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Is Work-related Mobile Learning in Public Spaces Effective? -Acknowledging Disruptions and Human Attention

Bachelor's Thesis
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Abstract

The ubiquitous digital devices and the necessity for lifelong learning have been merged into the concept of mobile learning. This trend in corporate organizations expects the employees to acquire work-related knowledge in the interstices of life outside the workplace. The decontextualized learning takes place in dynamic, flexible, and complex public open spaces. Hereby a considerable challenge on human cognitive resources is imposed, particularly on attention, which is essential for meaningful learning to occur. This paper reviews literature on effectiveness of mobile learning and indicates its limitations. Dependency of cognitive learning processes on context is described and the impact of variable and disruptive learning spaces on attention allocation during mobile learning is analyzed. The evidence is discussed and implications are suggested.

Introduction

The ubiquitous information and communication technology (ICT) has become even more pervasive through the spread of handheld devices and wireless networks at the beginning of the 21st century. A representative telephone survey showed that estimated 3.6 million of Swiss inhabitants possessed a smart phone and 1.7 million a tablet-computer (Beyeler, 2013). Sixty-nine percent of users never leave house without their smartphone and 57% use them daily to access an internet service (Google, 2012). A continuous automated data collection over nine months revealed that smartphones are most frequently used for sending short messages, half as often for voice calls and a quarter as often for browsing the internet (Do, Blom, & Gatica-Perez, 2011). When waiting for public transportation the preferred applications are clock, calendar, voice calls, and web browsing, indicating a need for communication and information. The favored locations for use of smartphones in general are home and work.

Mobile devices are connected to corporate networks in 89% of globally surveyed corporations (Dimensional Research, 2012). Hereby managers stay in continuous and unlimited contact with their employees and provide them with the latest updates on enterprise related issues. Hoen (2006) reported that fully informed employees are willing to work harder and longer. Consequently, a continuous sharing of information with employees is an effective tool to enhance the overall organizational performance. On the other hand if the amount of received information exceeds human information processing capacity, people act confused, are unable to set priorities, make wrong decisions, and the objective job performance as well as the subjective job satisfaction deteriorate (Eppler & Mengis, 2004).

Corporate learning and development (L&D) divisions, responsible for training and talent development of employees, have discovered mobile devices as a tool for training delivery. Michel (2012) reports the enterprise wide deployment of mobile learning (mLearning) as the latest trend in this field. Oftentimes commercial service companies, e.g., MdA Business Communications AG (http://www.mda.ch/), are appointed with full authoring of training materials and are made accountable for the effectiveness of instruction. This novel learning approach is meant to be presented on any device and any screen size, making learning possible anytime and anywhere (e.g., De-Marcos et al., 2010). It enables the L&D departments to set deadlines for completion of trainings disregarding the number of participants, and the spatial and temporal limits of traditional classroom training, making it an efficient instructional application.

This paper examines the effectiveness of work-related mobile learning in public spaces, taking disruptions and human attention into account. After defining learning and what is needed for it to occur, mobile learning is distinguished and its characteristics are discussed. Further, literature on effectiveness of mLearning is reviewed and its limitations regarding work-related learning outside the workplace are pointed out. A closer look at learning processes and how they could be impaired in dynamic and complex locations follows. Later sections describe human attention and how it is challenged during mLearning in disruptive open public spaces. The paper closes with a summarizing discussion of findings and their possible implementations for practice and future research.

Learning

Finding a definition of *learning* turns out to be a difficult endeavor, as the field has not agreed upon one binding terminology. The American Psychological Association (2013) gives a concise definition on their website, stressing the close conceptual relationship between *learning* and *memory*:

> Learning is the acquisition of skill or knowledge, while memory is the expression of what you have acquired. Another difference is the speed with which the two things happen. If you acquire the new skill or knowledge slowly and laboriously, that is learning. If acquisition occurs instantly, that is making a memory. (Learning & Memory, para 1)

Wakefield (1996) on the other hand sees learning as “a relatively permanent change in behavior based on an individual's interactional experience with its environment.” While the former definition stresses the process of learning, the latter puts more emphasis on its behavioral outcome. MacKeracher (2004) has supplemented the definition of learning by “making sense of and giving meaning to life’s experiences”. According to her these insights inform later decisions and actions, which for their part either confirm or disconfirm the former ones. The above examples reflect the different perspectives on learning, ranging from the invisible process itself and its observable outcomes to the conditions, which have to be fulfilled for learning to occur.

Schneider and Stern (2010) have summarized the findings of cognitive science on learning, which assumes that knowledge acquisition is the core of learning. *Knowledge* in this context refers to the cognitive foundation of diverse competences, which may be fragile and limited or durable, broad, and adaptive. It is the underlying knowledge organization that determines these resulting characteristics. Schneider and Stern (2010) list ten conclusions from the cognitive research on learning, whose application universally and significantly enhances the quality of learning.

The following principles should therefore apply to mobile learning settings as well. (a) The learner occupies the center stage within the learning environment and should hence be stimulated to stay mentally active, as it is her herself constructing the knowledge. (b) Prior knowledge in the domain of interest should be addressed and continuously assessed to adapt the instruction accordingly. (c) Different pieces of knowledge should be presented in a way to enable their integration into hierarchical knowledge architecture. (d) Proportionally intertwined combination of concepts, skills, and meta-cognition should be offered. (e) Suitable frameworks enhance the construction of soundly organized complex knowledge out of more basic pieces of knowledge. (f) Adequately structured and professionally designed learning opportunities should guide the process of the learner’s knowledge construction. (g) Reducing the working memory load through information chunking, keeping the language and materials as simple as possible and providing worked-out examples optimizes the transfer of the information to the long-term memory. (h) Good learning environments take into account the dynamical interaction and interdependence between emotion, motivation and cognition and are sensitive to the learner's needs and goals. (i) Addressing meaningful real-life problems fosters transfer between different domains and between the learning situation and everyday life. (j) The success of learning is strongly influenced by time and effort spent on practice and knowledge acquisition, which should be encouraged by a stimulating learning environment.

Mobile Learning

Mobile learning is a very recent development within the educational field and it is thus not surprising that the researchers have not yet reached a consensus regarding its definition and how to precisely distinguish it from other types of learning. The first descriptions of mobile learning were predominantly technocentric (Traxler, 2005) and characterized it as any instruction on a handheld or palmtop device. These could include smart phones, personal digital assistants, tablet computers and to a certain extent laptop computers. Such classifications simply put an additional label on *eLearning* made portable. O'Malley et al. (2003) extended the definition of mobile learning by the mobility of the learner: „Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies."

Both definitions clearly favor the term *mobile* in mobile learning and seem to take the *learning* part for granted. Georgiev, Georgieva, and Smrikarov (2004) consider mobile learning as part of *eLearning*, which itself is kind of *distance learning* based on computer and net technologies. From their point of view however the definition of mobile learning has to include the possibility to learn anywhere and anytime and therefore wirelessly. Following similar argumentation Mostakhdemin-Hosseini (2009) additionally emphasizes the need for the development of a distinct pedagogy for mobile learning, which would address both the content of the presented materials and the context, in which it is presented.

None of the above definitions takes the *learner* into consideration with her own characteristics such as needs, motivations, innate cognitive resources, time constraints, preferred learning environments, etc. The portable learning materials give the learner the freedom to choose her learning space and time. The hereby-arising spatial and temporal dynamics can create contextually and temporarily congruent learning opportunities, which are known as "*just-in-time*" learning (Pimmer & Gröhbiel, 2011), like consulting an online manual on how to set up a printer while in the office. But it can also place the learning activity completely out of context, as e.g., studying safety instructions for some work related software while commuting on a train, known as "*just-in-case*" learning (Pimmer & Gröhbiel, 2011). Learning taken out of the proverbial classroom or structured learning environment puts the learner in unstructured, dynamic, and highly complex locations, which could impact the learner and the learning processes by the multiple and varied distractions and disruptions (Schneider & Stern, 2010). Many of them are of sensory nature, e.g., acoustical, visual, physical, or olfactory but some might be arising out of conflicting personal goals at the very moment, trying not to forget certain plans (prospective memory), or simply because of mental or physical exhaustion.

Laouris and Eteokleous (2005) have proposed an abstract formula as a definition of mobile learning, which is meant to better conceptualize the different components involved in this educational experience and their complex interrelations.

"MLearn = f {t, s, LE, c, IT, MM, m} "

The *mobile learning experience* (MLearn) is hereby a function of *time* (t), which can be discrete or continuous. The *space* (s) can vary between stable, constrained, and structured to dynamic, open, versatile, and complex. The *learning environment* (LE) comprises of the learner and her equipment and to a varied extent of the instructor, the access to materials, relevant tasks and curriculum, the interaction between the learner, instructor and the materials, and/or other members of the learning community. The structure of *content* (c) can be either uniform and standardized, or highly interdisciplinary and flexible. The *technology* (IT) term includes all features of the employed mobile device and the closely related aspects of available services, antennas, external devices, etc. The *learner* (MM) with her characteristics is represented by her mental abilities, motivation, interests and other individually unique properties. Last but not least the authors also indicate an influence of the *method* (m) of design, presentation, and interaction with the learning content. This very complex and abstractly formulated definition manages to address more precisely the specific nature of mobile learning and its many constituent variables than the rather simplistic descriptions accounting for the utilized technology only.

Laouris and Eteokleous (2005) continue to detail even further the interdependencies between the variables, which is beyond the scope of this paper, though. Two sub-functions however are relevant for further discussion and are described below.

“s = f {MM}“

This formula emphasizes the active role of the *learner* (MM) in the choice of the *learning space* (s) or ecological context. The choice may depend on her preferences but also constraints like available time, imposed deadlines, or even well-being. Therefore the learner might either freely decide where to learn or in order to comply with some external requirements also take up learning in subjectively unsatisfactory spaces.

The *mental abilities* (MM) of the learner are further described as

“MM = f {MA, k, p, α }“.

Interestingly enough Laouris and Eteokleous (2005) decided to subdivide in this function the human cognitive resources into the *mental attributes* (MA) and *attention* (α). The authors mention their other project to model the mental attributes, which might be a reason for such segmentation and lacking specification. Attention may refer to different parts within the learning environment, within the learning space and also to the own thoughts, emotions, feelings, and visceral perceptions. Attention is dynamic both in time and space, which makes it difficult to be monitored and predicted. The above function additionally includes the learner's *prior knowledge* (k) and *preferences* (p). The authors suggest that all of the parameters have to be known and considered when designing educational environments and choosing an adequate pedagogy. They admit that their approach imposes challenging requirements on the conceptualization of instructional design.

The principles to enhance the quality of learning as described in previous chapter (Schneider & Stern, 2010) and the definition of mobile learning given by Laouris and Eteokleous (2005) apparently complement one another. The latter just names the features, which add up to a mobile learning experience, while Schneider and Stern (2010) specify in some detail how to enhance any learning experience.

The dynamic and so far unique nature of mobile learning in regard to time and space could have a significant impact on the course of the human cognitive processes involved in learning and could ultimately affect the learning outcome. Hence this paper focuses on the *learner* (MM), especially her *attention* (α) and the context of *learning spaces* (s), in which mobile learning takes place. The term *space* refers to the ecological context or physical surroundings and is used interchangeably with *location*, *place,* or *surroundings* to avoid confusion with the term *learning environment* as defined above (Laouris & Eteokleous, 2005).

Effectiveness of Work-related Mobile Learning in Public Open Spaces

Seventy-four eLearning experts from German speaking Europe expressed their expectations about learning in corporations in an online survey (Michel, 2012). They considered mobile learning the top trend at least till 2015 despite open issues of specific didactics and uncertain demand from corporations and individuals. Mobile learning approach is anticipated to develop to “Umsatzlokomotive” (turnover engine) within the coming years, large enterprises being the main target group. The learners are expected to prefer applications for smart phones and tablet computers, to demand learning modules embedded in a complex learning architecture, and to be willing to accept pop-up advertisements during their learning activities. No explanation for such assumptions was reported.

Pimmer and Gröhbiel (2011) surveyed 56 international academics, L&D managers, and vendors, who anticipated the use of mainly individual computer based "just-in-case" learning in corporate settings. It means learning that may have a potential value to the work processes sometime in future as opposed to "just-in-time" learning, which is job-embedded and of immediate relevance. The experts appreciated however a possible contextualization and integration of mobile learning in work processes, while at the same time regarding it as quite challenging due to technical and organizational issues. Additional time needed for learner's reflection in such a case was also emphasized.

In the face of the anticipated wide dissemination of mobile "just-in-case" learning out of the workplace a question of effectiveness of this novel learning approach arises. A recent meta-analysis of studies on mLearning revealed that only 12% investigated adult population and 58% of all examined studies evaluated the effects of mLearning but only 28% of them, accounting for 20, used experimental research methods (Wu et al., 2012). However, the most cited study, turned out to be observational or quasi experimental at best. There was no random assignment, no control group, and only 20% of participants used mobile devices, while the rest used PCs to listen to the podcasts. The participants filled a survey to subjectively evaluate the use, effectiveness, and satisfaction with the learning activity on a Likert scale (Evans, 2008). Also other studies, which were not included in the meta-analysis by Wu et al. (2012) turned out to be non-experimental, because they either did not perform random assignment, did not include a control group, based their evaluation on survey outcomes or a combination of the above (e.g., De-Marcos et al., 2010; Georgieva, Smrikarov, & Georgiev, 2011; Schepman, Rodway, Beattie, & Lambert, 2012). None of the aforementioned studies dealt with mobile learning in corporate settings.

This finding is in agreement with Pimmer and Gröhbiel (2011), who report that the majority of scientific research considers mobile learning in schools and institutions of higher education. Most of the papers on corporate mobile learning are not scientific and systematic research on mLearning in companies is lacking. Recently a book has been released on work-based learning (Pachler, Pimmer, and Seipold, 2011) but the presented examples do not include work-related mobile learning happening on the move outside the workplace.

Two studies run with university students shed some light on listening to educational podcasts on the go. Their findings might be applicable to mLearning of professionals outside the workplace. Coens, Dagryse, Senecaut and Clarebout (2011) let students listen twice to a 4 minute long educational podcast either while sitting, walking, or jogging. All three groups performed equally well on a subsequent seated knowledge test. When the podcast lasted 12 minute and was listened to only once then the sitting group outperformed the jogging group. This finding indicates that shorter chunks of narrated information and their review might be an effective way of mobile learning, while longer podcasts prove less effective during a more vigorous physical activity. The study did not take place in an open public space, which limits its generalizability. Besides, the fact that in the longer podcast condition the sitting group outperformed the jogging group could be attributed to a discrepancy in the internal, physiological state between the learning and the seated test situation as described by Miles and Hardman (1998). The authors of the study interpret their results as indicating an inability to multi-task between two equally strenuous tasks.

Kazlaukas and Robinson (2012) explored the adoption of podcasts by a group of university students. Their survey revealed that 20% of the participants chose not to listen to podcasts at all, indicating lack of time due to paid work as the main reason. Only 20% of listeners used MP3/4 players and this predominantly in the learners' traditional study locations, indicating a preference for a clear boundary between study and recreation. This finding corresponds with Evan's (2008) data that only 20% of participants opted for listening to podcasts on MP3/4 players. Kazlaukas and Robinson (2012) conclude that despite the flexibility and opportunities afforded by podcasts they may not be for everyone, and that many learners might prefer traditional study spaces.

Pimmer (2009) points out that the majority of mLearning projects focuses on content delivery while leaving the context behind. He stresses that context consideration is critical to mLearning with its changing temporal and spatial circumstances. Investigations on the impact of context on the learning activity on the move have been lacking, although some authors had explored the different kinds of context possible during mLearning in prior years (e.g., Bhaskar & Govindarajulu, 2008; Winters & Price, 2005). Research arising out of the importance of context for mobile learning aims at developing guidelines how the devices and applications could recognize the learner's location and context to support or augment her current situation, leading to context-aware mobile learning applications (Winters & Price, 2005). This development however does not address mobile learning of decontextualized contents as assigned by the L&D departments to their employees.

Impact of Context on Learning Processes and Their Outcomes

This chapter examines how the variable, dynamic, and complex mobile learning locations with their specific spatial and temporal contexts, could influence the learning processes and the resulting learning outcomes.

One of the best predictors for retained information is the amount of time spent studying it. The fact has been well documented since Ebbinghaus's (1885) famous discoveries related to the human memory and confirmed for performance in diverse areas of expertise (Ericsson, Krampe, & Tesch-Römer, 1993). Our skills are grounded in extensive practice, which is known as the total time hypothesis (Baddeley, 2009). Closely related and also first described by Ebbinghaus (1885) is the finding that it is more effective to spread studying evenly over given period of time rather than learning everything at once. The principle of distributed practice (Baddeley, 2009) has a considerable impact on the long-term memory and together with the total time hypothesis it could speak in favor of mobile learning. The learner could potentially use every free minute available anywhere for studying, leading to a considerable amount of total time. Additionally learning could be well distributed over time, either deliberately or because of other intervening obligations.

This line of reasoning is distorted by the finding that memory for studied material is strengthened even more when the learner actively recreates the material rather than simply being passively provided with it again. Such immediate self-testing after a round of studying was described by Slamecka and Graf (1978) on pairs of synonyms and has been shown even more powerful when creating visual imaginations of the material (Sweeney & Bellezza, 1982). Learning on the go in disruptive spaces could impair the deliberate mental recreation of learning material and hereby compromise the learning outcome. The phenomenon known as generation effect (Slamecka & Graf, 1978) illustrates that the way, the learning material is manipulated by the learner, determines how well it will be stored in memory.

The impact of information processing on the learning outcomes is described in the levels of processing model (Craik & Lockhart, 1972). Verbal information can be considered structurally, just how it looks like, phonetically, how it sounds, and semantically, what it means. The latter is regarded as a deep level of processing, leading to longer lasting memory traces. The concept of deep analysis is not fully explained but the proposed theories all agree that the material has to be actively attended to in order to enable deeper processing (Craik & Tulving, 1975; Eysenck & Eysenck, 1980; Tyler, Hertel, McCallum, & Ellis, 1979).

When learning on the go, in loud, crowded places, or even in an open space office with an ambient noise, focusing attention fully on the learning task might be difficult if not impossible to obtain. Although mobile learning offers additional time for learning, the simultaneously present distractions interfere with the mental manipulation of the learning material, necessary for learning to occur. The deeper more effortful level of processing involves not only making meaning of the presented material but also organizing it into new (Tulving, 1962) or within the preexisting knowledge hierarchies (Bower, Clark, Lesgold, & Winzenz, 1969) and connecting it to prior knowledge (Bransford & Johnson, 1972). These processes need both time and deliberate, focused effort. The countless stimuli competing for the learner's attention in the changing and complex spaces might therefore turn out to be a major obstacle for effective "just-in-case" mobile learning.

Even when we regard things as important and worth remembering, they may still turn out irretrievable when attempting a recall. Such unintended memory failure also known as incidental forgetting (Anderson, 2009) has been attributed to different factors. One of the possible explanations, relevant when discussing mLearning, is that it may be caused by changing context, which provides cues of altered relevance (Mensink & Raaijmakers, 1988). These can hinder the retrieval of previously accessible memory.

Tulving and Thomson (1973) have demonstrated the powerful effect of cues that are present and encoded together with a learning item. They described the encoding specificity principle as follows "…Specific encoding operations performed on what is perceived determine what is stored, and what is stored determines what retrieval cues are effective in providing access to what is stored." It means that we remember what we experience and attend to, and we can use a part of this trace to later recall the whole experience from our memory. Therefore deeper processing at encoding helps to construct stronger and more durable associations between the trace of interest and the contextual cues, which later can facilitate cued recall.

Incidental contextual fluctuation during encoding and retrieval influences the accessibility of the memorized material. Godden and Baddeley (1975) demonstrated the dependency of human memory on the ecological context. Divers learnt a list of words either on the beach or under water, which they then had to recall in either location. The best recalled items on the beach were the ones learnt on the beach, the best recalled words under water were the ones learnt under water. Aggleton and Waskett (1999) showed a similar effect for odors that can enhance the recall of longer stored memories.

Smith and Vela (2001) reviewed people's sensitivity to spatial context, whose impact was strongest if people paid at least some attention to it during encoding and if retrieval was attempted long thereafter. However it is not necessary to immerse oneself in the original surroundings, to obtain the effect it's enough to try to think back and to imagine the space present upon encoding. Given the changing locations in which learning on the move happens one could easily fall pray to the source misattribution error. It is remembering the correct fact but confusing the context in which it happened (Schacter, 1999). Thus one could mentally reinstate a mismatched learning location, which would inhibit the recall of the target memory. One would attempt to retrieve a memory trace with an irrelevant cue.

Learner's internal, physiological state can also function as a cue. Miles and Hardman (1998) showed that participants who learnt a list of words while exercising remembered them best when exercising again, while participants who learnt the words at rest remembered them best at rest. It has been therefore concluded that the physiological state serves as a cue and improves recall. This finding may be of some importance for mobile learning experiences. Listening to a podcast while e.g., rushing to catch the train leaves the learner in a different physiological state than recalling the information during a meeting with a client.

Our memory is mood-dependent (Eich, Ryan, & Macaulay, 1994). Material learnt in a given mood — positive, neutral, sad — is best recalled in the same mood. A mobile learning scenario in a not self-elected location could induce anger, frustration, or stress in the learner. Due to a mismatch of mood in a more relaxed recall situation it could lead to impaired memory.

Cognitive context during encoding can function as a cue for later recall. For example the language, in which one studies influences what one remembers. This effect has been shown on bilingual individuals in the areas of autobiographical and academic information (Marian & Fausey, 2006; Marian & Neisser, 2000). Therefore language of instruction may be of particular relevance for mLearning in large multinational companies with employees often routinely speaking more than two languages at work.

The above review emphasizes the importance of incidental context during encoding for later recall in differing contextual surroundings. For the retrieval success attention to cues is crucial not only during the encoding but to a certain extent also to their presence during the recall (Fernandes & Moscovitch, 2000; Naveh-Benjamin & Guez, 2000).

Evidently, learning processes can be considerably challenged during mobile learning due to strained attention not only through the constantly changing locations but also through the flexible physiological, emotional, and cognitive states of the learner. Additionally the learner also actively keeps in mind her plans and goals for the very next future. Prospective memory reminds her to carry out an action as planned mostly without any external cues at the right place and right time. McDaniel, Robinson-Riegler, and Einstein (1998) have shown that prospective memory performance is better with full attention than with divided attention . Thus not only the countless contextual stimuli put high demands on the human attention during a mobile learning experience but also our own prospective memory challenges it.

The reviewed evidence illustrates that a mobile learning experience imposes a considerable strain on the human cognitive resources, particularly attention.

Human Attention and Its Limitations

Attention is needed for processing the relevant information in all aspects of our lives, including learning and remembering. It is essential during information encoding and its later retrieval. Scientific evidence on attention facilitates the understanding of the challenges imposed on the learning processes during a mobile learning activity. Therefore the relevant concepts regarding human attention are recapitulated below.

Attention has been investigated extensively and intensively for well over a century, but the most frequently cited definition of attention dates back to William James (1890):

It is the taking possession by the mind, in clear and vivid form, of one out of what

> seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, ... (pp.403-404)

Within this paradigm *attention* is seen as a mechanism directing the presumed limited cognitive resources to relevant information. One talks of *focused* or *selective attention* in this case. Two systems have been suggested for orienting attention (Corbetta & Shulman, 2002; Posner, 1980). On the one hand there is the endogenous /top-down system, which is voluntary, slow and goal-directed, and on the other hand there is the exogenous /bottom-up system, which is automatic, fast and stimulus-driven.

Stimuli, which are regarded salient, distinct, or task relevant might capture attention. However a distractor that is entirely irrelevant to any attentional settings of the current task has clearly been demonstrated to capture and captivate attention if of abrupt onset (Forster & Lavie, 2011).

When an individual tries to distribute attention between multiple targets then it is a case of *divided* or *split attention*. When more than one task is performed at the same time then it is *multi-tasking*. Divided attention has been associated with induction of errors and delays in response (Roda, 2011). It has been demonstrated that if two tasks must be performed close together in time, the response to the second stimulus is slowed down as the interval between the two stimuli is reduced. This phenomenon is termed the psychological refractory period (Pashler, Johnston, & Ruthroff, 2001). Its suggested cause is a bottleneck in the processing system, which can only maintain one active task at a time. The decisions about the right responses can therefore be only taken in a serial fashion, hence the name central bottleneck theory.

The ability to focus attention on one task in the face of distractions is of considerable importance in everyday life. Lavie, Hirst, Fockert, and Viding (2004) have suggested two selective attention mechanisms. A perceptual selection reduces the distractor perception in situations of high perceptual load in the primary task, which exhausts the perceptual capacity in processing relevant stimuli. The second mechanism of cognitive control corresponding with working memory reduces interferences from distractors through specifying of what is currently relevant and differentiating between targets and distractors. As long as working memory is not overloaded the cognitive control functions can maintain current priorities and can contribute to selective attention allocation. High perceptual load in the primary task has been shown to reduce the processing of internal distractors as well, like thoughts or mind wandering (Forster & Lavie, 2009). Consequently situations with high perceptual and low working memory load in primary task are optimal to focus attention.

The aforementioned research on human attention was carried out in laboratories. Thus one needs to be careful transferring its findings and conclusions into naturalistic settings. Two phenomena which have been obtained under realistic conditions appear therefore of general importance. It’s the observation of *change blindness* and *inattentional blindness*. Change blindness relates to the failure to detect changes (e.g., movement, disappearance, color change) in the visual environment and inattentional blindness describes the failure to detect an unexpected object appearing in a visual field (Eysenck & Keane, 2010). Attentional processes play an important role in both phenomena. Cartwright-Finch and Lavie (2006) have demonstrated that the level of perceptual load in the primary task determines whether a task-irrelevant stimulus will enter visual awareness. With increased perceptual load in the relevant task more participants exhibit inattentional blindness. This finding has been also reported for change blindness (Lavie, 2006). Recently a cross modal effect of visual perceptual load could be demonstrated (Macdonald & Lavie, 2011). Under high visual load a novel phenomena of *inattentional deafness* has been established.

The above theories and phenomena of human attentional control serve an examination of learning in dynamic and complex spaces with a surplus of potential distractors and interruptions.

Significance of Distractions for Mobile Learning

The L&D divisions of large enterprises assume that because the desk time of their employees is limited, they would rather not be engaged in an obligatory online training in the office. "But ask those people if it would be beneficial for them to do their learning whilst they are on a train or in an airport lounge or during on-the-go moments when day-to-day business is restricted, then they'll almost certainly say yes" (Lea, 2011, para 3). The work-related learning activities are hereby pushed outside the workplace and work time, intruding the employees' personal time. It is implicitly required to obtain job relevant knowledge and skills during the transitional interstices of life, e.g., when commuting.

Streets, public transportation, restaurants and other public spaces have not yet been investigated as working and learning locations for knowledge workers. Therefore a description of findings regarding distractions in open space offices, which might occasionally be used for mobile learning activities, is presented. The derived conclusions are extrapolated to mobile learning in public spaces.

In a literature review on workplace related distractions Mardex (2004) reported that employees regarded a workplace most effective if it allowed them "to do distraction-free solo work" while at the same time appreciating opportunities for spontaneous interactions. The literature cited by Mardex (2004) additionally revealed that open space offices produced noise, visual distractions, and physical stressors like e.g., draught that all can disturb the employees and jeopardize their performance.

Even a superficial look discloses that public open spaces are much more complex, variable, and packed with a superabundance of potentially distracting features, which are completely beyond the learner's control. All distractions happening in open space offices are even more frequent in public spaces. Additionally some olfactory perceptions or physical invasions into the personal space may cause disruptions of a mobile learning activity in an open public space. It is probable that the employees' wish for distraction-free workplaces (Mardex, 2004) implicitly includes places to learn.

An observational study of a team in an investment company showed a distinctive fragmentation of work (Gonzales & Mark, 2004). On average people spent 3 minutes continuously working on one task before switching to another one. The use of any given working tool like software or paper document lasted a little longer than 2 minutes before turning to another tool. Looking at strings of events, which contribute to a single transaction or project, Gonzales and Mark (2004) found that these time segments lasted just above 12 minutes. The authors concluded that knowledge workers are not multi-task processors but that they rather require attentional resources to constantly switch between versatile tasks, tools, and projects. On the grounds of this finding a continuous mobile learning activity can be anticipated to last no longer than 3 minutes, given the turbulent learning locations.

Burmistrov and Leonova (2003) found in their experiment on interrupted computerized text editing that the performance on cognitively simple tasks was not influenced by interruptions while the performance on cognitively complex tasks was slowed by interruptions. They attribute the observed task deterioration to the necessary task re-orientation after the interruption. Any learning activity is cognitively demanding, as it requires deeper processing to be effective (Craik & Lockhart, 1972). Hence mobile learning can be susceptible to distractions and interruptions.

Overhearing a cell phone conversation is a common experience in open public spaces. Galvan, Vessal, and Golley (2013) found in their experimental study that an overheard one-sided cell phone conversation was perceived as more disturbing than a two-sided discussion. Bystanders, who were engaged in unscrambling anagrams, remembered more words used in the one-sided cell phone conversation than in the two-sided. The primary anagram task however was not affected by either conversation. The authors suggest that cell phone conversations may be a frequent cause of distractions with negative impact at workplaces and in public spaces.

A task interruption can also occur without an external prompt and lead to switching the focus to a different task. It is called an internal or self-interruption. Dabbish, Mark, and Gomez (2011) showed that people working in open space offices self-interrupted at a higher rate than people in conventional offices. External interruptions experienced in a previous hour were found to increase self-interruptions in the subsequent hour. The authors suggested that external interruptions might condition people to self-interrupt, because they became habituated to periodical interruptions. Another interesting finding was that individuals were more likely to self-interrupt in order to return to their major project, which they were solely accountable for (Dabbish, Mark, & Gomez, 2011). It suggests that self-interruption may occur as an expression of prospective memory, reminding to perform the originally intended activity and hereby leading to timely completion of main working assignments. Following this evidence the frequency of external and internal interruptions during mLearning might be high and learning activity may be considered a secondary task when on the go.

It could be hypothesized that frequent multi-tasking, like the one required at the modern technology supported workplaces or when using multifunctional devices, lets people practice task switching and attention allocation. Therefore a learning effect could be expected, the more frequent the task switching the better the attentional control. Ophir, Nass and Wagner (2009) examined this question in their study of heavy and light media multi-taskers. Surprisingly, it turned out that heavy media multi-taskers have greater difficulty filtering out irrelevant stimuli from their environment and are more susceptible to interferences from irrelevant representations in memory. Their task switching ability was worse that the one of light media multi-taskers. The obtained data indicate that the light media multi-taskers have a more pronounced tendency for top-down attentional control, allowing them to easier focus their attention on a single task despite present distractions (Ophir et al., 2009). The heavy media multi-taskers on the other hand tend to a bottom-up control of their attentional processes and might therefore be prone to sacrificing the key task in favor of irrelevant stimuli. As mobile learning is rooted in multimedia and multifunctional devices the above findings might be directly applicable to mobile learning activities.

Bailey, Konstan, and Carlis (2001) studied the effects of interruptions caused by running applications on primary task performance and the user's annoyance and anxiety. The more difficult the primary task was the longer it took their participants after the interruption to switch back to it again. The annoyance experienced by the users due to an interruption increased with the difficulty of the interrupted task. The interrupted participants reported higher anxiety levels than the uninterrupted control group. Correspondingly handheld devices offer diverse automatic notification services, which, though unrelated to the mobile learning activity, compete for the learner's attention and may occasionally cause interruptions and anxiety.

A survey conducted within 18,000 employees in Germany (Lohmann-Haislah, 2012) revealed that the main causes for perceived work related stress were multi-tasking (58%), followed by time pressure (52%) and work interruptions (44%). A promotion of mandatory work-related mobile learning assignments outside the workplace, which afford multi-tasking and are subject to interruptions, might therefore contribute to work related stress.

Above findings demonstrate that distractors and interruptions, which can be expected in open public spaces, impair performance on primary task and negatively affect emotional state of the learner.

Discussion and Implications

Public open spaces as a venue for work-related mobile learning have been confirmed on the rise and the trend is expected to continue at least till 2015 (Lea, 2011; Michel, 2012; Pimmer & Gröhbiel, 2011). The intensive spread of such novel learning approach would require evidence on its effectiveness regarding the attainable learning outcomes. However systematic research on mLearning outside the workplace has been lacking to date (Pimmer &

Gröhbiel, 2011). This dearth is supported by a meta-analysis of literature on mobile learning, which shows that only 12% of all reported research deals with adult population, none with corporate settings and only 20 of studies on mLearning's effectiveness could be classified as experimental (Wu et al., 2012). A non-experimental design and the evaluation of learning outcomes with subjective surveys instead of standardized knowledge tests strongly limit the generalizability of presently available findings (e.g., De-Marcos et al., 2010; Georgieva et al., 2011; Schepman et al., 2012).

The combination of rapid dissemination of work-related mLearning into open public spaces with the lack of scientific evidence on effectiveness of such approach generates an urgent need for research in this area. It is crucial to design experimental studies with adequate control groups and to compare the learning outcomes using standardized tests. Research conducted in real life scenarios yields the limitation of countless uncontrollable variables. But it could still contribute additional insights to the evidence obtained under controlled laboratory conditions. To strengthen the validity of findings even further it seems desirable to approach the corporate Learning and Development divisions and involve them in research. The generated evidence could be hereby more immediately and directly transferred into daily practice.

The L&D departments promote mLearning on handheld devices outside the workplace in the assumption that employees prefer learning after work due to tight time constraints at work (Lea, 2011). Lohmann-Haislah (2012) confirmed that 52% of surveyed employees perceived work-related stress due to time pressure. So acting according to the employees' needs would comply with the principles proposed by Schneider and Stern (2010), putting the learner at the center of learning environment to enhance the quality of learning.

Current evidence however contradicts the expectations of L&D divisions. The monitored preferred locations for general use of smart phones are home and work, while making voice calls is the preferred application in context of transportation (Do et al., 2011). Vast majority of students assigned to educational podcasts chose to listen to them in their traditional learning spaces, despite that 20% of them used MP3/4 players for studying (Evans, 2008; Kazlaukas & Robinson, 2012). Participants, who had a paid job along studying, indicated a lack of time as a reason for not listening to podcasts at all (Kazlaukas & Robinson, 2012). A preference for traditional learning approaches was indicated, with a remarkable aversion for podcasts reported by working students, whose workload could be compared with corporate employees'.

The arising implication that corporate learners might in fact not be in favor of work-related mLearning in disruptive public spaces is supported by Mardex's (2004) literature review on work-related disruptions. The employees demanded distraction free solo work opportunities to work effectively and efficiently while open space offices exposed them to acoustical, visual, and physical distractors and stressors. Overhearing a phone conversation in public open spaces might be even more common than in open office spaces (Do et al., 2011). One-sided phone conversations have been shown to be more disturbing and better incidentally remembered by bystanders than two-sided discussions (Galvan et al., 2013).

The above evidence strongly questions if employees really prefer learning on the move on a handheld device to a more structured traditional learning place. They may indicate a lack of time for "just-in-case" learning at the workplace in order to highlight their heavy workload but there is no evidence for employees' intention to push work-related learning outside work. To objectively determine preferences of a professional learner automatic monitoring of activities on handheld devices could be investigated along with a GPS enabled recording of locations. The technically less demanding surveys by independent researchers to ascertain anonymity and honest answers could shed at least some preliminary light on the preferences regarding the learning spaces and suggest implications for the corporate mLearning approaches.

Laouris and Eteokleous (2005) detail the numerous variables, which intertwine to a mobile learning experience. Unique to this novel learning approach is not only the obvious inclusion of IT but also the possible choice of flexible, dynamic, and complex learning space that interacts with the learner's cognitive processes. Therefore the aforementioned reluctance towards educational activities on the go, like listening to podcasts, and the wish for disruption free working spaces may reflect the employees' experience and/ or awareness that cognitively complex tasks require deliberate and undisturbed focused effort over time as repeatedly shown in the past (Baddeley, 2009, p.71; Bower at al., 1969; Bransford & Johnson, 1972; Ebbinghaus, 1885; Ericsson et al., 1993; Schneider & Stern, 2010; Tulving, 1962). These deep levels of information processing, needed for long lasting learning to occur, all demand active attention to the learning material (Craik & Lockhart, 1972; Craik & Tulving, 1975; Eysenck & Eysenck, 1980; Schneider & Stern, 2010; Slamecka & Graf, 1978; Tyler et al., 1979). The familiarity with the negative effects of disruptions on focused attention and with task switching due to interruptions may lead employees to be cautious to adopt work-related learning on the go.

A recent German study on perceived work-related stress supports this assumption as 44% of the surveyed participants reported being stressed by interruptions and even 58% by multi-tasking (Lohmann-Haislah, 2012), which emphasizes the negative valence of those experiences. Interruptions caused by unexpected notifications from running software applications were found to induce anxiety in users (Bailey et al., 2001), which is in line with the results of the survey by Lohmann-Haislah (2012). At the same time this finding calls into question the expectation of eLearning experts that learners would be willing to accept pop-up advertisements during mLearning (Michel, 2012). Such disruptions would probably both impair the learning processes and cause anxiety or stress in the learner. Human memory is mood-dependent and physiological state can function as a cue upon recall, thus stress and anxiety upon encoding may impair later recall in a less aroused emotional and physiological state (Eich et al., 1994; Fernandes & Moscovitch, 2000; Miles & Hardman, 1998; Naveh-Benjamin & Guez, 2000).

The finding that employees might actually prefer more traditional learning spaces to learning in open public spaces is supplemented by the evidence that interruptions compromise performance on primary task and leave the individual emotionally distressed. Under such circumstances a corporation wide spread of mandatory mLearning assignments may not only result in ineffective learning outcomes but also in more stressed and less satisfied employees, whose performance might deteriorate as a result (Eppler & Mengis, 2004). Therefore research on the effects of mLearning outside the workplace should be extended beyond the attainable gains in knowledge to include its effects on learners' emotional state. This could be measured either subjectively with questionnaires or objectively by collecting physiological data like heart rate, salivary cortisol levels or pupil dilation (Henckens, Hermans, Pu, Joëls, & Fernández, 2009). The insights of such studies could help evaluating how different mLearning applications (e.g., podcasts or animations of different duration, verbal vs. pictorial instructions) outside the workplace impact the learner's emotional state.

Apparently external interruptions not only cause distress and compromise primary task (Bailey et al., 2001; Burmistrov & Leonova, 2003; Pashler et al., 2001; Roda, 2011) but they also increase the frequency of so-called self-interruptions in the subsequent hour (Dabbish et al., 2011). Dabbish et al. considered self-interuptions as corresponding to prospective memory, which redirects the attention back to the major task. However prospective memory was shown to be better with full attention, too (McDaniel et al., 1998). Therefore external disruptions may compromise the performance on primary task both directly through dividing attention between the primary task and the distractor and indirectly by impairing the prospective memory to return back to the primary task. It appears probable that when commuting employees have more than learning on their minds. They may even consider the learning assignment as a secondary task giving priority e.g., to catching the train, shopping for groceries or making a packing list for the next day's trip. Investigations on the achieved learning outcomes in dependency of the prospective memory load (remembering varied number of planed activities) in the face of external distractors could disclose the probable interrelations and allow further statements on effectiveness of work-related mobile learning in the interstices between professional and personal life.

Gonzales and Mark (2004) observed a distinctive fragmentation of office work, when people switched from one task to another approximately every 3 minutes. The authors suggested that knowledge workers had to strain their attentional resources to constantly switch between versatile tasks. Since open public spaces offer a superabundance of diverse distractors it can be assumed that during mobile learning in such surroundings the learner would have to divide her attention even more often than every 3 minutes.

Divided attention is associated with errors and delays (Bailey et al., 2001; Pashler et al., 2001; Roda, 2011), which are even more pronounced for cognitively complex tasks (Burmistrov & Leonova, 2003). Thus frequent interruptions of learning processes can be expected to jeopardize the learning effect. Forster and Lavie (2011) showed that not only task relevant distractors might capture attention but also distractors, which are entirely irrelevant to any of the attentional settings of the major task, if they are of abrupt onset. Countless features of open public spaces are irrelevant for the learner while being mobile, fluctuating, flashing and unpredictable, which predisposes them to capturing attention by their abrupt, unexpected emergence.

To be able to keep attention focused despite present distractors the perceptual/ visual load of the primary task should be high while the working memory load should be low (Lavie et al., 2004). In this case instructional message design could contribute to continuous attention allocation on the learning activity. Videos and animations would probably fulfill the requirement for high perceptual load. Written and pictorial instruction would need to be gradually tested to determine the necessary perceptual threshold. However if the working memory load can continuously be kept low is questionable, as learning requires deeper processing, which corresponds to manipulating the learning material in working memory (Craik & Lockhart, 1972; Slamecka & Graf, 1978; Sweeney & Bellezza, 1982). High perceptual load reduces the processing of task-unrelated thoughts or mind wandering (Forster & Lavie, 2009), which could enhance the learning activity. However if the learner ends up interrupting the learning task and allocating her attention partly on the distractor, which presumably is perceptually complex (e.g., pop-up notification on the user interface, flashing information board, a glimpse of passing vehicles, etc.) than she might experience either inattentional blindness or change blindness (Cartwright-Finch & Lavie, 2006; Lavie, 2006). Such scenario would leave the learner potentially missing an important piece of instructional information, esp. from animated instructions containing changes in previously present elements or emergence of new features.

This conclusion points to the importance of instructional message design for the attainable effectiveness of the novel mobile learning approach. Development of instructional design principles specific to mLearning has been lacking to date (Wang & Shen, 2012). The existing message design recommendations for multimedia learning as proposed by Mayer and Moreno (2003) could be tested in mobile learning scenarios as a first step and then adjusted accordingly. Additionally mLearning design principles need to be expanded to include spoken material only, as appearing in podcasts. Coens et al. (2011) demonstrated differences in learning outcomes between short, repeated and long podcasts under three different physical strains, which indicates a need for further investigation of varied podcast design.

Macdonald and Lavie (2011) reported inattentional deafness under high visual load. Given the complexity of open public spaces, it can be hypothesized that listening to a podcast while visually attending to such surroundings may result in missing some details from the podcast, which may in the end compromise the learning outcome. In conclusion research on effective specific visual and spoken message design is needed to better evaluate possible effects of mobile learning outside the workplace, which is in agreement with Mostakhdemin-Hosseini's (2009) call for development of a distinct pedagogy for mLearning.

It might have been expected that frequent and repeated exposure to surroundings rich in diverse distractors when attempting to focus attention would provide a training effect and improve sustained attention allocation. Ophir et al. (2009) however found that heavy media-multitaskers had more difficulties to ignore irrelevant stimuli and were less skilled in task switching than light multi-taskers. The authors suggested that these differences might either result from frequent multi-tasking itself or might be a reflection of stable individual traits. Investigations should be launched to clarify the causality of this findings and its possible impact on other cognitive processes. If multi-tasking leads to disabilities in top-down attention focusing without any associated cognitively beneficial effects then the society might need to reconsider the deployment of technology and the innovational processes for the future. The promotion of mobile learning in disruptive places would be unreasonable under such circumstances. If however individual differences are the reason then awareness about them should be raised in society and tolerance advocated. So far multi-tasking has been appreciated by society as a whole and job recruiters in particular. It has been neglected however that multi-tasking might sacrifice the performance on the important main task.

The dynamic, changing surroundings that are specific to mLearning provide diverse contextual cues, which incidentally might get encoded together with the items of interest. They can later facilitate cued recall of learnt items if they were attended to during encoding and are present or mentally reinstated upon recall (Mensink & Raaijmakers, 1988; Smith & Vela, 2001; Tulving & Thomson, 1973). The accessibility of the memorized material is influenced by incidental contextual fluctuation during encoding and retrieval (Aggleton & Waskett, 1999; Godden & Baddeley, 1975). This means that recall of items learnt in public open spaces would not be facilitated by spatial context at the workplace, either due to the absence of relevant contextual cues or as a result of a source misattribution error (Schacter, 1999).

Not only fluctuation of spatial cues can cause incidental forgetting of the learnt material but also a switch of language between a learning event and the recall situation (Marian & Fausey, 2006; Marian & Neisser, 2000). Internal communication and training in multinational corporations is provided in English and sometimes next to it in the language of the local country. It might be assumed that depending on the employee's proficiency in the language of instruction used for mobile learning and its correspondence with the language used during recall she may be better or worse able to use the acquired knowledge. Investigations on use and transfer of acquired knowledge in relation to the native language, language of instruction and language of practice could help adjusting the instruction accordingly to enhance the application of the learnt material at the workplace.

The reviewed literature underlines that only broad and detailed consideration of context can reflect its significance for the attainable learning effectiveness. It is the interaction between the contextual features of the learning space with the individual, particularly cognitive features of the learner herself, the learning material, and its presentation on a handheld device. The need for such perspective was indicated by several authors (Bhaskar & Govindarajulu, 2008; Mostakhdemin-Hosseini, 2009; Pimmer, 2009; Winters & Price, 2005) and most explicitly and completely expressed in their detailed definition of mobile learning by Laouris and Eteokleous (2005). Acknowledgement of all the numerous parameters during a conceptualization of instructional design is admittedly a very challenging requirement (Laouris & Eteokleous, 2005). However, according to the above evidence, without such thorough approach grounded in scientific research work-related mobile learning on the go is probable to prove ineffective. This paper makes it obvious that to establish an effective mobile learning approach, much more is needed than just an adaptation of traditional instructional contents to smaller screen sizes of handheld mobile devices, which were in fact not designed with educational purposes in mind (Kukulska-Hulme, 2007). Effective mobile learning has to address the limitations of human attentional resources in disruptive public spaces.

References

Aggleton, J. P., & Waskett, L. (1999). The ability of odours to serve as state-dependent cues for real-world memories: Can Viking smells aid the recall of Viking experiences? *British Journal of Psychology*, *90*, 1-7.

American Psychological Association . *Learning & memory*. Psychology topics. Retrieved on January, 20, 2013 from http://www.apa.org/topics/learning/index.aspx

Anderson, M. C. (2009). Incidental forgetting. In Baddeley, A., Eysenck, M., & Anderson, M. C., *Memory* (pp. 191-216). Hove: Psychology Press.

Baddeley, A. (2009). Learning. In Baddeley, A., Eysenck, M., & Anderson, M. C., *Memory* (pp. 69-91). Hove: Psychology Press.

Bailey, B. P., Konstan, J. A., & Carlis, J. V. (2001). The effects of interruptions on task performance, annoyance, and anxiety in the user interface. *Proceedings INTERACT '01* (pp. 593-601).

Beyeler, R. (2013, February 5). *Doppelt so viele Tablet-Nutzer wie im Vorjahr* [press release]. Retrieved from Comparis website: http://www.comparis.ch/comparis/press/medienmitteilungen/artikel/2013/telekommunikation/smartphone-verbreitung/tablet-verbreitung.aspx

Bhaskar, N. U., & Govindarajulu, P. (2008). Context Exploration For Requirements Elicitation In Mobile Learning Application Development. *International Journal of Computer Science and Network security*, *8* (8), 292-299.

Bower, G. H., Clark, M. C., Lesgold, A. M., & Winzenz, D. (1969). Hierarchical retrieval schemes in recall of categorized word lists. *Journal of Verbal Learning & Verbal Behavior*, *8* (3), 323–343.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior*, *4* (2), 717-726.

Burmistrov, I., & Leonova, A. (2003) Do interrupted users work faster or slower? The micro-analysis of computerized text editing task, in Jacko, J., & Stephanidis, C. (Eds.), *Human-Computer Interaction: Theory and Practice (Part I) - Proceedings of HCI International 2003*, Vol. 1 (pp. 621-625). Mahwah: Lawrence Erlbaum Associates.

Cartwright-Finch, U., & Lavie N. (2006). The role of perceptual load in inattentional blindness. *Cognition*, *102* (3), 321-340.

Coens, J., Degryse, E., Senecaut, M., Cottyn, J., & Clarebout, G. (2011). Listening to an Educational Podcast While Walking or Jogging: Can Students Really Multitask? *International Journal of Mobile and Blended Learning*, *3* (3), 23-33.

Corbetta, M., & Shulman, G.L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reiews Neurosci*ence, *3* (3), 201–215.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: a framework for memory research. *Journal of Verbal Learning & Verbal Behavior*, *11*, 671-684.

Craik, F.I.M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General*, *104*, 268-294.

Dabbish, L., Mark, G., & González, V. (2011, May). Why do I keep interrupting myself? : environment, habit and self-interruption. *Annual Conference on Human factors in computing systems (ACM CHI '11)* (pp. 3127-3130). Vancouver, Canada.

De-Marcos, L., Hilera, J. R., Barchino, R., Jimenez, L., Martinez, J. J., Gutierrez, J. A., …, Oton, S. (2010). An experiment for improving students' performance in secondary and tertiary education by means of m-learning auto-assessment. *Computers and Education*, *55* (3), 1069-1079.

Dimensional research. (2012). *The impact of mobile devices on information security: A survey of IT professionals* [report]. Retrieved on March 15, 2013 from CheckPoint website: http://www.checkpoint.com/downloads/products/check-point-mobile-security-survey-report.pdf

Do, T., Blom, J., & Gatica-Perez, D. (2011, November). Smartphone Usage in the Wild: A Large-Scale Study of Applications and Context. *Proc. ACM Int. Conf. on Multimodal Interaction (ICMI)*, Alicante.

Ebbinghaus, H. (1885). *Über das Gedächtnis. Untersuchungen zur experimentellen Psychologie*. Verlag von Duncker & Humber. Leipzig. Retrieved on February 3, 2013 from http://www.uni-leipzig.de/~psycho/wundt/opera/ebbing/memory/GdaechtI.htm

Eich, E., Macaulay, D., & Ryan, L. (1994). Mood dependent memory for events of the personal past. *Journal of Experimental Psychology: General*, *123*, 201-215.

Eppler M., & Mengis J. (2004). The Concept of Information Overload: A Review of Literature from Organization Science, Accounting, Marketing, MIS, and Related Disciplines. *The Information Society. An International Journal*, *20* (5), 1-20.

Ericsson, K. A., Krampe, R. Th., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363-406.

Evans, C. (2008). The effectiveness of m-learning in the form of podcast revision lectures in higher education. *Computers & Education*, *50* (2), 491–498.

Eysenck M.W., & Eysenck M.C. (1980). Effects of processing depth, distinctiveness, and word frequency on retention. *British Journal of Psycho*logy, *71*, 263-274

Eysenck, M.W., & Keane, M. T. (2010). *Cognitive Psychology: A Students Handbook (6th ed.)*(pp.143-144*).* Hove: Psychology Press.

Fernandes, M.A., & Moscovitch, M. (2000). Divided attention and memory: Evidence of substantial interference effects both at retrieval and encoding. *Journal of Experimental Psychology: General, 129*, 155-176.

Forster, S., & Lavie, N. (2009). Harnessing the wandering mind: The role of perceptual load. *Cognition*, *111* (3), 345-355.

Forster, S., & Lavie, N. (2011). Entirely irrelevant distractors can capture and captivate attention. *Psychonomic Bulletin & Review*, *18* (6), 1064-1070.

Galvan, V.V., Vessal, R.S., & Golley, M.T. (2013). The Effects of Cell Phone Conversations on the Attention and Memory of Bystanders. *PLoS ONE 8* (3): e58579.

Georgiev, T., Georgieva, E., & Smrikarov, A. (2004). M-Learning: A new stage of E-Learning. *Proceedings International conference on Computer Systems and Technologies, CompSysTech' 2004* , IV.28 (pp.:1-5).

Georgieva, E., Smrikarov, A., & Georgiev, T. (2011). Evaluation of mobile learning system. *Procedia Computer Science*, *3*, 632–637.

Godden, D. R., & Baddeley, A. D. (1975). Context-dependent memory in two natural environments: On land and under water. *British Journal of Psychology*, *66*, 99–104.

González, V., & Mark, G. (2004) Constant, Constant, Multi-tasking Craziness: Managing Multiple Working Spheres. *Proceedings of CHI 2004* (pp. 113-120), ACM Press, Vienna, Austria.

Google. (2012). *Our mobile planet: Switzerland. Understanding the mobile consumer* [research study]. Retrieved on march 15, 2013 from http://www.thinkwithgoogle.com/insights/library/studies/our-mobile-planet-Switzerland/

Henckens, M. J., Hermans, E. J., Pu, Z., Joëls, M., & Fernández, G. (2009). Stressed memories: how acute stress affects memory formation in humans. *The Journal of Neuroscience*, *29,*(32), 10111-10119.

Hoen, F. (2006). Make yourself heard: Are there more effective ways of getting your employees' attention than e-mail? *Communication World*, *23* (2), 35-37.

James, W. (1890). *Principles of psychology*. New York: Henry Holt and Company

Kazlauskas, A., & Robinson, K. (2012). Podcasts are not for everyone. *British Journal of Educational Technology*, *43* (2), 321-330.

Kukulska-Hulme, A. (2007). Mobile Usability in Educational Contexts: What have we learnt? *International Review of Research in Open and Distance Learning*, *8* (2), 1–16.

Laouris, Y., & Eteokleous, N. (2005, October). We need an Educationally Relevant Definition of Mobile Learning. *Proceedings of the 4th World Conference on mLearning*, Cape Town, South Africa. Retrieved on February, 3, 2013 from http://www.mlearn.org.za/CD/papers/Laouris%20&%20Eteokleous.pdf

Lavie, N. (2006). The role of perceptual load in visual awareness. *Brain Research*, *1080* (1), 91-100.

Lavie, N., Hirst, A., De Fockert, J. W., & Viding, E. (2004) Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*, 339-354.

Lea, P. (2011, September 19). *Effectively using mobile technology for learning and development.* Retrieved from HR Magazine website: http://www.hrmagazine.co.uk/hro/features/1020115/effectively-mobile-technology

Macdonald, J. S., & Lavie, N. (2011). Visual perceptual load induces inattentional deafness. *Attention Perception & Psychophysiology*, *73* (6), 1780-1789.

MacKeracher, D. (2004) *Making sense of adult learning (2nd edition)* (pp. 7-8). Toronto: University of Toronto Press.

Mardex, J. (2004). *Auditory, Visual, and Physical Distractions in the workplace*. Cornell University, Department of Design and Environmental Analysis. Retrieved on February 16, 2013 from http://de.scribd.com/doc/13038258/Auditory-visual-and-physical-distractions-in-the-workplace

Marian, V., & Fausey, C.M. (2006). Language-dependent memory in bilingual learning. *Applied Cognitive Psychology*, *20* (8), 1025-1047.

Marian, V., & Neisser, U. (2000). Language-dependent recall of autobiographical memories. *Journal of Experimental Psychology: General*, *129*, 361-368.

Mayer, R. E. & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. In Bruning, R., Horn, C. A., & Pytlik-Zillig, L. M. (Eds.), *Web-based learning: What do we know? Where do we go?* (pp. 23-44). Greenwich, CT: Information Age Publishing.

McDaniel, M. A., Robinson-Riegler, B., & Einstein, G. O. (1998). Prospective remembering: Perceptually-driven or conceptually driven processes? *Memory & Cognition*, *26* (1), 121-134.

Mensink, G.J.M., & Raaijmakers, J.G.W. (1988). A model for interference and forgetting. *Psychological Review* , *95* (4), 434-455.

Miles, C., & Hardman, E. (1998). State-dependent memory produced by aerobic exercise. *Ergonomics*, *41* (1), 20-28.

Michel, L. (2012). Mobile Learning-kurzer Hype oder stabiler Megatrend? *MMB-Trendmonitor I /2012.* MMB-Institut für Medien- und Kompetenzforschung. Essen

Mostakhdemin-Hosseini, A. (2009). Analysis of Pedagogical Considerations of M-Learning in Smart Devices. *International Journal of Interactive Mobile Technologies*. *3* (4), 33-34.

Naveh-Benjamin, M., & Guez Y. (2000). The effects of divided attention on encoding and retrieval processes: Assessment of attentional costs and a componential analysis. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *26*, 1461-1482.

O'Malley, C., Vavoula, G., Glew, J., Taylor, J., Sharples, M., & Lefrere, P. (2003). *MOBI learn WP4 – Guidelines for Learning/Teaching/Tutoring in a Mobile Environment.* Retrieved on January 21, 2013 from http://www.mobilearn.org/download/results/guidelines.pdf

Ophir, E., Nass, C.I., & Wagner, A.D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences USA*, *106*, 15583–15587.

Pachler, N., Pimmer, C. & Seipold, J. (Eds.). (2011). *Work-Based Mobile Learning. Concepts and Cases.* Oxford: Peter-Lang.

Pashler, H., Johnston, J. C., & Ruthruff, E. (2001). Attention and performance. *Annual Review of Psychology, 52*, 629-651.

Pimmer, C. (2009, November). *Mobile Learning at Work: Contextual Issues*. Paper presented at the Alpine Rendez-Vous, STELLAR Network of Excellence. Garmisch-Partenkirchen, Bavaria. Retrieved on February 13, 2013 from http://www.christoph.pimmer.info/wpcontent/uploads/2008/08/ChristophPimmer1.pdf

Pimmer, C., & Gröhbiel, U. (2011). Mobile learning in corporate settings: Results from an expert survey. In N. Pachler, C. Pimmer & J. Seipold (Eds.), *Work-Based Mobile Learning. Concepts and Cases* (pp. 335-354). Oxford: Peter-Lang.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32* (1)*,* 3–25.

Roda, C. (2011). Human attention and ist implications for human-computer interaction. In Roda, C. (Ed.), *Human Attention in Digital Environments* (pp.11-62). Cambridge University Press.

Schacter, D. L. (1999). The Seven Sins of Memory: Insights From Psychology and Cognitive Neuroscience. *American Psychologist* , *54* (3), 182–203.

Schepman, A., Rodway, P., Beattie, C., & Lambert, J. (2012). An observational study of undergraduate students' adoption of (mobile) note-taking software. *Computers in Human Behavior*, *28* (2), 308–317.

Schneider, M., & Stern, E. (2010). The cognitive perspective on learning: Ten cornerstone findings. In Organisation for Economic Co-Operation and Development (OECD) (Ed.), *The nature of learning: Using research to inspire practice* (pp. 69-90). Paris: OECD.

Slamecka, N., & Graf, P. (1978). The generation effect: delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory*, *14*, 592-604.

Smith, S. M., & Vela, E. (2001). Environmental context dependent memory: A review and meta analysis. *Psychonomic Bulletin and Review*, *8* (2), 203-220.

Sweeney, C.A., & Bellezza, F.S. (1982). Use of the keyword mnemonic for learning English vocabulary. *Human Learning*, *1*, 155-163.

Tulving, E. (1962). Subjective organization in free recall of unrelated words. *Psychological Review*, *69*, 344-354.

Tulving, E., & Thompson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, *80*, 352-373.

Traxler, J. (2005). Defining mobile learning. *IADIS International Conference Mobile Learning 2005*. Qawra, Malta.

Tyler, S. W., Hertel, P. T., McCallum, M. C., & Ellis, H. (1979). Cognitive effort and memory. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 607–617.

Wakefield, J.F. (1996). *Educational Psychology: Learning to be a Problem-Solver (*p. 364). Boston: Houghton Mifflin.

Wang, M., & Shen, R. (2012). Message design for mobile learning: Learning theories, human cognition and design principles. *British Journal of Educational Technology*, *43* (4), 561-575.

Winters, N., & Price, S. (2005). Mobile HCI and the learning context: An exploration. International Workshop on Context in Mobile HCI, *Mobile HCI 05*, Salzburg.

Wu, W., Wu, Y. J., Chen, C., Kao, H., Lin, C., & Huang S. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education*, *59* (2), 817-827.