the following, we report the main empirical findings from our literature review on the relationship between ICT use and the different energy constructs. All reviewed studies, their methods, samples and main findings are presented in Table 2 in the Appendix. In the narrative review that follows, we follow the order of Section 2 and present the results for each term separately, focusing on the main patterns that arise from the literature.

Even though a meta-analysis of the results was out of scope of this review (not least because of the variation in definitions and assessment of subjective energy among the studies), we also present the effect sizes of these relationships, where possible. We derived the effect sizes either from the standardized beta coefficients from regression and structural equation models, the partial eta squares from analysis of variance, and Cohen d values from t-tests. Where possible, we calculated the effects sizes from reported mean differences and standard deviations. Where no effect sizes were reported and no derivation was possible or applicable, we annotated it with not reported/not applicable (NR/NA; Table 2, Appendix). In the narrative review that follows, a slight increase/decrease refers to a small effect size in the relationship (e.g. ß < .3; Cohen d < .2), a large, substantial increase/decrease refers to a large effect size (e.g. ß >.5; Cohen d < .8).

4.1. The Effects of Technology Use on Work-related Emotional Exhaustion and Vigor

Studies on the effects of technology use on *emotional exhaustion* bear an overwhelming support that technology use is related to employees' exhaustion. All seventeen studies that examined this relationship found an association, at least among some groups of employees.

The first and main cause for emotional exhaustion is the *ubiquity* of ICT reach and the *interruptions* that come with it. Technology makes the employees available for interruptions anywhere and at any time during office hours (Ayyagari et al., 2011), but also at home and after work hours (Gaudioso et al., 2017; Piszczek, 2017; Ragsdale & Hoover, 2016; Xie et al., 2018). As a result, the employees seem to have no private sphere left that allows them to unwind or recover from the workday. Chen and Karahanna (2018) show for example that these ubiquitous interruptions leave the employees emotionally exhausted and drained not only by their work, but also by the demands of their personal life.

The interruptions are not only strain per se, but also cause personal and *work-life conflicts*, which are one of the strongest predictors of emotional exhaustion. Whereas the main, direct effect of work-related ICT use after work hours on emotional exhaustion is usually non-significant (Piszczek, 2017) or small (ß =.20 to ß =.27; Ragsdale & Hoover, 2016; Xie et al., 2018), the effect it has indirectly through work-life conflict is substantial (all effects over ß =.44). This phenomenon has therefore also been termed "tech-invasion" (Gaudioso et al., 2017). The results can be interpreted as an organizational policy problem rather than a technology problem because different organizations have different expectations about how available their employees should be in their free time (Piszczek, 2017). The fact remains however, that due to its ubiquity, ICTs blur the work-life boundary and demand a lot of conscious and sometimes equally tiring effort from employees to control this boundary.

A second cause for emotional exhaustion caused by ICT ubiquity and frequent interruptions is the creation of *information or interruption overload* (Ayyagari et al., 2011). This effect of overload on emotional exhaustion is on the border between small and medium (ß =.26 to ß =.33) and is usually caused by what attention-scholars call "task-switching" (Ayyagari et al., 2011; Chen & Karahanna, 2018). Task-switching due to interruptions is especially aggravating after work hours where the constant engaging and disengaging from work can account for as much as 23% of the variance in emotional exhaustion (Chen & Karahanna, 2018).

Work-related technology use after work hours is not the only cause of emotional exhaustion. Using the internet at work for private purposes, i.e., cyberloafing, has also been related to emotional exhaustion (ß =.28 to ß =.47; Aghaz & Sheikh, 2016). Rhee and Kim (2016) have shown that even taking work breaks on a cellphone causes emotional exhaustion in comparison to conventional breaks. Specifically, messaging and surfing on a phone during the breaks cause employees to feel more fatigued directly after the break and more emotionally exhausted at the end of the workday when compared to employees who have lunch, talk to colleagues, or take a walk during their breaks.

The introduction of new organizational systems and the learning and adaptation this requires has also been found to wear down (Bala & Bhagwatwar, 2018; Gaudioso et al., 2017). The technological *pace of change*, which creates overload and role ambiguity at work, is an additional, although weaker factor (Ayyagari et al., 2011). Employees are often forced by technology to work faster, which drains their energy (Ayyagari et al., 2011; Gaudioso et al., 2017). This is especially true for employees whose personal values are not compatible with the introduction of a particular information systems (Hennington et al., 2011) or for employees low on self-efficacy (Salanova et al., 2000). The results imply that mandatory introduction of technology as well as inadequate tech-training can contribute to employees' emotional exhaustion.

The negative effect of technology use on employees' subjective energy at work and at home is however dependent on the individual. For example, Reinke and Chamorro-Premuzic (2014) have shown that the relationship between perceived e-mail overload and emotional exhaustion has more to do with the employee's personality than the actual number of received e-mails. Some employees have better coping strategies with stress caused by technology (Gaudioso et al., 2017), others prefer to integrate their work into their personal life (Xie, Ma, Zhou, & Tang, 2018). Such employees suffer no emotional exhaustion consequences from work-related ICT use after hours. Similarly, employees high on "cellphone attachment", i.e., those who are voluntarily non-stop on their phones and who respond immediately to notifications demonstrate surprisingly little emotional exhaustion after work-related cellphone use during non-work hours (Ragsdale & Hoover, 2016). This seems to contradict the findings by van Zoonen and Rice (2017) who have shown that it is low-responsiveness that buffers against emotional exhaustion. Judging by the correlation paths and mean values in all of the considered studies, we can conclude that ICTs are much more strongly related to maladaptive than adaptive coping strategies and that on average the employees want to separate their work and personal lives. They furthermore want to feel autonomous and control when to respond to messages, i.e., feel in control of the work-life boundary (Xie et al., 2018). This means that it is only a very small population of employees who prefers and can cope with the "techno-overload" and "techno-invasion" caused by ICT ubiquity.

The only domain where the majority of studies do not show overwhelming support for a negative effect of technology use on employees is the domain of telework. Namely, when employees are allowed to work remotely they can show slightly reduced (n.s. to ß = .28) emotional exhaustion (Sardeshmukh et al., 2012; Windeler et al., 2017). Telework can reduce exhaustion because it reduces the interpersonal interactions and role conflicts that are common in the office, as well as the time pressure. Telework also slightly increases employees autonomy, which is one of the strongest buffers (ß = -.34 to ß = -.44) against emotional exhaustion. Being able to get "task closure", i.e., finish some tasks from home gives some employees a positive feeling and can also slightly decrease exhaustion (Chen & Karahanna, 2018). However exhaustion caused by emotional involvement with clients is not erased by telework (Ishii & Markman, 2016), and can sometimes

even be amplified because of it, potentially because telework also decreases feedback and social support from colleagues and it increases the role ambiguity (Sardeshmukh et al., 2012).

Finally, not all technologies are equal in the extent to which they cause emotional exhaustion. For example, answering e-mails after office hours is not as detrimental as using the phone and messaging (Chen & Karahanna, 2018), while SNS use has an overall negative effect (van Zoonen & Rice, 2017). For students, different types of internet use also have different effects: whereas SNS use, blogging and social gaming slightly increase exhaustion, action gaming slightly decreases it (Hietajärvi et al., 2019).

The studies that focused on the effects of technology use on the positive energy dimension at work and at school, i.e., work- and school-related *vigor*, do not fully support such an overwhelmingly negative picture as the studies that focused on emotional exhaustion. Six out of nine studies found a negative association but just as many found that there are types of employees and contexts that can induce a positive association between technology use and vigor.

First, it is interesting that some of the processes that were shown to exhaust employees were also found to invigorate. For example, using cellphones during work breaks can increase work vigor in the same way that conventional breaks do (Rhee & Kim, 2016). Specifically, using a cellphone increases short-term energy affect after the break and work vigor at the end of the workday. This might explain why employees use cellphones during work breaks, even though these types of breaks are also regularly associated with fatigue and exhaustion. Note again here that exhaustion and vigor are bivariate constructs that can co-exist.

Furthermore, technology use after work hours can invigorate those employees who voluntarily engage in work-related activities and are not expected to respond immediately after receiving notifications (Llorens et al., 2007; van Zoonen & Rice, 2017), or those employees who want to respond immediately (Ragsdale & Hoover, 2016). The results imply that when employees are in control of the interruptions and their tasks, that is, when autonomy is given, technology can increase vigor. This is confirmed with studies on teleworkers, which show that the increased autonomy is the biggest factor through which telework increases vigor at work (Sardeshmukh et al., 2012). Yet, vigor can also slightly suffer from the decreased feedback and colleges' support for teleworkers (Sardeshmukh et al., 2012), as well as from technical failures for tele-lecturers (Chen, 2017).

The studies on the relationship between technology use and vigor amongst students are equally mixed. Technology use (including social media and gaming) has been moderately positively related to vigor at school in some samples (Rashid & Asghar, 2016) but slightly negatively or neutrally in others (Hietajärvi et al., 2019). Using ICTs to gain and share knowledge is slightly positively (ß = .18 to ß = .28) related to school vigor at all ages (Hietajärvi et al., 2019)

4.2. The Effects of Technology Use on Depletion and Vitality

The major pattern in the studies that focused on *depletion* was to focus on specific kinds of online activities or different types of display presentation. For example, customization of online products (Kang & Shyam Sundar, 2013), playing difficult video games (Engelhardt et al., 2015), or learning from Wikipedia articles while texting and watching TV (Kononova et al., 2018) have all been found to deplete self-control on a subsequent task, although to different degrees. Similarly,

reading display presentations that do not match one's cognitive style (Engin & Vetschera, 2017), or reading e-commerce result pages with a high number of listed results per page (Ahn et al., 2018) have been shown to deplete cognitive resources. Online shopping while multitasking on the other hand, seems to deplete less than reading Wikipedia articles does (Kononova et al., 2018). These insights can be used to create less depleting experiences, for example by matching the presentation style of the decision maker in graphic displays or lowering the number of search results per page in e-commerce search results.

This mitigation of depletion effects through better system design can be complemented by using technology to strengthen self-control. Cranwell and colleagues (2014) investigated how this could be done. They tested a smartphone application designed to train self-control using a modified Stroop-task. After four weeks, participants who trained self-control with the app performed better than a control group on self-control tests.

When it comes to subjective *vitality* on the other hand, studies found that it is slightly negatively associated (ß = -.13) with problematic Internet use in general (Akın, 2012) and Facebook use specifically (ß = -.24; Satici & Uysal, 2015). Problematic use, also termed "compulsive use", "excessive use" or "Internet (Facebook) addiction", is evident when users spend a lot of time thinking about the Internet or Facebook, when they use it to feel better, when they feel an urge to use it more often and when they suffer if they are not using it (Aboujaoude, 2010; Andreassen, 2015; Young, 1996). In all conceptualizations of problematic use there is also an aspect of self-regulation failure, termed "relapse", "diminished impulse control" or "cognitive-behavioral control". As was shown, the strength model of self-control postulates that self-control costs energy, whereas self-determination theory shows that vitality is an energy construct deeply related to a person's autonomy. When users are addicted, they are failing to cut down Internet or Facebook use and this personal lack of autonomy prevents them from experiencing vitality. Unfortunately, there is an increasing number of users who fall into this problematic use category, especially among adolescents. Some numbers suggest that depending on country, up to 38% of adolescents have a problematic relationship with the Internet, social media or their mobile phones (Durkee et al., 2012; Pedrero-Pérez, Rodríguez-Monje, & Ruiz Sánchez de León, 2012; Vigna-Taglianti et al., 2017).

A study that focused on the importance of fit between the user and the specific technology, found that the data management and social features of fitness apps help increase the vitality of those users who are intrinsically motivated to do sports, that is, those who enjoy exercising (James et al., 2019). These features could help vitalize also those who are "amotivated", that is, those who lack motivation to exercise. For those who are extrinsically motivated and only exercise to lose weight, such device features decreased vitality. Thus, the same device options can increase vitality of some users and drain it from others. These results illuminate the role of motivation in how technology effects play out on energy. No such moderating role could be found for personality traits though, specifically self-esteem in context of Facebook use (Jang et al., 2018).

4.3. The Effects of Technology Use on the Affective States of Energy and Fatigue

Exactly half of the twelve studies that looked into the effects of technology on affect were interested in "positive technology". Positive technology is explicitly developed to induce positive affect such as vigor. Examples of positive technologies are relaxation inducing virtual reality (VR) technology or active video games. Relaxation inducing VR is built to reduce tense energy or

increase calm energy (vigor), whereas active video games (also known as “exer-games” or “fitness games”) are specifically designed to motivate users to exercise as physical activity is part of the game. A moderate physical exercise, such as a walk, has long been shown to increase and sustain the feeling of calm energy and decrease the level of tense energy (Thayer, 1987).

Short-term studies considering VR mood induction procedures have shown that technology can increase momentary vigor and decrease arousal when designed to relax users with variable success (small to very large effect sizes; Cohen’s d =.38 to d =.73; Herrero et al., 2014; Serrano et al., 2016). However, in a long-term simulated spaceship mission for astronauts, Botella and colleagues (2016) found no monthly changes in vigor or fatigue despite mood-inducing relaxation VR. The authors noted that the astronauts were in exceptionally good health and spirit and this might be the reason for the finding. Thus, the reported ability of mood-inducing VR technology to generate desired moods, especially those that last for a longer period of time, is only in its beginnings and results so far are mixed. Similarly mixed effects were observed for active video games that were sometimes found to increase vigor, but sometime even decrease it (Huang et al., 2017; Lee et al., 2017).

The other half of the studies that looked at the relationship between technology and affect considered everyday technologies, such as cellphones and SNS. The results of these studies are predominantly negative, even though some showed a positive effect of at least some technologies for some groups of people. For example Myrick (2015) has shown that when people are asked to remember their subjective energy pre and post watching online cat videos, they report slightly higher feeling of being “energetic” and substantially lower feeling of being “depleted” after watching the videos. Consequently, people might turn to cat videos when they feel depleted in order to increase energy.

In a diary study, Quinones and Griffiths (2017) have shown that among users who already have a problematic relationship with the Internet, controlling Internet use at work and at home is harder when the work day is energy draining. These users are prone to cyberloaf a little more and be online at home a little longer when the work demands on the day are high. This increased Internet use then further decreased their after-use momentary energy, i.e., made them even more tired. However, the study also showed that out-of-control Internet use can also increase feelings of relaxation and recovery among users who do not perceive their excessive use as a problem. This is especially true when excessive users believe they can control their use and when they do not feel the need to self-regulate. Thus, heavy Internet use at work and at home seems particularly detrimental for those who fight the compulsion or feel guilty about it (Reinecke, Hartmann, & Eden, 2014).

The negative consequences of compulsive Internet use for subjective energy and fatigue, as measured with the SF-36 scale, was further demonstrated by Kelley and Gruber (2010). Using this month-long vitality-fatigue measure, they have shown that problematic Internet use is negatively related to subjective energy. Similarly, repeated failure to self-control SNS use has been related to a slight decrease in feelings of subjective energy and an increase in feelings of tiredness, as measured with the AD ACL, directly after using the social networks (Du et al., 2018). In sum, problematic Internet or Facebook use decreases both immediate as well as long-term feelings of subjective energy. The question is then, where is the line between benign, controlled and compulsive, out of control Internet use and when and why do people cross it?

Finally, in a study about airplane automation and pilot experience, Hancock (2007) has convinsingly shown that the more automated the airplane, the more fatigued the pilots feel after flying it (the study found no effect on vigor). This study further suports the hypothesis that human autonomy in relationship with technology is esential for the feeling of subjective energy, that is, when autonomy is taken away by technology then dealing with it fatigues in the short run and exhausts in the long.

4.4. Social Media Features that Cause Social Media Exhaustion and Fatigue

When it comes to the newly introduced phenomena of social media exhaustion and fatigue, the focus of the examined studies was on those features of SNS that cause users to feel exhausted and fatigued. The results for exhaustion and fatigue were almost identical, even though as we saw, SNS fatigue is defined as a bit shorter feeling and is broader in range than SNS exhaustion. The results were similar across devices and SNS platforms.

In the examined studies, the experience of overload appeared as the most prominent cause for SNS exhaustion and fatigue. Authors have distinguished between information overload and social overload but also communication overload and system feature overload (Cao & Sun, 2018; Gao et al., 2018; Lee et al., 2016; Lo, 2019; Luqman et al., 2017; Maier et al., 2015; Zhang et al., 2016). Information overload refers to the feeling of having to deal with more information than one can process, which leaves the user overwhelmed by the amount of information available on the social networks. Social overload refers to the feeling of having to deal with excessive amount of friends' problems or caring about the SN friends too much and too often. Both types of overload have been repeatedly related to social network exhaustion and fatigue, but social overload tends to be a stronger predictor ($ß_{info}$ = .20 to $ß_{info}$ = .26; $ß_{social}$ = .24 to $ß_{social}$ =.62; Cao & Sun, 2018; Gao et al., 2018; Lee et al., 2016; Lo, 2019; Luqman et al., 2017; Maier et al., 2015; Zhang et al., 2016).

Communication overload, which refers to receiving too many notifications from SNS, has also been related to SNS fatigue (Lee et al., 2016) but not to SNS exhaustion (Cao & Sun, 2018). Finally system feature overload, which refers to the social network platforms having too many unnecessary and poorly designed (complex) features, also relates to SNS fatigue (ß = .24 to ß =-.25; Lee et al., 2016; Zhang et al., 2016).

Information overload is associated with SN exhaustion because of the ubiquitous reach, especially due to smartphones (Gao et al., 2018). This is similar to the interruption overload effect observed for work-related emotional exhaustion. Information overload is further linked to the ambiguous nature of information posted on the platforms, i.e., the tendency of SN posts to mean different things to different users (Lee et al., 2016). Social overload on the other hand is associated with the number of friends one has on the platforms (Maier et al., 2015). Both types of overload are exacerbated when the social networks are used excessively, that is, the more often one uses social media the more likely they are to feel information and social overload (Cao et al., 2018; Maier et al., 2015; Zheng & Lee, 2016). Again, it is the excessive use that occurs as a core factor for fatigue.

Similarly to after hour work interruptions, excessive use creates family, work and personal conflicts and is linked to SNS exhaustion because of this (Zheng & Lee, 2016). Excessive use is also related to self-control failure and consequently diminished energy and increased tiredness (Du et al., 2018). However, Cao et al. (2018) have shown that trying to cut back and control the SNS

use can lower SNS exhaustion. We can thus speculate that there might be different energy consequences depending on whether the self-control of SNS use is successful or it results in failure.

Another route through which SNS create exhaustion is through the increased possibility of social comparison and the increased shame that comes with it (Lim & Yang, 2015). A positive side of SNS for energy is the social support that users can get on the platform. For example, when SNS users think that their friends are caring and supportive then SNS exhaustion is less likely (Lo, 2019). However, only the emotionally stable and lonely users can profit from such social support on the platforms. For those who are emotionally unstable (irrespective of whether they are lonely or not) as well as those who are not lonely (irrespective of whether they are emotionally stable or not) social support does not prevent exhaustion. That said, social overload exhausts all users alike and is a stronger predictor of exhaustion than social support, which makes the social support aspect an insufficient buffer.

Finally, the findings for SNS fatigue can also be applied to mobile messengers: information overload created by mobile messengers is related to mobile messenger fatigue, especially if the users care what other people think of them (Shin & Shin, 2016).

5. DISCUSSION, CONCLUSION AND FUTURE OUTLOOK

The first aim of the present study was to systematically structure and classify the many concepts used to describe and access subjective energy. With that we have created a conceptual baseline for future HCI and IS researchers who are interested in the effects of digital technology use on the subjective energy of its users. We show that researchers need to distinguish between long lasting feelings of subjective energy (e.g. vitality, emotional exhaustion, work-related vigor, and social network exhaustion) and momentary or relatively short feelings of energy (e.g. depletion, and the energy and fatigue moods). They also need to distinguish between narrow (e.g. emotional exhaustion) and broader concepts (e.g. work-related vigor) of subjective energy as well as concepts bound to the context (e.g. social network fatigue) vs. context-free subjective energy (e.g. fatigue affect). Most importantly, researchers need to consider the bivariance between subjective energy and fatigue and not blend the different energy processes together. A lot of valuable information is potentially lost when energy and fatigue are aggregated in the same variable, especially in relation to ICT use.

Second, we show that the current state of the art on the relationship between technology and subjective energy suggests a predominantly negative picture. Technology causes chronic emotional exhaustion with work. It can cause momentary fatigue and depletion. In the case of social networks and messengers, it is additionally related to fatigue with the technology itself. On top of this, there is a negative impact of technology on the positive dimension of energy as well. Digital technology can deplete momentary feeling of energy as well as the more permanent states of work-related vigor and life vitality.

Ubiquity, perceived overload, lack of autonomy, and excessive use of technology are the most common ways through which technology drains subjective energy, especially if the users see it as a problem or try to control their use. This is true for most of the conceptualizations of subjective energy, short, long, broad and specific. The ubiquitous reach of technology forces people into a constant “presenteeism” (Ayyagari et al., 2011) that many suffer from. This permanent reachability can create work and interruption overload, for example when employees receive work-related

notifications after work hours. Permanent reachability can also create social and communication overload when people receive too many personal messages or too much is happening on their social media news feeds. If they are expected to answer immediately (also termed responsiveness) the notifications interrupt their personal lives thereby creating work-life imbalances and personal-life conflicts. Excessive use is another reason for personal and work conflicts and together with responsiveness it deprives people of their autonomy. When constantly interrupted or online, people no longer manage their own time. Even consciously refraining from going online or responding immediately demands self-control, especially when people care what others think. All these processes are related to exhaustion and fatigue and deplete vigor and vitality. Thus, ubiquitous technology reach drains people of subjective energy at their work as well as their personal lives.

However, our analysis also shows that technology can have an energizing effect in all conceptualizations of subjective energy. The main path through which technology energizes its users is by increasing their autonomy. Autonomy is relevant for work-related vigor, but also for vitality of intrinsically motivated users. Technology increases user autonomy when it is designed with absolute user-control, but also more generally, when it allows for task control, that is, when it allows the user to decide when and where to do the tasks. These findings are in agreement with self-determination theory, which postulates that satisfying the need for autonomy, i.e., being self-determined, enables eudemonic well-being, i.e., vitality.

The second energizing aspect of technology use is its hedonic side. The new ICTs offer countless entertaining and relaxing content, as well as socializing opportunities. Pleasant online activities, such as watching cat videos, have been found to energize users at least in the short run, and thus people use the Internet when they feel low on energy. It is no wonder then that this behavior is prevalent and increasing during work hours (cyberloafing), on the work breaks, in schools, as well as in people's free time.

Still, the most important findings of this review is that the positive impact of technology on the energy dimension is often accompanied by a negative impact on the fatigue dimension. All but one study that looked at both a positive and a negative energy construct, found a negative impact of technology and the strength of the negative impact was usually stronger (Hancock, 2007; Rhee & Kim, 2016; Sardeshmukh et al., 2012; van Zoonen & Rice, 2017). This means that potentially, the processes that energize can also deplete energy either at the same time or in the long run. For example, when people use new digital technology to relax and re-energize, they might be leaving themselves vulnerable to exhaustion both at work and at home. Trying to increase the hedonic well-being in the short term might therefore decrease the eudemonic well-being in the long run. What is more, continuous technology use for hedonic or mood-modifying reasons can form a compulsion and turn into excessive and problematic use of these technologies, especially social media. Excessive use, as we have repeatedly seen, drains energy and might create a vicious circle where in a state of low energy people turn to the "re-energizing" technologies to relax which further drains them of energy and initiates and exacerbates a "loss-cycle". Then, both excessive Internet use as well as social network fatigue create the need to self-regulate usage, which further drains energy needed for self-control.

5.1. Limitations and Future Outlook

As we considered only studies that made it into the leading HCI and IS journals (*n=53*), we cannot exclude that there are some studies or conference papers that we have missed and that would

have added additional insights to our review. As it stands though, the current literature points to a predominantly negative effect of ICTs on human energy, but also gaps in research that need to be closed in order to increase the confidence of our findings. First, the majority of the studies were correlational, and only one tested for a reversed causation, which leaves open the important question of causality in the relationship between ICT use and human energy: Do people use certain technologies because they are tired, are they tired because they (over)use certain technologies or is there a cycle of reversed causations? Specifically, if employees cyberloaf because they feel emotionally exhausted, do they exacerbate their exhaustion because they cyberloaf? Similarly, does excessive Internet use deplete users of vitality or are the less vital more likely to become excessive Internet users and enter an energy "loss cycle"? Different authors argued for different causation paths, which means that both ways are plausible, and we suggest that a reverse causation is probable. Future research should try to clarify these questions.

Second, the vast majority of the studies measured energy on only one dimension (n = 37, 70%), or combined the energy and fatigue scales (n = 4, 8%). Since energy and fatigue are shown to be bivariate, a lot of essential information is lost when researchers combine the scales or only look at one dimension. For example, Rhee and Kim (2016) showed that the correlation between the momentary feeling of energy and the momentary feeling of fatigue was smaller for the employees who took cellphone breaks (r = -.30, p < .001) than for employees who took conventional breaks (r = -.48; p < .001). What is even more interesting is that work-related vigor and emotional exhaustion were not even related for the employees who took smartphone breaks (r = 07, n.s.), whereas for the employees who took conventional breaks the correlation was moderate, as expected (r = -.40, p < .001). In other words, only for those who used conventional breaks the intuitive was true: feeling more vigorous meant feeling less exhausted and vice versa. This result suggests that the parallel invigorating and draining processes might be technology specific. Combining the scales or focusing on only one energy dimension would have missed those insights. In our sample only 12 studies (22%) used both positive and negative energy measures and almost all of them found different effects on the different measures. Future studies should always use bivariate scales, especially when the variance in energy is to be predicted by technology use. This opens new questions such as can there be social media vigor next to social media fatigue? Studies of user experience on Facebook that used physiological correlates of arousal and valence have shown that while on Facebook, users do exhibit optimal physiological experience akin to flow (Cipresso et al., 2015; Mauri, Cipresso, Balgera, Villamira, & Riva, 2011). Hence, it would be interesting to see what the relationship between the energizing and fatiguing aspects of social network use is.

Third, authors either focused on the short-term or long-term experience of energy, even when they did look at both energy and fatigue as separate, bivariate constructs. Only Rhee and Kim (2016) used multiple energy instruments for momentary feelings as well as for the durable experience of exhaustion and vigor. Thus, we do not know what the relationship between short-term energy boosts and longer-term experience of energy and fatigue is. If short hedonic energy boosts from certain technologies do result in a durable emotional exhaustion as our review suggests, it is important to uncover the processes through which this happens. Do short hedonic boosts turn into excessive use? Do they prevent users from satisfying their growth need by distracting from long-term self-actualizing goals? Or is it that even though energizing, certain technologies simply create overload and users cannot get a chance to properly rest and recuperate in the same way as they would in less stimulating environments (Berman, Jonides, & Kaplan, 2008; Berto, 2005; Herzog, Maguire, & Nebel, 2003). Another possibility is that the effect of certain

technologies on the positive energy dimension is faster than on the fatigue dimension and thus users learn that the technology is energizing while missing its longer-term fatiguing effect. This is analogous to people's mostly unconscious mood modifying tendency to use fast energizing sugar snacks when tired even though in the long run sugar snacks cause fatigue. While the opposite is true for a mild physical exercise, fewer people realize the connection. Thus, sugar snacks are the preferred mood (energy) regulating strategy (Thayer, 1987).

This opens the question about the role awareness plays in the experience of the moods of energy and fatigue, especially since habitual use is per definition low on awareness. Awareness of a problem increases the need for self-regulation and can thus itself be depleting. The question is, would the excessive but non-compulsive users lose the ability to re-energize online if they were made aware that their excessive use is a problem (Quinones & Griffiths, 2017)? And is awareness related to fatigue only because aware users are likely to try to self-regulate? For example Reinecke and colleagues (2014) have shown that when people feel drained and unable to self-control they are more likely to feel guilty when they fail to stay off entertainment media (games and TV). The guilt is related to feeling of fatigue post watching or playing. Future research can clarify the relationship between awareness, self-control and self-control failure both for short term as well as for long term experiences of mental energy and fatigue.

Finally, our analysis shows that not all technologies have equal effect. Even though very few studies directly looked at the differences between different media and mental energy, we can conclude that there is a general trend that links social media and (smart)phones to fatigue and emotional exhaustion both in private as well as in organizational context (Gaudioso et al., 2017; Hietajärvi et al., 2019; van Zoonen & Rice, 2017). However, since the majority of studies only referred to technology in general, such as "the Internet", future research would profit greatly from distinguishing between different types of technology, different types of devices, different types of media as well as different types of media content. Based on what we have shown, we can hypothesize that seductive technology that is designed to "hook" and that is based on a business model dependent on excessive use (Eyal, 2014; Zuboff, 2019) will be more depleting than neutral or positive technology at least in the long run. Future research can try to categorize the different technologies and may even give a human-centered seal of approval to the ones with a strong positive relationship with vitality and eudemonic well-being.

5.2. Conclusion

Our review shows that different researchers use different conceptualizations (terms) of subjective energy, and that these diverse conceptualizations differ in duration, range and specificity of cause. Depending on term, the relationship between ICTs and subjective energy shows some specific patterns, but also some overarching ones. The review also shows that some (negative) patterns are specific to certain technology such as social networking sites.

In general, ICTs drain energy across different energy concepts when they decrease users' autonomy, increase overload and cause excessive use. On the other hand, ICTs can have the ability to energize their users when they increase autonomy and when they fit to their users' needs, personalities and values. At the moment, the general pattern of ICT use on energy is more negative than positive, especially on the longer-term energy concepts. However, our review shows that this topic is under researched and that if the bivariate conceptualizations is more readily embraced, we might see a more nuanced picture. Future research should try to uncover a more holistic view, so

that we can create technology that truly nourishes the valued resource of human energy, i.e., improves the well-being of the technology users.

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APPENDIX. OVERVIEW AND SUMMARY OF THE REVIEWED EMPIRICAL STUDIES

Table 2. Summary of the empirical studies on the relationship between technology use and subjective energy

Study	Subjective Energy Term	Instrument	Methodology; Method	Sample	Main Findings	Effect size
Aghaz and Sheikh (2016)	Work-related emotional exhaustion (as part of job burnout)	MBI	Survey study Structural equation modeling	298 employees in 5 knowledge-intensive firms	Job burnout is related to both cyberloafing activities and cyberloafing behaviors	ß =.28 ß =.47
Ahn, Bae, Ju, and Oh (2018)	(Attentional) Depletion	Eye tracker (fixation and duration)	Experiment 1: Within-subject experiment; randomly alternated e-commerce search results from various types of retailers Experiment 2: identical to Experiment 1, but changed length of search results and placed ads at various places of the result page Lorenz curve and Gini coefficient analysis, mixed effect regression analysis	97 e-commerce users 70 e-commerce users	Consumers' attention span decreases exponentially, instead of linearly, from the top to the bottom of a search result page. The total number of available options influences the speed and pattern of attention depletion. Attention can be refreshed and renewed with ads when they are positioned in the middle of a search results listing Ads are ignored, visual attention after ads is higher, however it depletes very rapidly after this attention renewal	NR/NA
Akın (2012)	Subjective vitality	SVS	Survey study Hierarchical regression	328 university students	Internet addiction is negatively related to vitality (and it further mediates the link between	ß = – .13

					Internet addiction and happiness)	
Ayyagari et al. (2011)	Work-related emotional exhaustion (strain)	Adopted MBI	Survey study Structural equation modeling	661 employees	Presenteeism indirectly increases exhaustion through work-home conflict, work overload and role ambiguity Pace of change indirectly increases exhaustion through work overload, role ambiguity and job insecurity	ß = 52, ß =.17 ß = 61, ß =.26 ß =.61, ß =.27 ß =.14, ß=.26 ß = .23, ß = .27 ß = .14, ß = .10
Bala and Bhagwatwar (2018)	Work-related emotional exhaustion	Adopted MBI	Study 1: Longitudinal study, 3-wave survey study; Pre-system implementation, 3 months and 6 months post-implementation. System = functional health and safety management system Study 2: Longitudinal study, 3-wave survey study; Pre-system implementation, 3 months and 6 months post-implementation System = enterprise system Structural equation modeling	257 employees from a large manufacturing firm 181 employees from the same manufacturing firm	Study 1. Deep structure use (whether the employee routinely uses the system features that were taught in training) decreased exhaustion. Cognitive absorption during use (whether the system use occurs without distractions, i.e., the users can immerse in the tasks) decreases exhaustion Study 2. Deep structure use increased exhaustion. Note. All measures, for both studies are from the same wave (Time 3 only)	ß = -.12 ß = -.19 ß = .28
Botella et al. (2016)	Vigor activity Fatigue inertia	POMS, monthly	Longitudinal study; 4 months long spaceship simulator study for astronauts with a mood-inducing VR.	6 astronauts	VR use did not impact month-long energy VR use did not impact month-long fatigue	n.s.

			Experiment: 2 monthly measures (before and after VR intervention); Did not report method of analysis; but did present raw data			
Bright et al. (2015)	SNS fatigue	Self-developed social media fatigue scale	Survey study Regression analysis	747 SNS users with an active Facebook account	Social media privacy, helpfulness, and self-efficacy increase SNS fatigue Social media confidence decreases SNS fatigue	ß =.45, ß =.20, ß =.22 ß = -.32
Cao et al. (2018)	Mobile SNS exhaustion (techno-exhaustion)	Adopted MBI for mobile SNS exhaustion	Survey (paper and pencil) study Structural equation modeling	505 mobile SNS app users (students)	Excessive SNS use and cognitive emotional preoccupation with SNS increase SNS exhaustion Cognitive-behavioral control (awareness and attempt to self-regulate use) moderates both relationships, i.e., it weakens them	ß =.34 ß =.09 ß = -.30 ß = -.15
Cao and Sun (2018)	SNS exhaustion	Adopted MBI for social media exhaustion	Survey study Structural equation modeling	258 SNS users (students)	Information overload and social overload increase SNS exhaustion	ß =.26 ß =.37

					Extent of after-hours work-related interruptions indirectly increases work exhaustion through psychological transitions and interruption overload	ß =.72; ß =.48 ß =.74; ß = .33
Chen and Karahanna (2018)	Work-related and non-work related emotional exhaustion	MBI	Survey study Structural equation modeling	237 knowledge workers	Extent of after-hours work-related interruptions indirectly increases nonwork (private life) exhaustion through interruption overload	ß =.74; ß = .29
					Extent of after-hours work-related interruptions indirectly decreases work exhaustion through task closure	ß =.51; ß = -.18
Chen (2017)	Work-related vigor (as part of work engagement)	UWES	Longitudinal study: Multi wave survey study: Baseline + 10 daily diary measures on 10 consecutive teaching days; Multilevel regression analysis	40 lecturers who teach synchronous distance courses	Technical problems with equipment reduce daily vigor	NR/NA
Cranwell et al. (2014)	Depletion	Stroop test Handgrip duration	Experiment. Study 1 Pre-Post training Stroop test. Training: 4 weeks self-control training with an app Experiment. Study 2 Pre-Post training handgrip test. Training: 4 weeks self-	29 students 33 students	Training with the app improved self-control (lowered depletion) both on the Stroop test as well as the handgrip	η_p^2 = 0.20 η_p^2 = 0.34

			control training with an app Analysis of covariance (ANCOVA)			
Du et al. (2018)	Energy Tiredness (well-being)	AD ACL (they combined the scales); Time frame: "After using social media …"	Longitudinal study: 2 wave survey study (4-weeks follow up), accessed Energy at Time 1 Simple correlations	405 SNS users at T1 354 completed the follow up	Experience of energy/tiredness after using SNS is related to (and predicts future) social media self-control failure	r = – .19 at T1 r = –.15 with T2
Engelhardt, Hilgard, and Bartholow (2015)	Depletion	Spatial Stroop task	Experiment: Manipulated the difficulty and violence in a video game (2 x 2 between subject design) Analysis of variance (ANOVA), General linear model (GLM)	205 students	Game difficulty and experience (and not violent content) predicts depletion	ß = –.24 (coefficient for interaction term)
Engin and Vetschera (2017)	Depletion	Number of errors in decision making	Experiment: Manipulated the display presentation (graph vs tabular) is a decision support system; Linear mixed model regression analysis	227 students	Display type when not matched with cognitive style of decision maker leads to depletion	NR/NA
Gao, Liu, Guo, and Li (2018)	SNS exhaustion	Adopted MBI for social media exhaustion	Survey study Structural equation modeling	528 SNS users	Ubiquitous connectivity causes SNS exhaustion directly, and indirectly through information overload	ß =.18; ß =.32, ß =.26

Gaudioso, Turel, and Galimberti (2017)	Work-related emotional exhaustion	MBI	Survey study Structural equation modeling	242 employees in a large government organization	Techno-invasion increases exhaustion trough work-family conflict and through maladaptive coping strategies	ß =.66; ß = .40; ß = 1.11
					Adaptive strategies weaken the relationship but work-family conflict has stronger relationship with maladaptive than adaptive strategies	ß = -.63; ß = .16 vs. ß = .40
					Techno-overload increases exhaustion through distress (adaptive coping strategies weaken the relationship)	ß =.51, ß = .50; ß = 1.11
					Adaptive strategies weaken the relationship but distress has stronger relationship with maladaptive than adaptive strategies	ß = –.63; ß = .21 vs. ß = .50
Hancock (2007)	Fatigue Vigor	POMS	Experiment: Manipulated level of automation/pilot control in a cockpit simulator; 4 groups ANOVA	30 experienced pilots	The pilots experienced progressive increase in fatigue as the degree of system control increased	NR/NA
Hennington, Janz, and Poston (2011)	Work-related emotional exhaustion	MBI	Survey study Structural equation modeling	71 nurses from a large urban hospital who have been using the IS (mandatory electronic medical	Incompatibility (ß reversed score for compatibility) of IS with personal values increases the emotional exhaustion through creating role conflict	ß = -..29; ß =.57

				record system) for 3 years		
Herrero et al. (2014)	Vigor energy Fatigue	1 item for intensity of the emotion vigor; 1 item question for change of the mood fatigue	Experiment: Pre-test Post-test treatment survey with 2h long mood inducing VR; t-tests	40 female patients with fibromyalgia	VR MIP increased vigor, made fatigue “somewhat better”(n.s.)	Cohen’s d =.38 Cohen’s d =.07 n.s.
Hietajärvi, Salmela-Aro, Tuominen, Hakkarainen, and Lonka (2019)	Study exhaustion Study vigor (as part of study engagement)	Adopted MBI for students Adopted UWES for students	Survey study Structural equation modeling	741 elementary school students from 33 schools; 1371 high school students from 18 high schools 1232 higher education students from 3 institutions	Elementary school students: SNS oriented Internet use and social gaming increase exhaustion Elementary school students: SNS oriented Internet use decreases; knowledge oriented increases engagement High school students: SNS, blogging and media oriented Internet use increase exhaustion; action gaming decreases it High school students: Knowledge oriented Internet use and social gaming increase engagement; action gaming decreases it. University students: SNS oriented Internet use as well as action and social gaming decrease engagement,	ß = .17, ß = .09 ß = -.22 ß = .22 ß = .10, ß = .13 ß = .11, ß = -.12 ß = .18 ß = .09 ß = -.18 ß = -.15, ß = -.25, ß = -.09, ß =.21

					knowledge oriented use increases it	
Huang et al. (2017)	Vigor	POMS	Experiment: Pre and post-intervention survey; control vs. intervention group; intervention = play randomly selected exer-games for 30 consecutive minutes once a week for 2 weeks; Repeated measures (RM) ANOVA	168 intervention 167 control group participants (university staff and students)	Playing exer-games increased vigor (in comparison to control group)	NR/NA
Ishii and Markman (2016)	Work-related emotional exhaustion	MBI	Survey study Bivariate regression analysis	130 IT online customer help desk employee (use phone, e-mail or chat to provide services9	Remote help providers feel more emotional presence with customers when they use phone than when they use e-mail or chat. Emotional presence in turn increases exhaustion. Frequency of e-mail communication increases affective presence which in turn increases exhaustion	NR/NA
James et al. (2019)	Subjective vitality	SVS	Survey study Structural equation modeling	880 fitness technology users (app and/or device)	Use of social interaction features of fitness tech moderates (increases) the relationship between intrinsic and integrated regulation and vitality, as well as non-regulation, but it decreases it for	NR/NA

					external and introjected regulation	
					Use of data management features of fitness tech moderates (increases) the relationship between intrinsic and integrated regulation and vitality, as well as non-regulation, but it decreases it for external and introjected regulation	
Jang et al. (2018)	Subjective vitality	SVS	Experiment 1: Participants were asked to update their FB profile by either writing about their true or their strategic selves. Post-experiment survey Experiment 2: Participants were asked to share a life event on FB profile that either reflected their true or their strategic selves; Post-experiment survey Regression analysis	136 SNS users 146 SNS users	Strategic self-presentation (as opposed to authentic) in both experiments had no effect on vitality	n.s.
Kang and Shyam Sundar (2013)	Depletion	Persistence on unsolvable anagram	Experiment: Participants were asked to customize an iGoogle webpage. 3 groups: customize for self, customize for students of the opposite gender and	54 students	Participants who were customizing for others were more depleted than those who customized for themselves, but no differences to control group	$\eta_p^2 = 0.11$

			control group; Survey and depletion task after customization ANOVA			
Kelley and Gruber (2010)	Vitality fatigue	SF 36	Survey study ANOVA	278 undergraduate psychology students from 2 universities	Problematic Internet use is related to lower vitality/higher fatigue	NR/NA
Kononova, McAlister, and Oh (2018)	Depletion Energy	Snack choice: healthy vs. unhealthy Arousal, Valence survey	Experiment: Participants were asked to multitask; 4 groups: (TV only; TV + texting; TV + texting + online reading (Wikipedia); TV + texting + online shopping (Amazon)), Post experiment depletion task and survey ANCOVA	140 students from 1 large university	Heavy multimedia multitasking, especially TV + texting + online reading (Wikipedia) leads to depletion Heavy multimedia multitasking, increased arousal and decreased valence (especially for TV + texting + online reading	η_p^2 = 0.11 η_p^2 = 0.12 η_p^2 = 0.33
Lee et al. (2016)	SNS fatigue	Self-developed SNS fatigue scale	Survey (online and offline) study Structural equation modeling	250 university students	Information equivocality increases SNS fatigue through information overload System pace of change increases SNS fatigue through system feature overload System complexity increases SNS fatigue through system feature overload	ß =.12, ß =.25 ß =.12, ß =.25 ß =.57, ß =.25

					Communication overload increases SNS fatigue	ß =.23
Lee et al. (2017)	Vigor Fatigue	Adopted POMS	Experiment: Pre-Post intervention survey. Intervention: 30 min Active video game session ANOVA, MANOVA	134 elementary school children (8-11 years old)	AVG session decreased the vigor and the fatigue of the school students, but the results for fatigue did not reach significance	η_p^2 = -.38 η_p^2 = .06
Lim and Yang (2015)	SNS exhaustion (burnout)	Adopted MBI for social media exhaustion	Survey study Structural equation modeling	446 SNS users	Social comparison increases SNS exhaustion directly, and through increase of shame	ß =.33 ß =.43, ß =.50
Llorens et al. (2007)	Vigor	UWES	Longitudinal study: 2-wave study where participants were solving group task exclusively via chat (mIRC), surveys pre and post task solving Structural equation modeling	110 psychology students	Task resources (time and method control = perceived autonomy inherit in chat technology) increase vigor through increasing efficacy beliefs; reverse causation is also present!	T1: ß =.44, ß =.61 T1, T2: ß =.20, ß =.23
Lo (2019)	SNS exhaustion	Adopted MBI for social media exhaustion	Survey study Structural equation modeling	1285 SNS users (university staff and students)	Social overload increases SNS exhaustion among all users (emotionally stable, emotionally unstable, lonely and not lonely) Social support on SNS decreases exhaustion only among the emotionally stable and lonely users	ß =.25, ß =.30, ß =.27, ß =.38 ß = -.14, ß = -.24

Luqman et al. (2017)	SNS exhaustion	Adopted MBI for social media exhaustion	Survey study Structural equation modeling	360 SNS users (students)	Excessive social use of SNS increases SNS exhaustion Excessive hedonic use of SNS increases SNS exhaustion Excessive cognitive use (=information overload) of SNS increases SNS exhaustion	ß =.17 ß =.14 ß =.27
Maier et al. (2015)	SNS exhaustion	Adopted MBI for social media exhaustion	Survey study Structural equation modeling	571 SNS users	Extent of SNS usage; the number of SNS friends, and the subjective social support norm all increase SNS exhaustion through social overload	ß = .24 ß = .12 ß = .46 ß = .62
Myrick (2015)	Energy, depletion	1 item questions about emotional state prior and post watching videos	Survey study t-test	6795 Internet users who watch cat videos	Watching cat videos increases energy and decreases depletion	Cohen's d =.91 Cohen's d =.37
Piszczek (2017)	Work-related emotional exhaustion	MBI	Longitudinal study: 2 wave survey study (1 month apart), emotional exhaustion was assessed at T2 Regression analysis	163 alumni of a human resource management master's degree program	After hours work-related cell-phone use expectations (from employer) increase emotional exhaustion directly, and indirectly through actual use and perceived boundary control (PBC lowers it). Both relationships are moderated by work-family segregation preferences	ß = .34 ß = .87, ß = -.55 ß = .17 ß = -.19

Quinones and Griffiths (2017)	Energy (recovery)	Self-developed 3 item recovery survey; momentary experience of energy	Longitudinal study: 3 times-a-day survey for 4 consecutive days Multilevel mixed model analysis	84 employees	Compulsive Internet use at work (on the day) and compulsive Internet use before bed both decrease energy (recovery) before going to bed only for the more compulsive users Compulsive Internet use at work (on the day) decrease energy (recovery) in the morning after only for the more compulsive users	ß = -.31 ß = -.39 ß = -.19 ß = -.52
Ragsdale and Hoover (2016)	Work-related emotional exhaustion Work related vigor (as part of work engagement)	MBI, UWES	Longitudinal study: 2-wave survey study: predictors at Time 1, criteria at Time 2 (after one week) Hierarchical regression	213 full time employees, cell-phone users	Work-related cell-phone use (WRCPU) increases emotional exhaustion only for those low on "cell-phone attachment" (CPA; those who answer immediately and cannot imagine their lives without a phone) WRCPU increases vigor (as part of work engagement) only for those high on CPA	ß = -1.38 (WRCPU x CPA) ß =1.57 (WRCPU x CPA)
Rashid and Asghar (2016)	Student vigor (as part of engagement)	UWES	Survey study Path analysis, Regression analysis	761 female undergraduate students	Technology use (in general) increases student engagement directly, and through self-directed learning	ß = .31, ß = .32, ß =.45
Reinke and Chamorro-Premuzic (2014)	Work-related emotional exhaustion (as part of burnout)	Unipolar OLBI scale: (emotional exhaustion and	Survey study Structural equation modeling	201 employees	Core self-evaluation (how satisfied people are with themselves) increases (felt) e-mail overload which in turn	ß = -.33; ß =.29

	Work related vigor (as part of work engagement)	vigor are combined			increases “burnout” (decreased vigor) The number of received e-mails is not a significant predictor	
Rhee and Kim (2016)	Energy as affect Fatigue as affect Work-related emotional exhaustion Work-related vigor	AD ACL MBI UWES	Survey study Structural equation modeling	425 employees	Type of break – smart-phone breaks(sb) vs. conventional break (cb) –moderate the relationship between psychological detachment and fatigue Type of breaks do not moderate the relationship between psychological detachment and energy Energy as affect is related to after-work vigor (no moderation) Fatigue as affect is related to emotional exhaustion (no moderation)	ß = -.19 for sb; ß = .04 for cb ß =.53 for sb ß = .42 for cb ß =.57 for sb ß = .66 for cb ß =.46 for sb ß = .30 for cb
Salanova, Grau, Cifre, and Llorens (2000)	Work-related emotional exhaustion	MBI	Survey study Hierarchical regression analysis	140 workers from five different companies form the tile sector and public administration	Computer training increases exhaustion for those low on self-efficacy; it decreases it for those high on self-efficacy	NR/NA
Sardeshmukh et al. (2012)	Work-related emotional exhaustion	MBI Britt’s (1999) job	Survey study Structural equation modeling	417 employees from	Extent of telework decreases exhaustion trough reducing time pressure and role conflicts, and through increasing autonomy	ß = .10; ß = .09; ß = -16; ß = .14 ß = .12; ß = -.34

	Vigor (as part of job engagement)	engagement scale		a large supply chain management company	Extent of telework increases exhaustion trough increasing role ambiguity and through decreasing feedback and social support	ß =.13; ß = .16 ß =-.22; ß =-.11 ß =-.10; ß =-.28
					Extent of telework increases engagement trough increasing autonomy	ß = .12; ß = .30
					Extent of telework decreases engagement trough decreasing feedback and social support	ß = -.22; ß = .23 ß = -.10; ß = .19
Satici and Uysal (2015)	Subjective vitality	SVS	Survey study Regression analysis	311 university students from 2 mid-sized universities	Problematic Facebook use is related to diminished vitality	ß =-.15, ß =-.24
Serrano et al. (2016)	Subjective arousal, Valence	Arousal, Valence survey (self-assessment manikin scale)	Experiment: Pre-test Post-test treatment survey with 1h long mood inducing VR; 4 different VR technologies ANOVA	136 adult participants who did not have anxiety and/or depression symptoms	After mood induction, arousal decreased and affective valence increased	NR/NA
Shin and Shin (2016)	Mobile messenger fatigue	Adopted the scale from Lee et al. (2016)	Survey study Structural equation modeling	334 mobile messenger users	Mobile messenger overload (commercial and non-commercial) drives messenger fatigue. Personality (relational self) moderates the non-commercial relationship	ß = .12; ß = .63 ß = .67; ß = .69

Steinberger, Schroeter, and Watling (2017)	Subjective arousal, Valence	Arousal, Valence survey (self-assessment manikin scale)	Experiment: Within-subject, repeated measure driving simulator study, 2 counterbalanced conditions, control and intervention; intervention = 16 min driving with a gamification app (phone with app mounted on the car window U-test	32 young male drivers	The gamified driving did not change subjective arousal	Cohen's d = .07
van Zoonen and Rice (2017)	Work-related emotional exhaustion Work-related vigor	MBI UWES	Study 2: Survey study Structural equation modeling	364 employees; 102 from a Telecom provider; 112 from a consultancy firm and 150 from a consumer electronics company	Using SNS for work purposes (Twitter, Linked In and Facebook) increases exhaustion through increasing work pressure Using SNS for work purposes (Twitter, Linked In and Facebook) decreases exhaustion through increasing autonomy Using SNS for work purposes (Twitter, Linked In and Facebook) increases vigor through increasing autonomy Responsiveness moderates the relationship between SNS use and autonomy	ß = .48, ß = .43 ß = .15; ß = -.25 ß = .15, ß = .37 ß = .08
Windeler, Chudoba, and	Work-related emotional exhaustion	MBI	Study 1: Longitudinal study: 2-wave survey study: 1 week prior to-	51 employees from a IT business unit of	Part time teleworking (PTT) increased exhaustion through external interaction	ß = -.11 pre; ß = .37 post teleworking

Sundrup (2017)			telework including baseline exhaustion and 4 months later (post telework); Structural equation modeling	a financial service firm randomly selected to part-time telework	PTT decreased exhaustion through external interaction	ß = .28 pre; ß = .03 post teleworking
					Job interdependence explained more of the exhaustion variance for no part time employees than for PT teleworkers	ß = .31 for No PTT, ß = .17 for PTT
				258 employees (160 part time teleworkers)		ß = .18 for No PTT, ß = .38 for PTT
			Study 2: Survey study; Structural equation modeling		External interaction explained less of the exhaustion variance for no part time employees than for PT teleworkers	ß = .19 for No PTT, ß = .05 for PTT
					Interaction quantity explained more of the exhaustion variance for no part time employees than for PT teleworkers	
Xie, Ma, Zhou, and Tang (2018)	Work-related emotional exhaustion	MBI	Study 1: Survey study Regression analysis Study 2: Survey study Regression analysis	447 college councilors 437 full time employees	Study 1. Work related ICTs use after work hours increases exhaustion even after controlling for integration preference. Integration preference is negatively related to exhaustion (even after controlling for ICT use). The interaction is also significant predictor	ß = .24 ß = –.26 ß = –.20 ß = .26 ß = .28

					Study 2. Work related ICTs use after work hours increases exhaustion even after controlling for integration preference. The interaction is between ICT use and integration preference is also a significant predictor	
Zhang et al. (2016)	SNS fatigue	Adopted and self-developed scale for SNS fatigue	Survey study Regression analysis	525 SNS (Qzone) users	System feature overload, information overload and social overload drive SNS fatigue	ß = .24 ß = .20 ß = .37
Zheng and Lee (2016)	SNS exhaustion (strain)	Adopted MBI for social media exhaustion	Survey study Regression analysis	550 mobile SNS users	Excessive SNS use and cognitive preoccupations increase SNS exhaustion through creating technology-family conflict; through technology-personal conflict; and through technology-work conflict. Technology-personal conflict is additionally predicted both by technology-family and technology-work conflict)	ß = .60, ß = .08 ß = -.08, ß = .65 ß = .42, ß = .23 ß = .11, ß = .08 ß = .18, ß = .65 ß = .17, ß = .23 ß = .35, ß = .45