Original Article

Time to Forget

Intentional Forgetting in the Digital World of Work

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Abstract: Emerging technologies at work encourage the collection and storage of large amounts of data. However, these vast quantities of data are likely to impair efficient work decisions by employees over time, with negative consequences for the organization. As human attention increasingly represents the scarce resource at work, the present paper focuses on a mechanism of attentional control at work – namely, intentionally forgetting unwanted and outdated internal (e.g., knowledge) and external (e.g., digital objects) information. The purpose of this paper is threefold. Based on a short review of the research on intentional forgetting, a prototypical conceptualization of an interactive assistive system (Dare2Del, cognitive companion) is provided, which should support employees in temporally ignoring or permanently deleting outdated information. Then, we completed a critical incident study to examine why and when employees might want to forget information at work, and to identify in which working situations an assistive system should be particularly helpful.

Keywords: information overload, intentional forgetting, self-control

Intentionales Vergessen in der digitalen Arbeitswelt

Zusammenfassung: Neue Technologien bei der Arbeit fördern die Sammlung und Speicherung großer Datenmengen. Große Mengen an möglicherweise irrelevanten digitalen Objekten können jedoch effizientes Arbeiten und Entscheiden der einzelnen Personen behindern und auf organisationaler Ebene zu Leistungseinbußen führen. Vergessensmechanismen beim Menschen sorgen in der Regel dafür, dass irrelevante Informationen situativ ignoriert und über die Zeit vergessen werden. Digitalisierung nutzt bislang diese menschlichen Vergessensmechanismen nicht. Ziel des Artikels ist es, basierend auf einer kurzen Übersicht über die Forschung zum intentionalen Vergessen darzustellen, wie Personen bei der Regulierung ihrer digitalen Wissensinhalte durch ein interaktives Assistenzsystem (*cognitive companion*, Dare2Del) unterstützt werden können. Durch situatives Ausblenden und permanentes Löschen digitaler Objekte soll erreicht werden, dass Personen irrelevante Information vergessen und dadurch ihre Aufmerksamkeit fokussieren können, mit positiven Konsequenzen für die Arbeitsleistung. In einer *critical incident* Untersuchung wird dann untersucht, in welchen Arbeitssituationen intentionales Vergessen eine Rolle spielt und ein Assistenzsystem hilfreich sein kann.

Schlüsselwörter: Intentionales Vergessen, Selbstkontrolle, Informationsüberlastung

Forgetting things can make us feel irritated and annoyed. At work, we put in a lot of effort to store information, for fear of forgetting something that could be important: We make notes, keep a to-do list, file or store documents on our computers, and make back-up copies on a regular basis. As a result of digitalization, organizations are increasingly seeing data, information, and knowledge as a key to success, and emerging digital technologies are encouraging the collection and storage of large amounts of data (Edmunds & Morris, 2000; Huber, 1991). This abundance of information should assist employees in doing their job, and organizations expect their employees to be able to manage these large primarily digitalized amounts of information efficiently.

However, research has found that large amounts of digitalized information (e.g., emails, files, newsletters) can be perceived as an information overload, which in turn challenges employees' attentional capacity; it is positively related to stress and negatively related to physical health, job satisfaction, perceived control, and decision making (e.g., Dabbish & Kraut, 2006; Edmunds & Morris, 2000; Eppler & Mengis, 2004; Hair, Renaud, & Ramsay, 2007; Soucek & Moser, 2010). Thus, working in a focused and goal-oriented manner requires not only storing all relevant information internally (in one's memory) or externally (on a computer) to guarantee its timely access, but also largely ignoring or forgetting task-irrelevant thoughts and even deleting redundant or unwanted digital objects such as files or emails. In today's increasingly digitized world of work, it is time to consider forgetting as a potentially effective strategy for dealing with the overwhelming amount of information (see also Kluge & Gronau, 2018).

Human forgetting, or "the inability to recall something now that could be recalled on an earlier occasion" (Tulving, 1974, p. 74), can be unconscious and automatic (*incidental forgetting*, e.g., decay) or conscious and intentional (*intentional forgetting*). From a cognitive perspective, intentional forgetting refers to a targeted attempt to limit access to information in memory that is emotionally distressing, unwanted, or irrelevant to task processing, such as an outdated work process or a conflict with one's supervisor (Anderson & Hanslmayr, 2014). In the present paper, we also consider intentional forgetting of memory contents which are related to external digital information such as task-irrelevant or outdated files.

Research in the field of cognitive psychology has shown the costs (i.e., impaired retrieval) and the benefits (i.e., increased learning) of intentional forgetting, and revealed that the ability to intentionally forget unwanted and irrelevant memory contents varies across individuals (e.g., Hulbert & Anderson, 2018; Levy & Anderson, 2008). A few studies suggest that intentional forgetting might also be affected by situational factors (e.g., competing tasks; Noreen & de Fockert, 2017; Schmeichel, 2007).

As research on intentional forgetting has been almost exclusively conducted in the laboratory (for an exception, see Streb, Mecklinger, Anderson, Lass-Hennemann, & Michael, 2016), in the present paper, we focus on the question of how workers' intentional forgetting of unwanted thoughts and digital information can be supported in a *digitalized workplace*. For this purpose, following a short introduction to the main theories and foundational empirical studies on intentional forgetting, and distinguishing this concept from related constructs (e.g., self-control), a prototypical conceptualization of an interactive assistive system (Dare2Del, a *cognitive companion*) is presented, which should support employees in temporally ignoring or permanently deleting outdated information. Dare2Del is based on an approach of interactive learning where the system can explain its decisions to the human, *and* human feedback is acknowledged to adapt the knowledge base of the system. Finally, in a critical incident study, we examined why and when employees might want to forget at work, to identify in which situations an assistive system should be particularly helpful.

Intentional Forgetting of Memory Contents

Intentional forgetting (or directed forgetting) is initiated with the goal of forgetting and thus happens consciously and on purpose (Anderson, 2009; Weiner, 1968). As the research on intentional forgetting has mainly been conducted in cognitive psychology (and not in work and organizational psychology), we give a short introduction to the basic results from the experimental research on intentional forgetting and its theoretical explanations, to further explore its role in the context of work. Specifically, we asked for whom it is easier or harder to suppress distracting thoughts, which situational factors support or hinder forgetting, and why people forget deliberately at work. Gaining insight into human intentional forgetting at work should inform the design of a context-aware assistive system, with regard to when and how to best support workers in temporarily ignoring or permanently deleting outdated information.

Research Paradigms

Research on intentional forgetting has revealed that individuals are able to deliberately forget memory contents at least for a certain period of time (Anderson & Green, 2001; Anderson & Hanslmayr, 2014; Anderson & Levy, 2009; Bjork, Bjork, & Anderson, 1998; Hotta & Kawaguchi, 2009; Nørby, Lange, & Larsen, 2010; Noreen & MacLeod, 2014). Intentional forgetting has been investigated using different experimental paradigms, demonstrating both its costs and benefits. The most commonly used paradigms are the directed forgetting paradigm (item method and list method; Bjork et al., 1998; Bjork, LaBerge, & Legrand, 1968) and the think / no think paradigm (TNT; Anderson & Green, 2001). In both paradigms, subjects are instructed to either forget learned items or remember them.

In a typical directed forgetting experiment using the list method, individuals are required to learn a list of words before being instructed to either forget (forgetting condition) or remember (remember condition) the words on this first list. Afterwards, individuals are instructed to learn new words from a second list. In a final recall, individuals are asked to remember as many words as they can from both lists, even if they were previously asked to forget the first list. Two results are relevant here: (1) Fewer words from the first list are remembered in the forgetting condition than in the remember condition; and (2) in the forgetting condition, words from the second list are better remembered than words from the first list (Bjork, 1989; but see Sheard & MacLeod, 2005).

The TNT paradigm (Anderson & Green, 2001) is an experimental paradigm to assess an individual's ability to suppress the retrieval of an unwanted memory. In the first phase, individuals have to learn pairs of words (e.g., lint–curtain) by practicing recalling the target word (e.g., curtain) whenever the cue (e.g., lint) is presented. In the

second phase, two thirds of the cues are presented, and the participants have to either remember the learned word (think, e.g., curtain) or not remember the learned word by preventing it from entering their awareness (no think, variant: replacing it with another word). The remaining third of cues is not presented again and serves as the baseline for the third phase. In the third phase, a memory test for all item pairs is conducted. The typical pattern of the results is that individuals remember the no-think items worse, and the think items better, than the baseline items. In contrast to the directed forgetting paradigm (which compares experimental conditions between participants), the TNT paradigm allows individual forgetting abilities to be measured (by comparing word lists within participants).

Both experimental paradigms, directed forgetting and TNT, reflect task requirements that can also be found in everyday situations. Directed forgetting reflects the situation in which entire events (in this case, lists) or actions have to be forgotten because they are irrelevant now and will continue to be in the future. In everyday working life, this situation is experienced when, for instance, some regulations are no longer relevant, because they have been replaced by new regulations. The TNT paradigm reflects situations where individuals who are distracted by unwanted thoughts actively inhibit and possibly replace these thoughts with other content. In day-to-day work, these cognitive processes are required in situations where, for example, thinking about a conflict with a colleague or the student thesis on one's desk can distract from one's actual work task, if one does not try to forget these unwanted thoughts. It seems that intentional forgetting is also of great importance in everyday work and does not seem to be just a laboratory phenomenon.

Theoretical Explanations

Three theoretical frameworks have been proposed to explain the costs and benefits of intentional forgetting. The *selective rehearsal hypothesis* (Bjork, 1972) postulates that being instructed to forget stops the rehearsal of the learned words (Sheard & MacLeod, 2005). The *retrieval-inhibition hypothesis* (Anderson & Green, 2001, Bjork, 1989; Conway, Harries, Noyes, Racsmány, & Frankish, 2000) assumes that being instructed to forget temporarily inhibits the retrieval of the corresponding memory contents (costs), which in turn reduces proactive interference with the first list and supports learning and retention of the second list (benefits). The third explanation, the *mental context change hypothesis* is a two-process hypothesis that attributes the costs and benefits of intentional forgetting to different processes (Sahakyan & Kelley, 2002; also Bäuml, Hanslmayr, Pastötter, & Klimesch, 2008; Lehman & Malmberg, 2011). The first process (context change) explains forgetting with the notion that being instructed to forget creates a different mental context when learning the new items. The new context thus does not serve as a retrieval cue for the first list, making recall more difficult. The second process is the strategy change process: In the forgetting condition, people use better strategies to learn the words in the second list.

Empirical evidence from at least one experimental paradigm exists for all three theoretical approaches. Anderson (2005) postulates that both the retrieval inhibition hypothesis and the mental context change hypothesis rely on a general inhibitory mechanism for the to-be-forgotten items, in that mental contexts can also be inhibited, which results in a lower recall rate (Anderson, 2003).

Related Concepts

Intentional forgetting can be distinguished from related constructs pertinent to human cognitive control including self-regulation, self-control, thought control, and implemental mindset. Self-regulation is a broad construct referring to a process ranging from goal setting and goal striving to monitoring goal progress and protecting goal striving by overcoming obstacles and temptations (Hofmann, Schmeichel, & Baddeley, 2012; Schmeichel & Baumeister, 2004). Self-regulation, and self-control to an even greater extent, are similar to intentional forgetting. Self-control as a narrower subset of self-regulatory processes refers to the ability to override or inhibit automatic, prepotent impulses, urges, or emotions to protect purposeful, goal-directed behavior (e.g., Baumeister, Vohs, & Tice, 2007; Metcalfe & Mischel, 1999). Thus, self-control comprises the inhibition of cognitions and emotions. Suppressing unwanted memory contents can be seen as a type of self-control strategy that takes the form of limiting access to unwanted memory contents rather than of suppressing impulses or negative emotions. Therefore, the main difference between intentional forgetting and self-control is that intentional forgetting focuses primarily on memory storage and memory processes rather than on goal setting and striving, emotion regulation, and resisting and overcoming temptations, which include also motivational processes. Self-regulation, self-control, and intentional forgetting have in common that they are the subjects of several executive functions (Hofmann et al., 2012; Miyake & Friedman, 2012), and inhibitory control processes are discussed as an important executive function concerning all three constructs (Anderson, 2005;

Hofmann et al. 2012; Schmeichel, 2007). It is important to note that intentional control, on the one hand, and self-regulation and self-control, on the other, stem from different research areas – namely, cognitive psychology and social psychology, respectively (Hofmann et al., 2012), with each investigating the respective phenomenon without referring to the other research area. However, recently Engen and Anderson (2018) have proposed in their analysis of this that memory control (i.e., intentional forgetting) might be an important component in emotion regulation – that is, one specific kind of self-control.

With respect to the question of how workers manage the abundance of information in their workplaces, examining memory processes such as intentional forgetting of irrelevant information rather than impulse control seems to be especially helpful.

Thought control is a cognitive control concept similar to intentional forgetting, and has mainly been investigated in clinical psychology. Thought control refers to the suppression of unwanted, intrusive thoughts (Wells & Davies, 1994; Wegner, Schneider, Carter, & White, 1987) which accompany anxiety disorders and posttraumatic stress. Unwanted intrusions are controlled with techniques such as thought stopping, controlled worry periods, cognitive reappraisal, and distraction (Wenzlaff & Wegner, 2000). In contrast to thought control, intentional forgetting is also directed at nonemotional memory contents, such as task-irrelevant information, rather than negative thoughts alone. In sum, we argue that the concept of intentional forgetting which refers to a process that controls irrelevant memory contents, can be especially helpful in dealing with the large volumes of digital information.

Complementing intentional forgetting is the concept of implemental mindset, which helps to focus on the task at hand by tuning an individual's cognitions to action-related information (information on where, when, and how to act; Gollwitzer & Bayer, 1999). Both concepts reflect motivated information processing. Intentional forgetting, however, aims to achieve the opposite result, by suppressing unwanted memory contents.

Some Key Findings Regarding Intentional Forgetting

Intentional forgetting is a conscious process: Forgetting increases when participants have time to prepare suppression (Hanslmayr et al., 2010) and even remains stable when they are paid for correct responses (Anderson & Green, 2001) – showing that the forgetting effect does not rely exclusively on the deliberate withholding of responses that participants were actually conscious of. Intentional forgetting limits immediate retrieval but does not necessarily occur after a single attempt to permanently forget (Hotta & Kawaguchi, 2009; Nørby et al., 2010; Noreen & MacLeod, 2014). The more often people try to stop the retrieval, the worse the final recall turns out to be (Anderson & Green, 2001; Anderson & Huddleston, 2011; Hanslmayr, Leipold, & Bäuml, 2010; Lambert, Good, & Kirk, 2010). Thus, it seems that suppressing unwanted thoughts helps people to temporarily forget (e.g., a competing task), whereby sustained forgetting requires many attempts to suppress memory. However, van Schie and Anderson (2017) found that suppressing unwanted thoughts for a longer period of time was more effortful than to do so for a shorter period of time. Over time, sustained engagement in suppression of unwanted thoughts even impaired inhibitory control. Consequently, support of workers' attempts to suppress task-irrelevant information temporarily or permanently in an information-rich context might be especially useful, as it would support the success of forgetting and reduce mental effort.

The line of research presented here seems to be in contradiction with the literature on the white bear phenomenon (see Wenzlaff & Wegner, 2000): To test this paradigm, participants were advised to not think of a certain object (e.g., a white bear) for several minutes. Results typically showed an ironic effect, as most participants reported frequent intrusions of the to-be-avoided object. This effect is often cited to show the ineffectiveness of thought suppression. However, one major difference from the TNT and directed forgetting paradigms is that in the white bear paradigm, the instruction to suppress already includes the to-be-suppressed memory, making it nearly impossible to ignore it. Rehearsing the instructions already involves a violation of the task goal. The TNT and directed forgetting paradigms work with reminders (specific cues or list affiliations) which do not refer to the target word. Further, van Schie and Anderson (2017) argue that suppression for a longer period of time reduces inhibitory control, which is the case with the white bear experiments.

Intentional forgetting has been shown to work not only with neutral memory contents, but also with emotional contents. This is important because to-be-avoided thoughts in everyday or working life are often complex, emotional, and negatively valenced. The forgetting effect has been widely replicated with both positive (Joormann, Hertel, Brozovich, & Gotlib, 2005; Nørby et al., 2010; for an exception, see Payne & Corrigan, 2007) and negative memory contents, albeit in an inconsistent manner. There is some evidence that the suppression of negative memories leads to inhibition comparable to that for neutral or positive stimuli (Depue, Banich, & Curran, 2006; Joor-

mann et al., 2005; van Schie, Geraerts, & Anderson, 2013). However, some studies have failed to find an effect for negatively valenced words (e.g., Chen et al., 2012; Nørby et al., 2010; Marx, Marshall, & Castro, 2008; Yang, Lei, & Anderson, 2016). Thus, forgetting negative content seems possible but more difficult than forgetting neutral or positive memories (Yang et al., 2016). Recently, based on neurobiological and behavioral studies, Engen and Anderson (2018) have argued that inhibitory control of memory contents plays an important role in emotion regulation.

Intentional forgetting was originally investigated with word lists and word pairs (e.g., Anderson & Green, 2001; Bjork, 1972) but also with pictures (e.g., face-picture pairs; Chen et al., 2012; see also Depue et al., 2006; Gagnepain, Henson, & Anderson, 2014), action phrases (e.g., verbally learning or symbolically performing short actions such as inflating a balloon; Sahakyan & Foster, 2009), autobiographical events (e.g., individual events occurring in everyday life; Joslyn & Oakes, 2005; see also Noreen & MacLeod, 2013, 2014; Stephens, Braid, & Hertel, 2013), and habits (Dreisbach & Bäuml, 2014). Using the list method of the directed forgetting paradigm, Dreisbach and Bäuml (2014) asked their participants to learn and practice stimulus–response rules which changed after a while. Participants were instructed to either remember or forget the stimulus–response rules they had practiced. The accessibility of these rules was reduced when participants were cued to forget them rather than to remember them. These findings indicate that not only words but also habits can be intentionally forgotten. This is especially important in the work context when working routines are changed as a result of a technological or organizational change: The workers have to forget their old routines in order to learn new ones.

Only a few studies have examined intentional forgetting outside of the laboratory. Joslyn and Oakes (2005) demonstrated that people are capable of intentionally forgetting autobiographical memories (e.g., narrative descriptions of specific events that occurred in the participant's everyday life) regardless of their valence and emotional intensity, which might explain the loss of at least some autobiographical memories over the course of one's lifetime. Streb and colleagues (2016) demonstrated that a high ability to forget was associated with less stressful intrusions in daily life. In a longitudinal field study, Niessen, Binnewies, and Rank (2010) have shown that suppression of thoughts related to previous work roles positively predicted adaptation to a new work role (in this case, becoming self-employed) by reducing negative consequences of psychological attachment to those previous roles.

Individual Differences

It is important to note that people differ significantly in their ability to intentionally forget. Who finds it easier or harder to suppress distracting thoughts? There is evidence that age is negatively related to intentional forgetting (Anderson, Reinholz, Kuhl, & Mayr, 2011; Hasher & Zacks, 1988; Rizio & Dennis, 2014). Recently, Hulbert and Anderson (2018) conducted experiments to test whether inhibitory control depends on practice. They found that individuals reporting a greater history of trauma – which should indicate that they have had more practice in suppressing unwanted thoughts – also had enhanced memory inhibition abilities. This might also be true for individuals with a high need to suppress intrusive memories in everyday working life – for example, workers in professions dealing with emotionally demanding situations such as paramedics, workers in emergency call centers, or psychotherapists. Levy and Anderson (2008) considered executive control ability to be responsible for these differences (*executive deficit hypothesis*).

Affective states also seem to have an influence on intentional forgetting: Bäuml and Kuhbandner (2009) showed that people in a neutral or negative mood were able to intentionally forget (study material was neutral). In contrast, Noreen and Ridout (2016) found forgetting effects only for positive, but not for negative mood inductions, using valenced study materials. Further analyses revealed that participants in the negative mood condition had more difficulty with forgetting negative materials, whereas those in the positive mood condition did not. In line with this finding, several studies have shown that depression can lead to a modification of typical forgetting patterns: Dysphoric and depressive people generally have more difficulty in forgetting intentionally (e.g., Hertel & Gerstle, 2003; Joormann & Tran, 2009; Noreen & Ridout, 2016; Power, Dalgleish, Claudio, Tata, & Kentish, 2000). This effect is probably due to the downsized activity in the dorsolateral prefrontal cortex – a brain area that is usually activated during memory inhibition processes (Anderson et al., 2004; Benoit & Anderson, 2012).

A few studies have also investigated whether personality and cognitive abilities matter for intentional forgetting. There is some evidence that empathy and sensitization correlate with forgetting difficulties, especially for forgetting of negative material (Geiselman & Panting, 1985). Aslan, Zellner, and Bäuml (2010) further showed that working memory capacity positively predicts intentional forgetting (see also Delaney & Sahakyan, 2007). Fawcett and Taylor (2012) suggest that intentional forgetting is associated with establishing control over the contents of working memory. As working memory, exec-

utive attention, and fluid intelligence are located together in the prefrontal cortex (Kane & Engle, 2002), it is likely that high fluid intelligence may also be positively associated with intentional forgetting abilities. Thus, it seems likely that people with a lower working memory capacity, with increasing age, with less practice in forgetting, and with a negative, depressed mood are likely to have more difficulty in suppressing irrelevant information, which could be compensated for by an assistive system.

Situational Factors

Situational factors which might foster or hinder intentional forgetting have been neglected in cognitive psychology research so far. Studies have shown that additional or competing tasks requiring executive control capacity (Conway et al., 2000; Levy & Anderson, 2008; Miyake & Friedman, 2012) impair the inhibition of unwanted thoughts and behaviors (e.g., Lavie, Hirst, de Fockert, & Viding, 2004; Schmeichel, 2007; Ward & Mann, 2000). More recently, Noreen and de Fockert (2017) investigated inhibitory control of unwanted thoughts under a low and high working memory load task. They found that under higher working memory loads, individuals switched their strategies to prevent unwanted memory contents from coming to mind: Individuals directed their attention toward the high load task and engaged less in suppression (interference-based strategy).

Thus, it seems reasonable that typical situational factors at work such as a high workload and high task complexity may impair the intention to inhibit memory content. Still, there is a lack of studies on intentional forgetting at work that also consider situational factors related to the work environment. This lack is particularly important for the development of any assistive system, which is supposed to support users under varying situational factors such as time pressure, task complexity, etc.

Functions of Intentional Forgetting

Why should workers forget at work? Although the functions of intentional forgetting have not been empirically investigated as yet, a broad range of potential functions has been proposed (Anderson & Hanslmayr, 2014; Nørby, 2015): Intentional forgetting should serve to regulate negative affect, justify inappropriate behavior (e.g., by forgetting moral rules), maintain beliefs and attitudes (e.g., by forgetting contradictory thoughts), deceive others and oneself, preserve one's self-image, forgive others, and maintain social relationships. Nørby (2015) further mentioned that intentional forgetting facilitates knowledge acquisition and learning (through the forgetting of redundant and false information), and context attunement (through the forgetting of outdated information). Thereby, forgetting redundant and false information helps to organize knowledge and to process information more efficiently.

Intentional Forgetting of Digital Information

Research on intentional forgetting has focused on forgetting memory contents. However, it is also important to consider the intentional forgetting of electronically stored information objects, such as emails and files in socio-digital systems. Imagine working on an attention-intensive information search while being confronted with files and emails referring to another, irrelevant task. These digital objects serve as cues for retrieving task-irrelevant memory contents, which are unwanted and distracting in that current situation. Consequently, individuals have to make an effort to ignore or suppress these intrusive thoughts to remain concentrated on the task at hand and to perform well. Actions such as deleting, archiving, filing, and hiding digital information can help individuals to forget related memory contents by removing cues which trigger those contents. Therefore, it is important to not equate deleting, archiving, filing, and hiding per se with intentional forgetting. These actions just serve to implement the intention to forget.

Often people express their unease with their storage and maintenance of digital information on their computer ("this is a mess"; Marshall & Bly, 2005). Boardman and Sasse (2004) showed that emails and bookmarks in particular are not well sorted, with negative consequences for search times. Participants in a qualitative study reported filing and deleting objects (e.g., "I really should clean this up") to be rather difficult (Jones, Phuwanartnurak, Gill, & Bruce, 2005). Furthermore, the maintenance and deletion of information seems to vary with personal habits (Malone, 1983) as well as the kind of information (e.g., emails or data files; Boardman & Sasse, 2004). As sorting and deleting digital information can be difficult, resource-intensive, and time consuming, this information management task should be assisted. To the best of our knowledge, there is no research on the psychological processes underlying the intentional forgetting of digital information by hiding, filing, archiving, or even deleting information.

While intentional forgetting of memory content refers to a motivated cognitive process in which encoding (Bjork, 1989) or retrieval (Anderson & Green, 2001) is actively inhibited, intentional forgetting of external objects (digital objects) occurs via actions either of the technical system itself (by hiding irrelevant information) or the acting users themselves. In both cases, the aim is to direct the person's attention to the task at hand and minimize distractions and interference from task-irrelevant information.

Support of Intentional Forgetting at the Workplace: A Context-Aware Assistive System

Intentional forgetting provides the human cognitive system with an effective mechanism for temporarily ignoring unwanted information and for the long-term decay of information, a process which helps workers to stay concentrated and perform and feel well in the digitalized world. Similar forgetting mechanisms might be incorporated into intelligent assistive systems that help users to manage large amounts of data. Only a very small number of assistive systems supporting users in forgetting or ignoring unwanted information have been developed (for an exception see Barua, Kay, Kummerfeld, & Paris, 2011).

According to the situated cognition approach (Clancey, 1993; Clark & Chalmers, 1998), human memory is embedded and linked to context (e.g., external technologies). Therefore, we propose that an intelligent assistive system should support intentional forgetting in at least four ways. First, ignoring irrelevant information can be facilitated by visually hiding the information on the computer screen. Making this information less visible should prevent the retrieval of obsolete information from memory, which directs attention away from the current goal (Chen et al., 2012; Kluge & Gronau, 2018; Nørby et al., 2010).

Second, as the literature review revealed, forming the intention to forget is a deliberate and resource-intensive act (Anderson, 2009; Lavie et al., 2004; Levy & Anderson, 2008; Ward & Mann, 2000). Therefore, prompting users to actively hide irrelevant information, or even delete digital objects, might not only support this cognitive process, but also motivate users to engage in intentional forgetting more often than before.

Third, as research has shown that individuals differ in their ability to forget, a companion system that hides and deletes or archives unwanted information might be particularly helpful for users who have difficulty ignoring irrelevant information when focusing on current goals, or who have difficulty deleting obsolete digital objects such as emails or files.

Finally, studies have shown that individuals must repeatedly try to stop retrieval, to completely forget unwanted thoughts (Anderson & Huddleston, 2011; Hanslmayr et al., 2010; Lambert et al., 2010). A companion system which reliably hides, archives, or deletes unwanted information could support this demanding process.

The Context-Aware Cognitive Companion System Dare2Del

Dare2Del is an assistive system which supports users in managing the complex task of dealing with ever-growing amounts of digital information (see Figure 1). It helps users to decide which files can be archived or deleted and thereby get rid of irrelevant digital detritus. A second area of support is to hide information which is irrelevant in a given task context, thereby helping the user to focus. Dare2Del takes the form of a cognitive companion (Forbus & Hinrichs, 2006; Siebers, Schmid, Göbel, & Niessen, 2017), in which human–computer interaction is understood as mutual support. This is in contrast to assistive systems where the system provides information but intelligent decision making is completely left up to the user; it is also in contrast to fully autonomous systems where the system decides for the user.

In general, a companion system should fulfill the following requirements (see Siebers et al., 2017): (a) the system's decisions should be transparent to the user – that is, the system must be able to explain its decisions by making the criteria that led to its decision explicit. (b) The system must be able to exploit predefined rules, such as specific company regulations or user preferences. (c) The system must be context aware such that it can infer what digital objects are relevant in a given working context, and it can infer when it would be appropriate to support the user. (d) The system must be able to adapt to the needs and preferences of specific users.

We illustrate how Dare2Del fulfills these requirements with two examples. In the first application scenario, Dare2Del recommends files to be deleted or archived, independently of whether the user still has the content of these files in his/her memory. When the contents of these files are represented in the user's memory, deleting external cues (e.g., the file) will hinder retrieval of task-irrelevant memory contents, which are unwanted and distracting in the current situation. Also, Dare2Del allows organizations to include regulations and legal obligations for data retention. These regulations are included in the

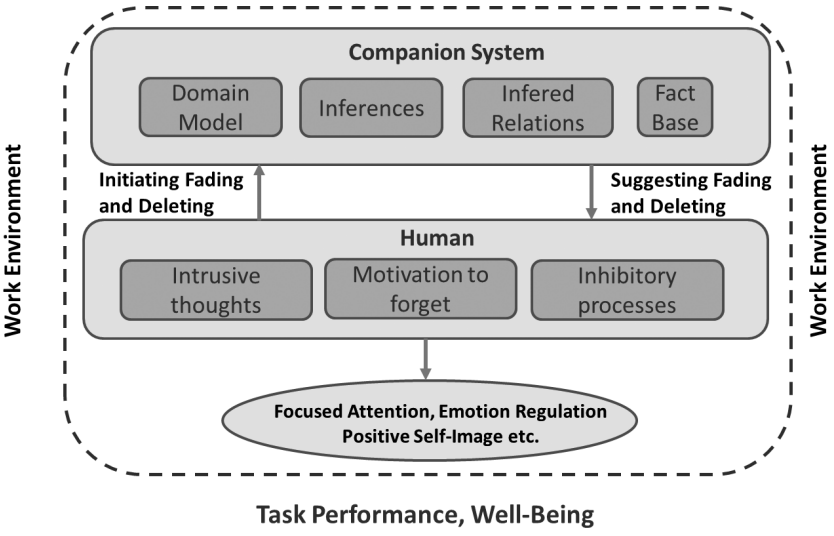

Figure 1. Conceptualization of the cognitive companion Dare2Del.

recommendations to delete data or files, as made by Dare2Del. Further, when a person starts using Dare2Del, they can also configure the times when the system will point to irrelevant files. And the number of files that will be presented each time can also be configured by the user. For example, one user might prefer to have short sessions at the end of every workday where only five files are suggested for deletion or archiving, while another user might prefer a longer session every Friday. The companion system will also detect when a new project or topic has been started, and will accordingly ask the user to delete or archive redundant or irrelevant files. Users should always be free to override the system dialogue (e.g., "not right now"). Furthermore, criteria about what files are irrelevant can be specified in accordance with company guidelines or personal preferences.

The user should be able to ask for an explanation whenever the system proposes a file to be irrelevant, regardless of whether they agree with the proposal or not (Siebers & Schmid, 2019). This explanation can be a verbalization of the underlying rule (e.g., "file X is considered to be a draft version of file Y"), thus informing the user why the file is proposed to be irrelevant (see Figure 2). Explanations can be further elaborated. A user might want to know why Dare2Del considers file X to be a draft, and Dare2Del can provide detailed information about the files that led to the classification as draft (e.g., "file X has a similar name to file Y and is older than file Y"). The files presented to the user are drawn from the sample of all files, using a probability distribution, and are tested against a set of rules. These rules classify a file as irrelevant or not irrelevant. Some of the rules are predefined as described above. However, it is crucial for the system that rules are learned from interactions with the user. After a selection of files has been presented, the user's decisions to accept or decline the proposal that a file is irrelevant are used as training examples for an incremental machine learning approach. In Dare2Del, we use an inductive logic programming (ILP) approach (see below).

A second application scenario for Dare2Del is that digital objects are temporarily hidden to support the user in focusing on their current task. For example, one might not want to be distracted by incoming emails while checking monthly balances. One way of looking at this scenario is in the example of spreadsheets. Spreadsheets often contain complex information over many rows and columns. A large number of these rows and columns might be irrelevant when checking certain information. For example, when checking annual holidays and overtime for employees from a specific department in a financial accounting spreadsheet, the rows for employees from other departments as well as many of the columns (e.g., private address, salary, etc.) are irrelevant. Although spreadsheet programs offer numerous capabilities to hide and filter information, many users do not have sufficient knowledge and skills to apply these tools in an efficient way. Therefore, Dare2Del makes it possible to hide information in spreadsheets on the basis of current user intentions, to support the inhibition of irrelevant information and thus to prevent disturbances which direct attention away from the task at hand. Users' intentions thus have to be inferred from their interaction with the program. In this, we can build on recently developed approaches to end-user programming and intention recognition (see below). However, it remains an open question as to how to identify the users' actual aims and needs.

Dare2Del is conceptualized as a so-called white-box learning system, which combines classic knowledge-based approaches (Beierle & Kern-Isberner, 2014) and

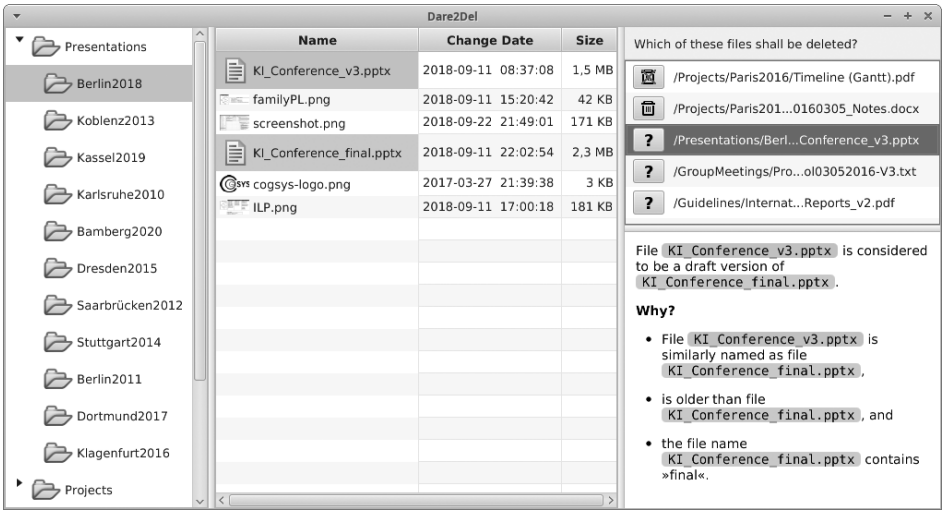

Figure 2. Example of a dialog field in Dare2Del.

machine learning; most notably, the LIME (Local Interpretable Model-Agnostic Explanations) system (Ribeiro, Singh, & Guestrin, 2016) shows how the classification decisions of a (deep) neural network trained on images can be made transparent using visualization. However, information in the context of forgetting digital objects is presented as a symbolic representation, such as file names or attributes. Thus, current approaches in the context of image classification are not suitable.

An even more powerful, symbolic approach to machine learning is inductive logic programming (ILP; Muggleton & de Raedt, 1994; Muggleton, Schmid, Zeller, Tamaddoni-Nezhad, & Besold, 2018). ILP forms the core of the Dare2Del companion. It naturally combines the exploitation of prespecified knowledge and machine learning and allows for learning not only based on simple features, such as the size of a file, but also on relations between objects, such as the fact that two files are stored in the same folder. However, ILP approaches – like most machine learning approaches – typically require the system to first learn from a sufficiently large and representative sample of labeled training examples; only afterwards is the trained classifier applied to new data – that is, there is a strict separation between learning and application. However, in the present context, an incremental and interactive approach to machine learning (e.g., Fails & Olsen, 2003) is necessary to make Dare2Del adaptive and take user feedback into account. Therefore, the end user programming approach (trying to identify user intentions from observable behavior; Demolombe & Fernandez, 2005; Gulwani, 2011) is adapted within Dare2Del for hiding and filtering operations.

As mentioned above, the cognitive companion Dare2Del should be transparent to the user by providing explanations for decisions, should include the opportunity to exploit predefined rules, and should be able to adapt to users' needs and preferences (Siebers et al., 2017). The system must also be context-aware in inferring when it would be appropriate to support the user. However, there is still an open question of when individuals need support to intentionally forget at work. The literature review has shown that there is sparse research on the question of why and when individuals are motivated to forget, in particular in the work context. Moreover, the widely used experimental paradigms on intentional forgetting require that participants are instructed to intentionally forget by the experimenter. In contrast, in daily working life, participants have to take the initiative to form the intention to forget rather than being asked to do so by another person.

Critical Incident Study for Identifying Situational Factors for Intentional Forgetting

To address these issues, we conducted an exploratory, qualitative study and asked (1) which situational factors foster and hinder intentional forgetting and (2) which functions of intentional forgetting in a work context exist. Gaining insights into the why and when of intentional forgetting in the workplace should inform the design of a user-centered and context-sensitive assistive system such as Dare2Del.

The first aim of the qualitative study was to explore the functions of intentional forgetting at work by collecting critical incidents. A further purpose of the study was to gain deeper insights into the situational factors that accompany intentional forgetting. We used the critical

incident technique as an inductive, systematic approach for collecting the experiences of many individuals in a certain domain. These experiences are then compared with existing theory and research (Flanagan, 1954). We aimed to explore situations in which participants were motivated to forget. Research has shown that individuals are aware of their intentional forgetting and retaining information (Friedman & Castel, 2011) and that they are aware of experiencing intrusions (Streb et al., 2016). Therefore, we assumed that participants were able to report a motivated attempt to forget. Moreover, we cued our participants to remember important aspects by asking specific questions about time, location, presence of other persons, and so on, to support retrieval so that the memory could come back piece by piece. However, we could not rule out the possibility that participants specifically reported situations or events which were more difficult or even impossible to forget.

Method

For our online survey, which was part of a larger project, we recruited 100 participants from Germany via professional networks (e.g., Xing). Of these, 65 participants met the inclusion criterium of working at least 17 hours a week, reported stories in which they were motivated to forget an event at work, and answered further prompts. However, not all participants responded to every question. Therefore, the sample sizes varied for different analyses. The mean age of our participants was 37 years (SD = 13.7), 49.6 % were female, and 56 % of our participants worked full-time. Participants worked in various industries (manufacturing 21.5 %; health and social work 20.0 %; administration 12.3 %; financial sector, insurance, consultancy 10.8 %; communication/information technology 9.2 %; trading 9.2 %; education and research 6.2.%, services 4.6 %; transportation and logistics 3.1 %; and other 6.1 %).

Participants were requested to describe a situation at work that they had wanted to forget in detail and then they were prompted by open-ended questions designed to gain more detailed information about the function (why) and situational factors (when) related to that effort at intentional forgetting (see Appendix). We used content analysis with inductive category development (Hsieh & Shannon, 2005; Mayring, 2010) to identify the respective categories. The analysis of the stories and responses to open-ended questions involved three steps (Hsieh & Shannon, 2005; Murphy & Ensher, 2008). First, the responses were read by one rater, and initial categories were developed. Second, functions and situational factors were sorted into this preliminary category system. A codebook was developed that included a description of each category, content excluded from that function, and examples and extracts from the data. Third, a second rater was trained to use the category system to classify the statements. In the case of coding discrepancies, the two raters discussed the classification and refined the category system. Finally, the second rater classified the statements again. Coding discrepancies were discussed until the two raters reached a consensus. The two raters coded 16 randomly chosen critical incidents. Interrater agreement between the two coders before reaching consensus was acceptable (Cohen's $\kappa = 0.85$).

Table 1. Functions of Intentional Forgetting

Functions	Example	%
Goal attainment	"To meet quality standards"	6.3
Maintaining positive self-view	"To improve my self-image again"	9.5
Maintaining positive relationships	"To maintain an unstressed working climate in the team"	11.1
Learning	"To accomplish the task differently next time"	7.9
Emotion regulation	"To get rid of the uneasy feeling when thinking about it"	47.6
Maintaining attentional control	"Improved concentration on the task at hand"	17.5

Note. % = percentage of the sample; n = 63.

Results

Table 1 lists the functions of intentional forgetting, illustrated with examples. Intentional forgetting served several functions at work.

We identified functions that were consistent with functions identified in previous research, such as emotion regulation, preservation of self-image, maintenance of social relationships and knowledge acquisition (Anderson & Hanslmayr, 2014; Nørby, 2015). We also found two additional functions: goal attainment and maintaining attentional control (see Table 1).

Emotion regulation was the most frequently observed function of intentional forgetting (47.6 %). Workers reported wanting "to get rid of the uneasy feeling when thinking about it" and "to get a more positive feeling." Some workers aimed to stop blaming themselves or to maintain their positive attitude by deliberately forgetting negative thoughts. Next, workers reported situations in which forgetting served to maintain attentional control (17.5 %) – for example, to "improve concentration on the

Table 2. Situational Factors

Situational factor	Example	%
Working condition		
Time pressure	"The task had to be finished in time"	24.4
Breaks	"Often when there was nothing to do"	9.8
Task characteristic		
Complexity	"Complex assignment"	9.8
Novelty	"Start of a new task"	10.8
Social characteristic		
Social interactions	"Important conversation"	9.8
Other		36.7

Note. % = percentage of the sample; $n = 41$.

task at hand" or to have more capacity for other cognitive activities ("freeing your mind for new tasks"). Some participants also reported forgetting in order to maintain a positive social relationship (11.1%). They meant, for example, that they sought "to maintain an unstressed working climate in the team." Others used intentional forgetting to preserve their positive self-view (9.5%; "to improve my self-image again"). Some workers (7.9%) expected to learn and develop at work when they tried to forget an unwanted event ("to accomplish the task differently next time", "growing with the experience"). Another function was goal attainment (6.3%) which comprised statements such as "to meet quality standards" and "to facilitate goal attainment."

Participants also reported a broad range of situational characteristics which stimulated intentional forgetting. They mentioned situations in which "the task had to be finished in time" (time pressure, 24.4%), or in contrast, "often when there was nothing to do" (breaks, 9.8%) (Table 2).

Workers also wanted to forget unwanted thoughts when working on other tasks which were complex or novel ("start a new task"; 20.6%). Some participants reported also intentionally forgetting in order to engage in a social interaction (9.8%, "important conversation"). Although we aimed at investigating situational factors and provided examples for situational factors in the instruction, some participants also reported personal factors such as self-worth, negative affect, and achievement motivation, which we do not discuss further in the present article.

Discussion

This qualitative study suggested that workers engage in intentional forgetting for different reasons, which range from maintaining attentional control to emotion regulation. In a work context, participants reported that they sought to control their memory contents mainly to regulate their mostly negative emotions. Another interesting finding was that our participants reported that they were especially motivated to forget under time pressure and, the reverse, during breaks. It seems that under high time pressure, individuals are necessarily motivated to forget unwanted thoughts so as to have enough attentional capacity to accomplish the task in time, whereas during breaks, they might have enough capacity for resource-intensive inhibitory processes, and therefore engage in intentional forgetting.

Implications for Cognitive Companion Systems

In addition to the obvious function of facilitating concentration on the task at hand by deleting, archiving, or hiding irrelevant digital information, a cognitive companion such as Dare2Del can also support emotion regulation, maintaining concentration, goal attainment, and a positive self-image. In cases where digital objects such as emails and photos are related to negative emotions or negatively affect one's relationships with others, archiving, deleting, and ignoring can also serve to regulate one's emotions (see also Streb et al., 2016) and protect social relationships (Anderson & Hanslmayr, 2014). The present critical incident study also showed that workers reported intentional forgetting when they had time to do so (e.g., during a break), when there was time pressure, or when a new or complex task requiring increased attention started. Thus, the companion system should support forgetting especially in situations with higher cognitive load, when cognitive demands exceed individuals' cognitive capacities to deliberately suppress irrelevant information. Moreover, as users have the possibility of configuring when the companion system shall propose irrelevant files, they can indicate times when there is little to do.

Recommendations for Future Research

We have argued that intentional forgetting of irrelevant information might be a helpful strategy to cope with the abundance of information in digitalized workplaces. Empirical studies have revealed that individuals are able to deliberately forget unwanted memory content even if several attempts are needed to limit the memory access. Intentional forgetting is demanding and resource-inten-

sive, and can be seen as a specific self-control strategy. Individuals differ in their ability to inhibit irrelevant information in memory. While intentional forgetting has been well studied in the lab, there is no research on intentional forgetting in the workplace. Our qualitative data suggest that workers intentionally forget information in order to regulate negative emotions, to protect self-esteem, and to be able to concentrate on the task at hand. In the digitized world of work, however, intentional forgetting is not only relevant for unwanted thoughts but also for external digital objects such as files or emails. Here, assistive systems as cognitive companions can help users to ignore or delete (i.e., intentionally forget) digital objects and thus to stay focused despite the large amounts of digital information. As there is not much insight into the impact of intentional forgetting in the work context and its support, we highlight three important future research areas.

First, research on contextual factors in the workplace that make intentional forgetting necessary for concentrated working is as yet unavailable in the literature, while it is especially important for the development of a context-sensitive cognitive companion system. The acceptance and use of such technical assistance depends strongly not only on how appropriate the irrelevance assessments are but also on the time at which time-irrelevant information is faded out. Our qualitative data suggested that, for example, high workloads and task complexity may motivate individuals to inhibit irrelevant information, which is a process that can be assisted by a cognitive companion system.

Second, future research should empirically investigate the proposition that a cognitive companion system such as Dare2Del supports intentional forgetting and, consequently, concentration and performance. Future research should also investigate potentially negative outcomes of a companion system. For example, hiding of irrelevant information helps to focus on the task at hand, but at the same time, this tense focus can blind individuals to important information unrelated to the task.

Third, a cognitive companion makes suggestions for deleting files and will be able to provide explanations for these suggestions. The issue of the generation of suitable explanations is still an open question. Explanations must be neither too general (e.g., "the file is old") nor too specific (e.g., "the file has not been accessed since 372 days 18 hours 12 minutes and 37 seconds"). The appropriate level of detail may be user, situation, and rule specific. Furthermore, if rules are learned or adapted from user feedback then the explanations (and possibly their appropriate level of detail) have to be learned or adapted, too.

Finally, it would be interesting to expand this from the individual's perspective and to investigate how individual intentional forgetting and its technical support might work within a social entity like a work group or an organization. For knowledge management in organizations, it is important to understand how individual forgetting affects others (team members, managers) in that these forgotten items are also no longer retrievable for others (Timm et al., 2017).

Conclusion

We have summarized selected key findings of research into intentional forgetting. In this, we have focused on individual differences and decisive situational factors for successful intentional forgetting and its positive outcomes. Building on these findings, we developed and evaluated an individualized, context-sensitive cognitive companion system – Dare2Del – that aims to support intentional forgetting and therefore should lead to better concentration, performance, and well-being. With the help of a qualitative survey, we were able to further identify critical situations in which forgetting might be especially helpful and should be supported by, for example, an assistive system.

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Appendix

Prompts for critical incidents

"In this study, we would like to learn more about situations in your working life that you wanted to forget. These may have been unpleasant experiences – such as personal failures or conflicts with colleagues – or information or projects that had become irrelevant or outdated. It is important that you deliberately wanted to forget these situations – for example, by instructing yourself to no longer remember this experience or information (e.g., 'I will forget that now!', 'I do not want to think about that anymore!'). Please describe this situation in detail."

Further prompts

(*Function*) What did you expect from intentionally forgetting the event?
(*Situational factors*) What were the external circumstances in which you wanted to intentionally forget the event? (e.g., time pressure, work on a complex task, during a break ...). Please describe the circumstances in detail.